Canada's Nuclear Regulator

Occupational Dose Data for Major Canadian Nuclear Facilities 2001–07

INFO-0775




June 2009

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Canada

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This document can be viewed on the CNSC Web site at nuclearsafety.gc.ca. To order a printed copy of the document in English or French, please contact:

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Introduction

Workers at nuclear facilities are exposed to radiation. Their dose is monitored and subject to Canadian Nuclear Safety Commission (CNSC) regulatory requirements, which aim to protect their health and safety. The amount of radiation to which employees are exposed is referred to as “occupational dose”. This report provides an overview of occupational radiation doses, from 2001 to 2007, at the major nuclear facilities licensed by the CNSC. It presents an objective summary of occupational dose information, and includes a glossary of terminology.

The data collected shows that the average doses for all facilities are far below the individual annual effective dose limit of 50 milliSieverts (mSv), set out in the *Radiation Protection Regulations*.

The report includes data for the following types of facilities:

- nuclear power plants
- uranium mines and mills
- uranium refineries
- fuel fabrication facilities
- research and radioisotope production facilities
- tritium light source production facilities

Each facility is unique in regards to the type of work performed, as well its current lifecycle stage (i.e., operating at reduced or full capacity, or in a phase of refurbishment, for example), and each provides varying programs to mitigate radiation doses to workers. The resulting collective and average doses are based on complex and differing work environments. Therefore, direct comparisons between facilities, in terms of occupational dose, are not possible.

Regulatory Radiation Dose Limits

The *Radiation Protection Regulations* limit the amount of radiation to which persons may be exposed. Table 1 presents the effective dose limits, as set out in paragraphs 13 and 14 of the regulations:

Table 1.
Effective Dose Limits in Canada as Specified by the *Radiation Protection Regulations*

Person	Period	Effective Dose (mSv)
Nuclear energy workers, including pregnant nuclear energy workers	(a) One-year dosimetry period	50
	(b) Five-year dosimetry period	100
Pregnant nuclear energy worker	Balance of the pregnancy	4
A person who is not a nuclear energy worker	One calendar year	1

The *Radiation Protection Regulations* also require CNSC licensees to implement radiation protection programs and to keep radiation doses as low as reasonably achievable (a concept referred to as the ALARA principle). The CNSC evaluates licensee radiation protection programs, and these evaluations include reviews of the occupational dose data, which is one among several indicators of a radiation protection program's effectiveness.

About the Data

Source

Statistics in this document are gathered from the National Dose Registry (NDR), Canada's central repository for occupational radiation doses[1]. Maintained by Health Canada's Radiation Protection Bureau, the NDR publishes annual reports on occupational dose information and trends, according to job type.

Due to the large number of CNSC-licensed facilities, this report does not include occupational dose information for every CNSC licensees. Please refer to the NDR Web site[2] to review Health Canada's reports.

Analysis

This report presents the following types of data:

a. average doses
b. collective doses
c. distribution of effective doses

a. Average doses provide a common means of indicating central tendencies of dose distribution, and show where doses lie, on average, with respect to annual dose limits

Notes on average effective doses:

1. This report presents two types[3] of arithmetic averages for individual effective doses:
   - averages that include only non-zero (positive) results
   - averages that include all monitoring results (including zero-value doses)

2. When assessing regulatory compliance, individual doses — not average doses — must be compared to individual dose limits in the *Radiation Protection Regulations*.

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1 In Canada, the *Radiation Protection Regulations* require licensed dosimetry services to submit dose information for nuclear energy workers (NEWs). While not required by law, dose information for non-NEWs is also typically submitted to the NDR. The data in this report does not distinguish between personnel designated as NEWs versus those who are not.

2 http://www.hc-sc.gc.ca/ewh-semt/occup-travail/radiation/regist/index_e.html

3 Some licensees monitor most or all workers (including those unlikely to be directly exposed to sources of occupational radiation), whereas other licensees monitor only employees likely to receive radiation doses. Therefore, two types of averages are presented: averages that consider only non-zero results and averages that consider all results. Both statistical approaches have merit and are included in this report. (Note: The exclusion of zero value doses in the averaging could unfairly bias findings against licensees with effective radiation protection programs.)

b. Collective doses indicate the sum of all the doses associated with a facility's operation, and can be used to estimate a facility's control of occupational doses.

Note on collective doses:

1. The *Radiation Protection Regulations* do not set limits on collective doses; however, the CNSC recommends that licensee radiation protection programs should aim to reduce collective doses. These values can indicate a facility's radiological detriment and help assess whether a facility is operating in accordance with the ALARA principle.

c. Distribution of effective doses shows the ranges in which effective doses are concentrated.

Effective dose calculations

By definition, effective doses cannot be measured precisely, but they can be approximated in order to determine radiation exposure and to assess the associated risks. Section 13 of the *Radiation Protection Regulations* defines the dose calculation methods used to determine effective doses, as expressed in millisieverts (mSv), which are based on measurable quantities in the operational environment.

Effective radiation doses are made up of various components, of which the most common (in Canada) are as follows:

- photons and neutrons from sources outside the body
- radon progeny, radon gas, long-lived radioactive dust (uranium dust) and tritium that are taken into the body

The effective doses reported to the NDR represent the sum of their applicable components. For example, the effective dose to a worker who received radiation doses from both neutrons and tritium would be the sum of these two quantities.

Note on average dose values:

1. Average values for each dose type (for example, tritium) are based on the total collective dose for that type, divided by the number of all the workers monitored for any dose type.

1.0 Facility-Wide Comparisons of Average Effective Doses

This section presents comparisons of average effective doses at all CNSC-licensed nuclear facilities included in this report, for each year within the 2001–07 reporting period:

- Figures 1.1–1.7 present averages based on non-zero (positive) results (Section 1.1)
- Figures 1.8–1.14 present averages based on all monitoring results (Section 1.2)

Notes on facility-wide comparisons of average effective doses:

1. Each facility type is represented by a different colour:
   - nuclear power plants – green
   - uranium mines and mills – purple
   - uranium refineries – yellow
   - fuel fabrication facilities – orange
   - research and radioisotope facilities – blue
   - tritium light source production facilities – red

2. See Sections 2.1–2.6 for facility-specific data depicted in Figures 1.1–1.14.

1.1 Average Effective Doses Based on Non-Zero Results at All Selected Facilities

Figures 1.1–1.7 show average effective doses based on non-zero results for each year from 2001 to 2007, for all the facilities presented in this document.

Figure 1.1. Average Effective Doses at All Selected Facilities for the Year 2001 (Based on Non-Zero Results)

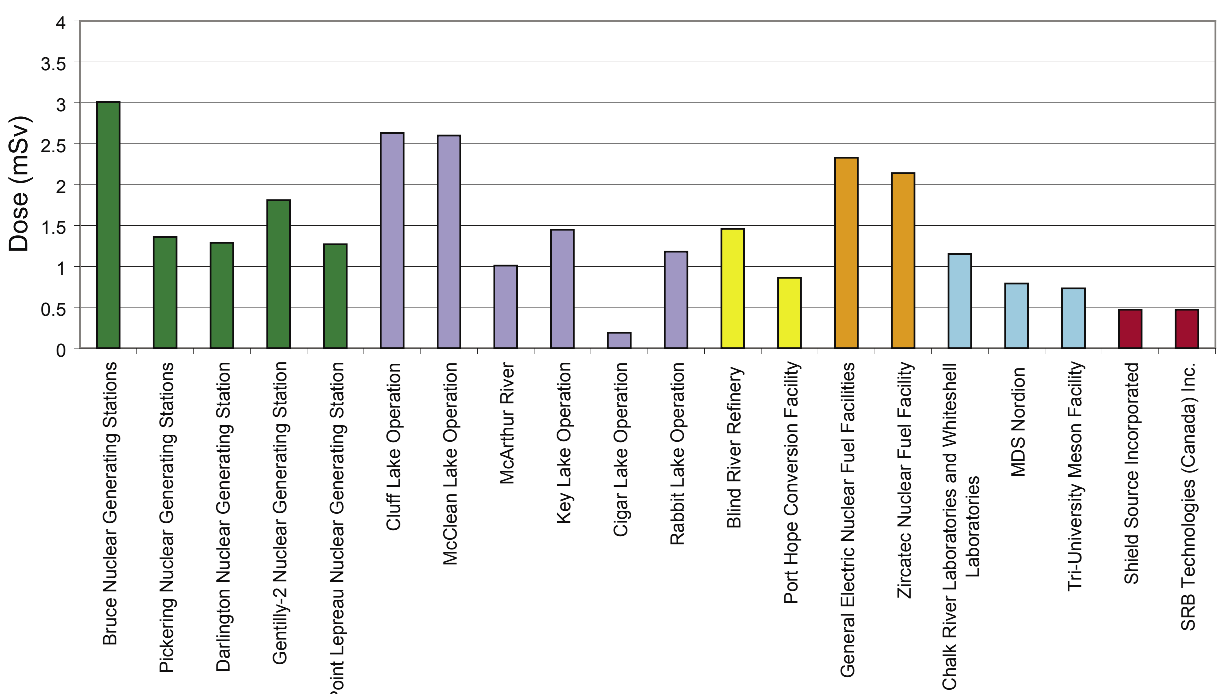


Figure 1.2. Average Effective Doses at All Selected Facilities for the Year 2002 (Based on Non-Zero Results)

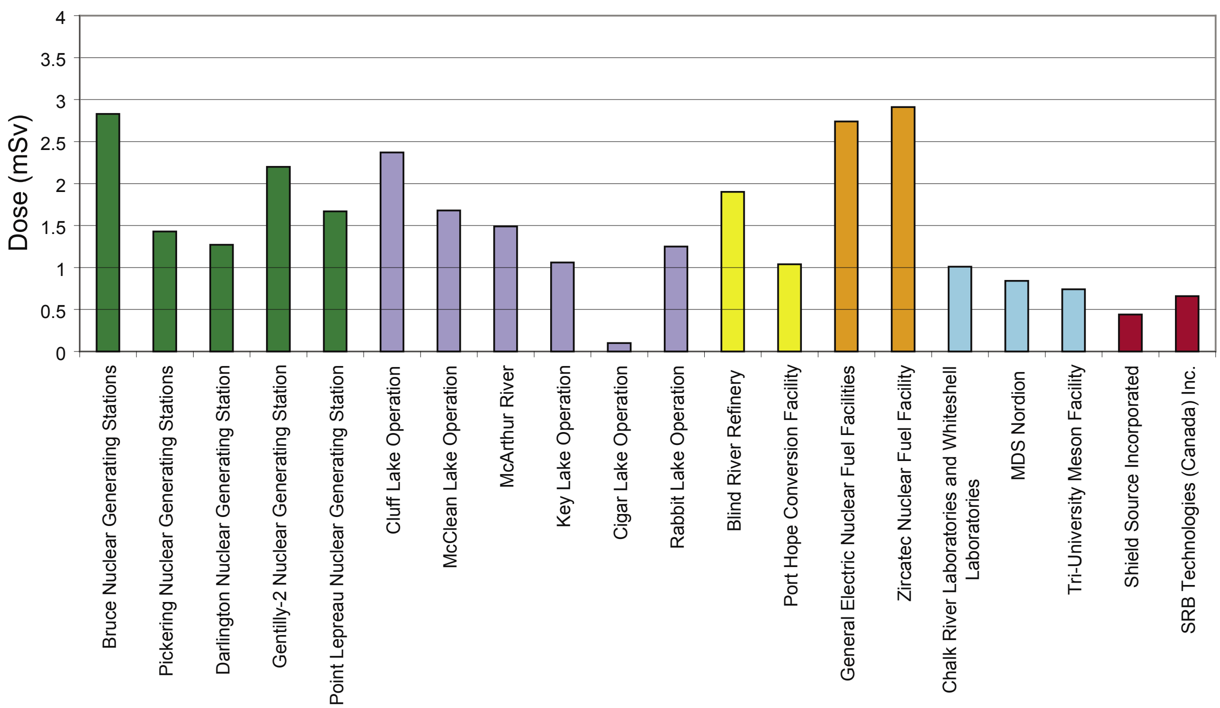


Figure 1.3. Average Effective Doses at All Selected Facilities for the Year 2003 (Based on Non-Zero Results)

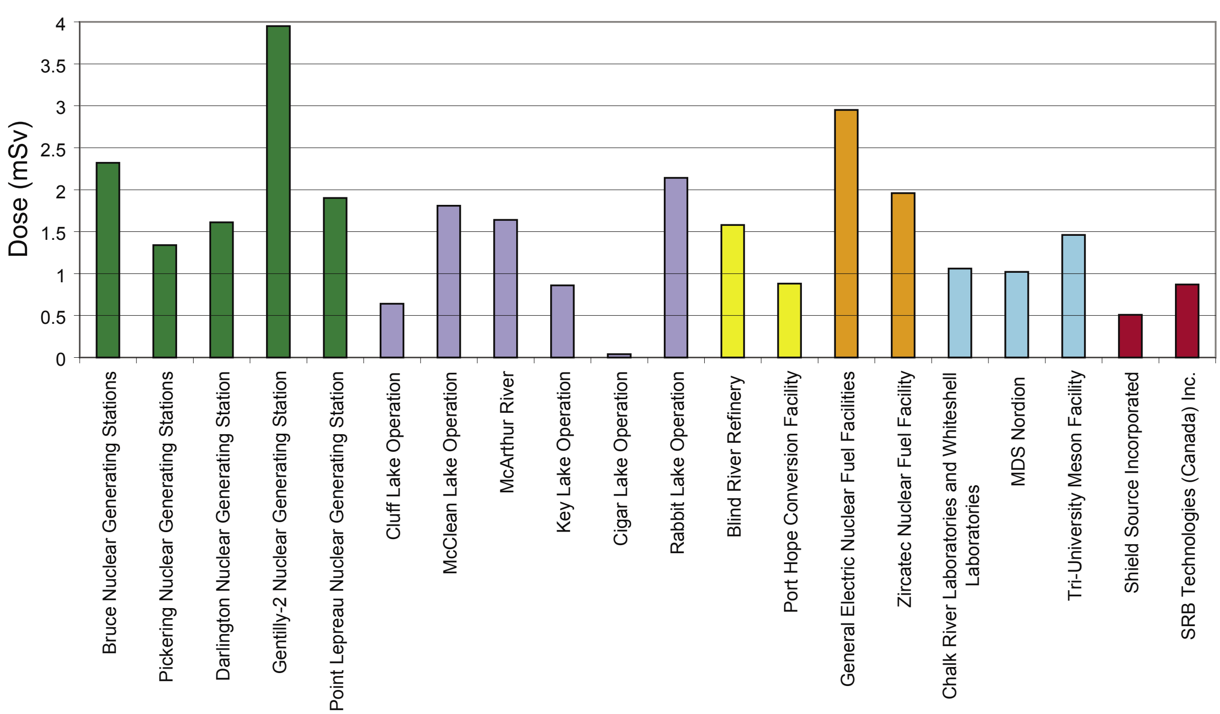


Figure 1.4. Average Effective Doses at All Selected Facilities for the Year 2004 (Based on Non-Zero Results)

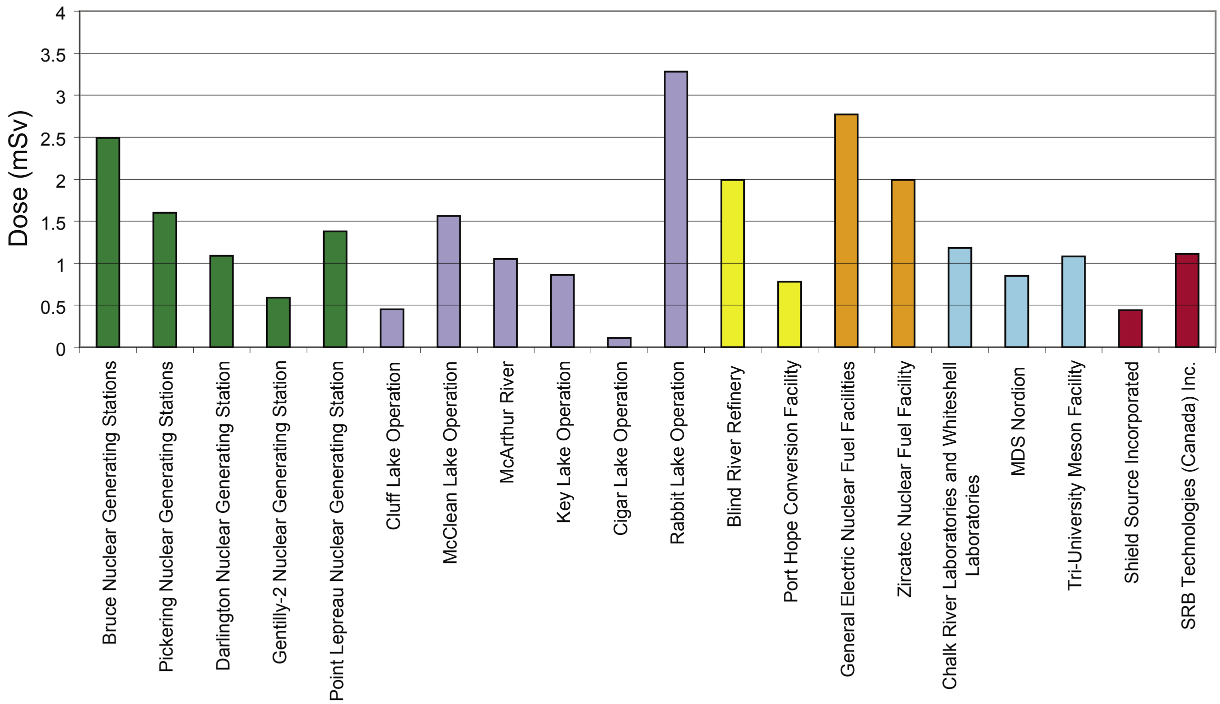


Figure 1.5. Average Effective Doses at All Selected Facilities for the Year 2005 (Based on Non-Zero Results)

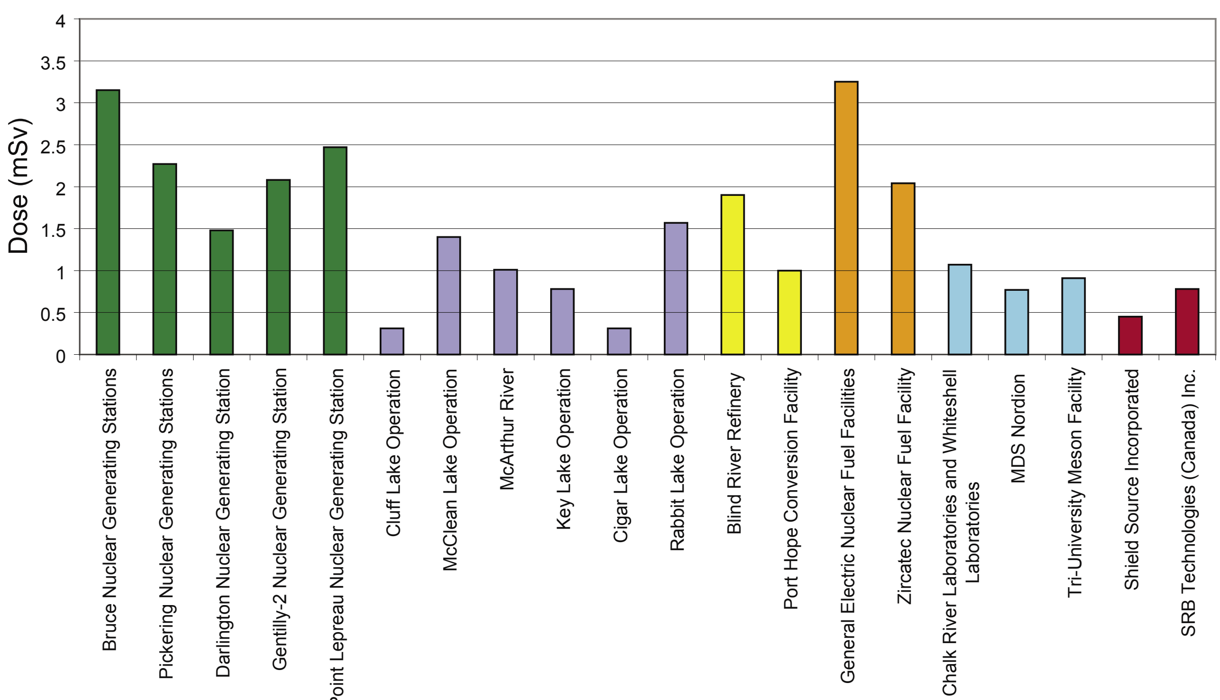


Figure 1.6. Average Effective Doses at All Selected Facilities for the Year 2006 (Based on Non-Zero Results)

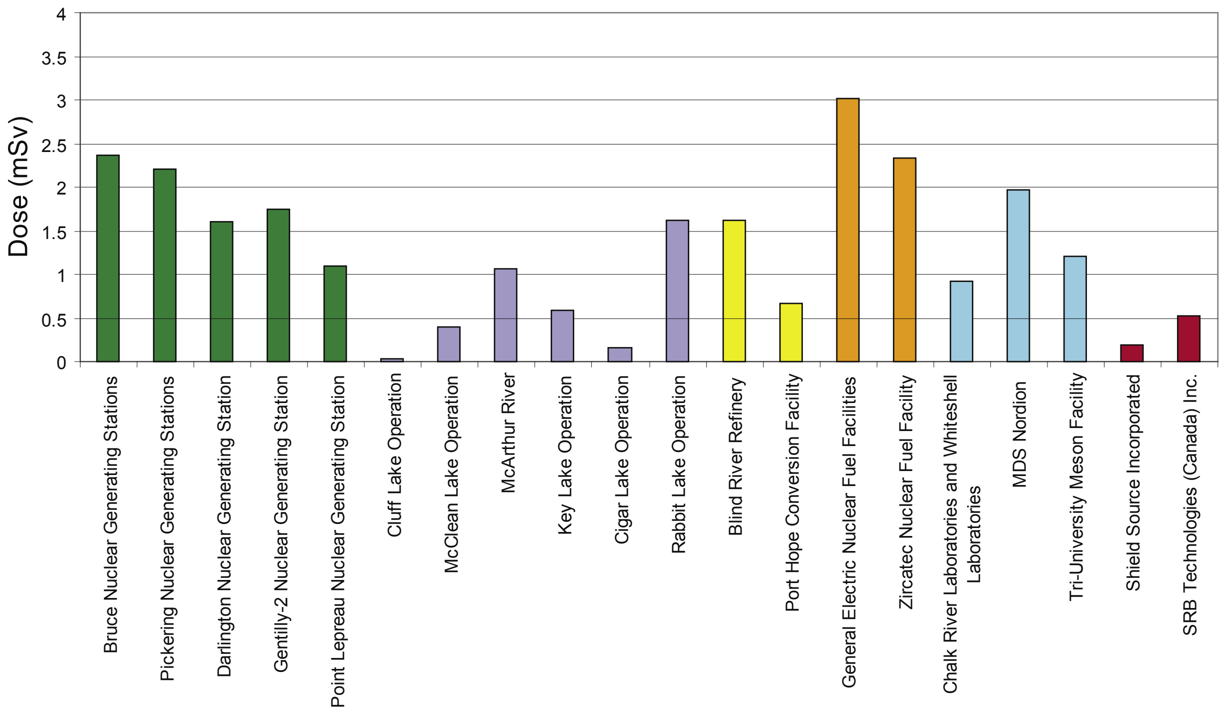
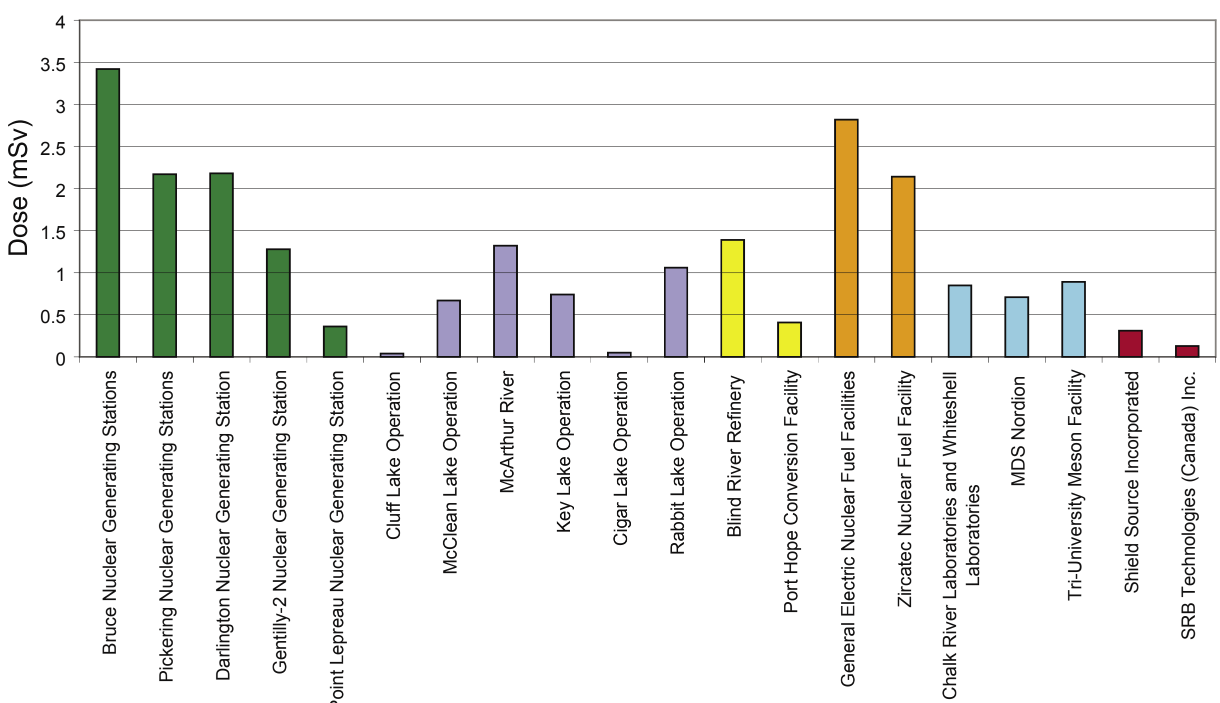


Figure 1.7. Average Effective Doses at All Selected Facilities for the Year 2007 (Based on Non-Zero Results)



1.2 Average Effective Doses Based on All Monitoring Results at All Selected Facilities

Figures 1.8–1.14 show average effective doses based on all the monitoring results for each year from 2001 to 2007, for every facility listed in this document.

Figure 1.8. Average Effective Doses at All Selected Facilities for the Year 2001 (Based on All Monitoring Results)

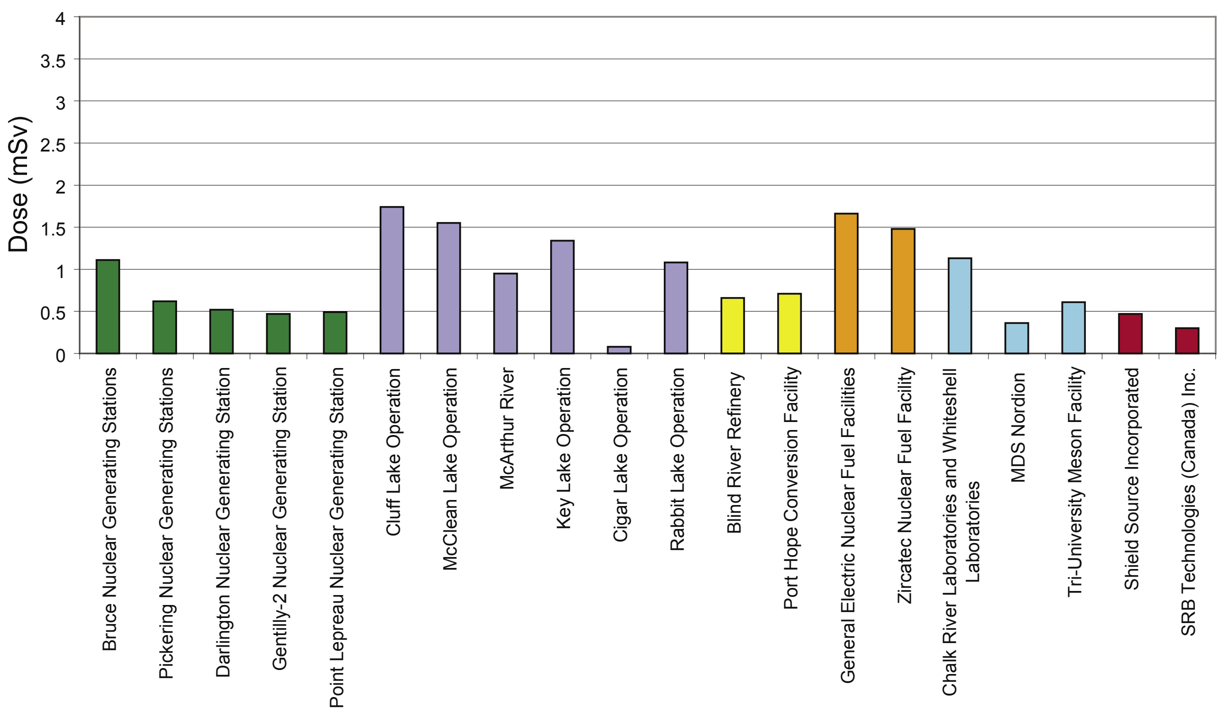


Figure 1.9. Average Effective Doses at All Selected Facilities for the Year 2002 (Based on All Monitoring Results)

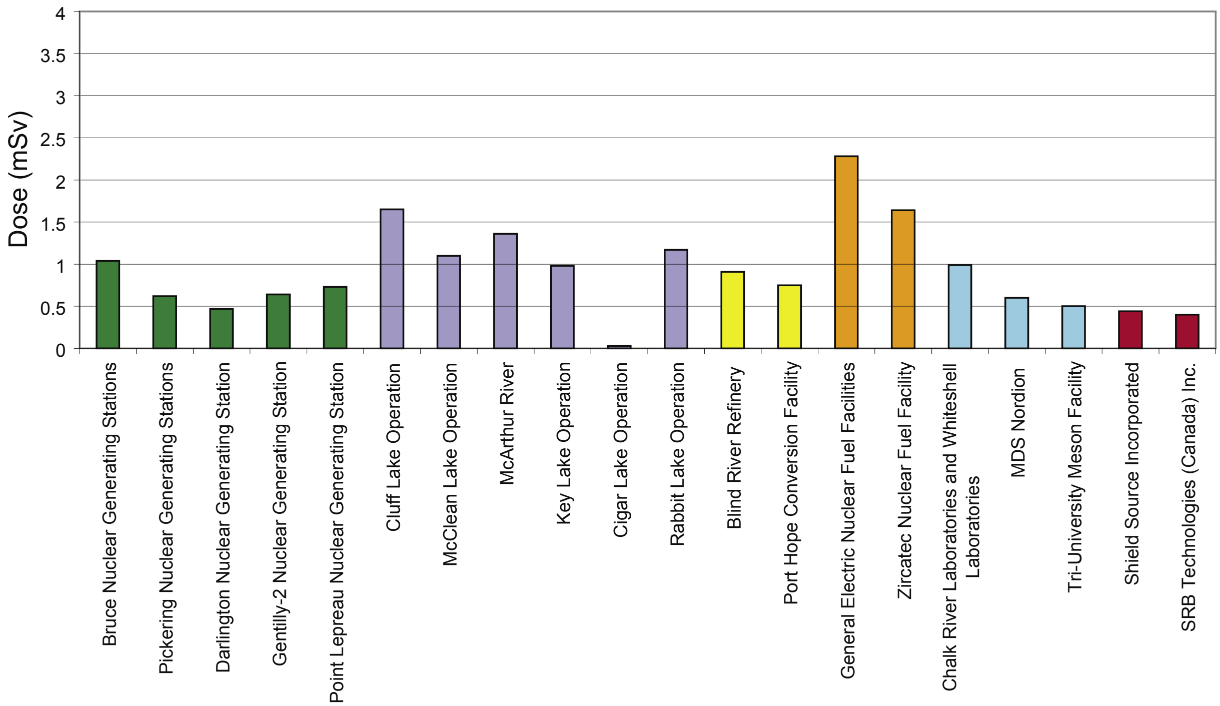


Figure 1.10. Average Effective Doses at All Selected Facilities for the Year 2003 (Based on All Monitoring Results)

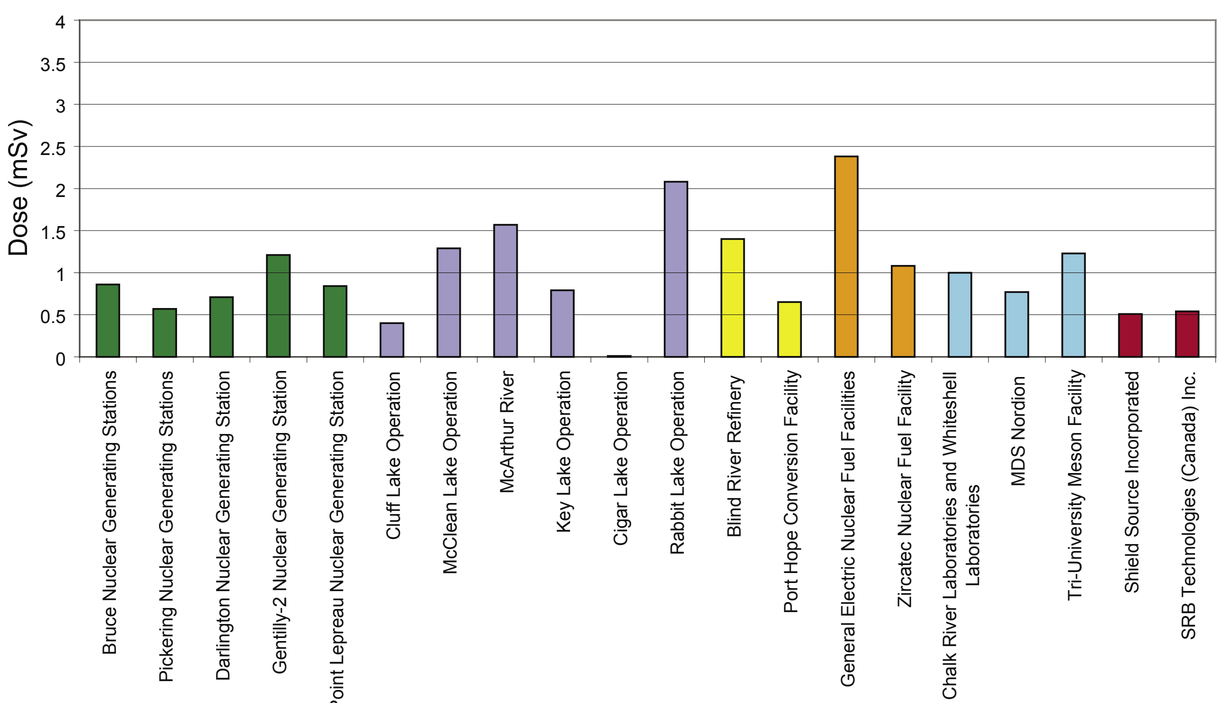


Figure 1.11. Average Effective Doses at All Selected Facilities for the Year 2004 (Based on All Monitoring Results)

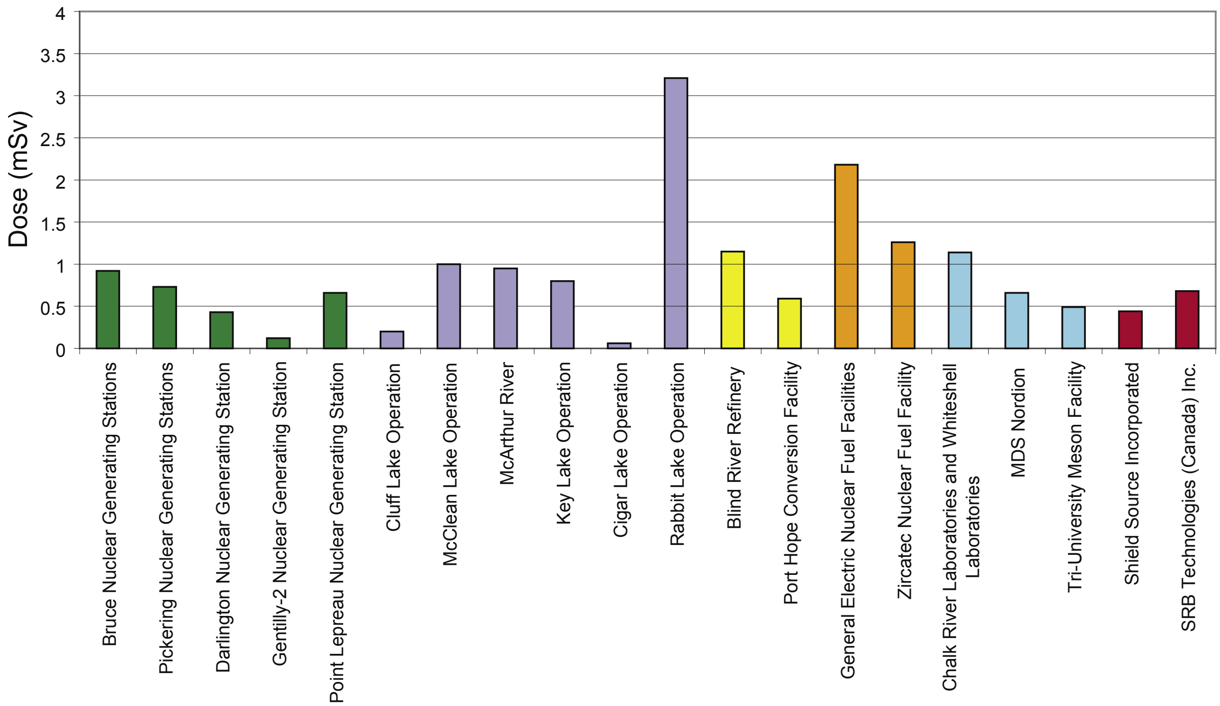


Figure 1.12. Average Effective Doses at All Selected Facilities for the Year 2005 (Based on All Monitoring Results)

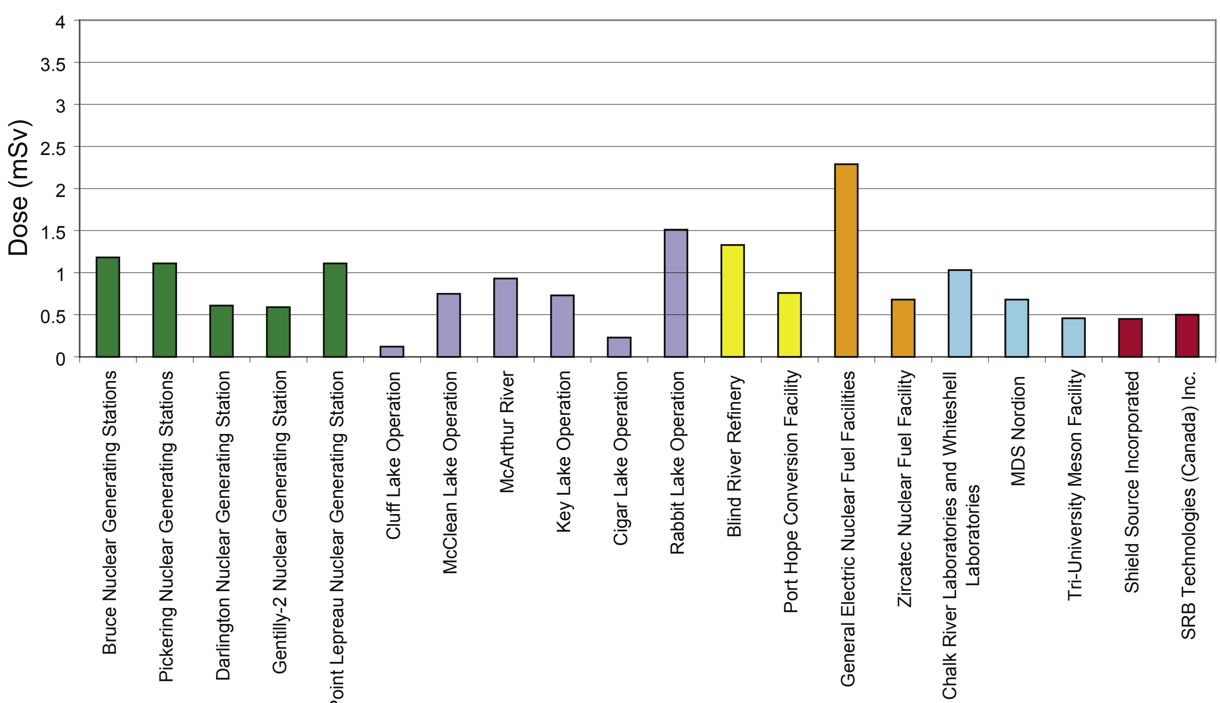


Figure 1.13. Average Effective Doses at All Selected Facilities for the Year 2006 (Based on All Monitoring Results)

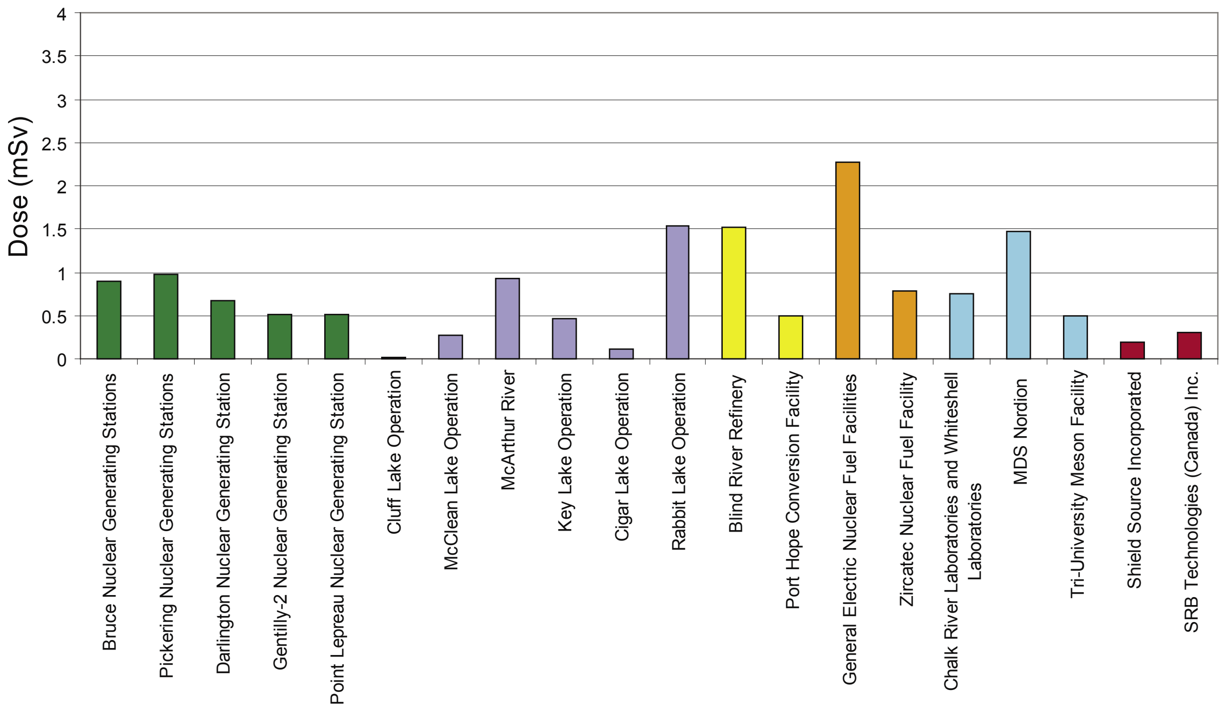
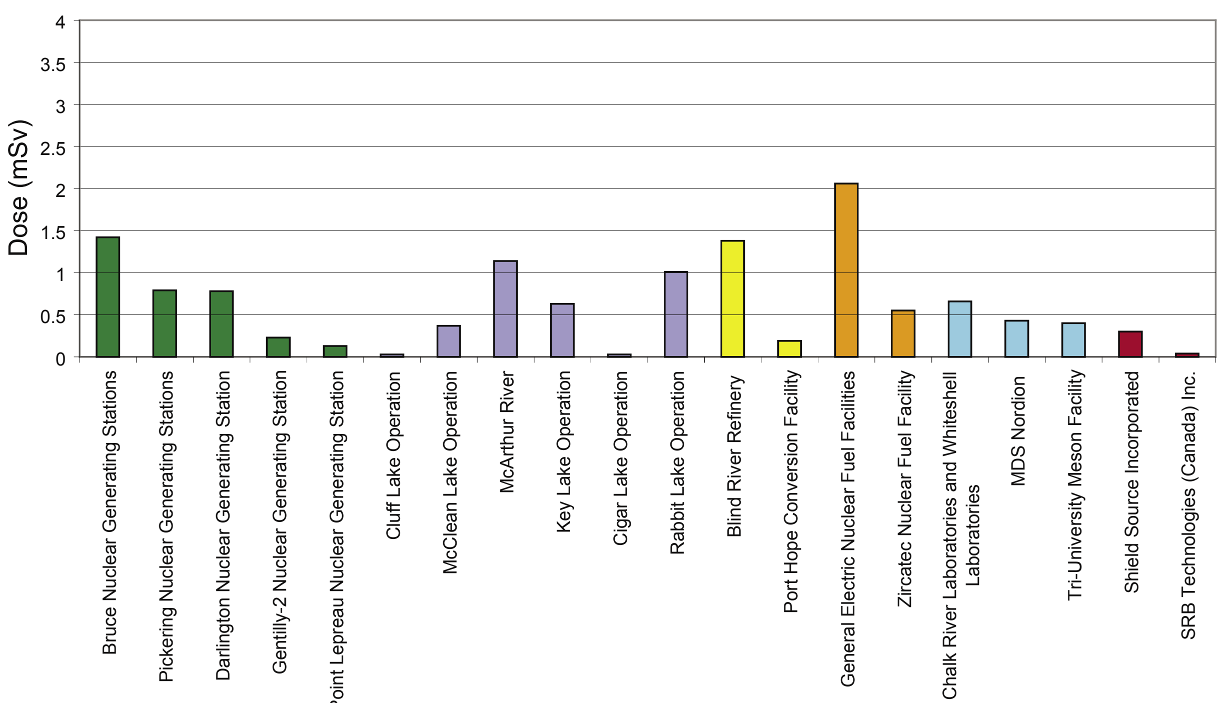


Figure 1.14. Average Effective Doses at All Selected Facilities for the Year 2007 (Based on All Monitoring Results)



2.0 Facility-Specific Overview of Occupational Doses

This section presents data for the following types of facilities:

- nuclear power plants (Section 2.1)
- uranium mines and mills (Section 2.2)
- uranium refineries (Section 2.3)
- fuel fabrication facilities (Section 2.4)
- research and radioisotope production facilities (Section 2.5)
- tritium production facilities (Section 2.6)

2.1 Nuclear Power Plants

This section presents dose information for the following nuclear power plants:

- Bruce A and Bruce B Nuclear Generating Stations (Section 2.1.1)
- Pickering Nuclear Generating Stations (Section 2.1.2)
- Darlington Nuclear Generating Station Section 2.1.3)
- Gentilly-2 Nuclear Generating Station (Section 2.1.4)
- Point Lepreau Generating Station (Section 2.1.5)

Graphs in this section indicate the following data for each nuclear power plant, from 2001 to 2007:

1. average doses based on non-zero (positive) results
2. average doses based on all monitoring results
3. collective doses
4. distribution of average effective doses

Notes on data for nuclear power plants:

1. Effective doses are composed of the following reported components:
   - doses from photons (labeled on the charts as “external”)
   - neutron doses
   - tritium doses

2. Collective dose data is presented in stacked bar graphs, where total effective doses are the sum of their respective components of photon, neutron, and tritium doses. Intakes of other radionuclides (for example, Iodine-131 or Carbon-14) occasionally occur, but these radionuclides are not included here, because the associated collective dose is very small. For this reason, certain collective dose values in this report may be slightly lower than the sum of their respective components as listed.

2.1.1 Bruce Nuclear Generating Stations

Bruce Power owns and operates the Bruce Nuclear Generating Stations located near Kincardine, Ontario, on the shore of Lake Huron.

- Bruce A consists of four nuclear reactors (units 1–4) and began operating in 1976
- Bruce B has four nuclear reactors (units 5–8) and started operating in 1984

As part of its extensive recovery program in 1997, the site's previous operator, Ontario Hydro (now Ontario Power Generation), temporarily shut down all Bruce A reactors and maintained them in a guaranteed shutdown state. Units 3 and 4 were later returned to service (in October 2003, and January 2004), while Units 1 and 2 remained in a guaranteed shutdown state.

Figures 2.1–2.4 present dose information for the Bruce Nuclear Generating Stations from 2001 to 2007. Graphs do not distinguish between doses received at Bruce A versus Bruce B.

Fig. 2.1 Average Dose Trends for Bruce Nuclear Generating Station (Based on Non-Zero Results)

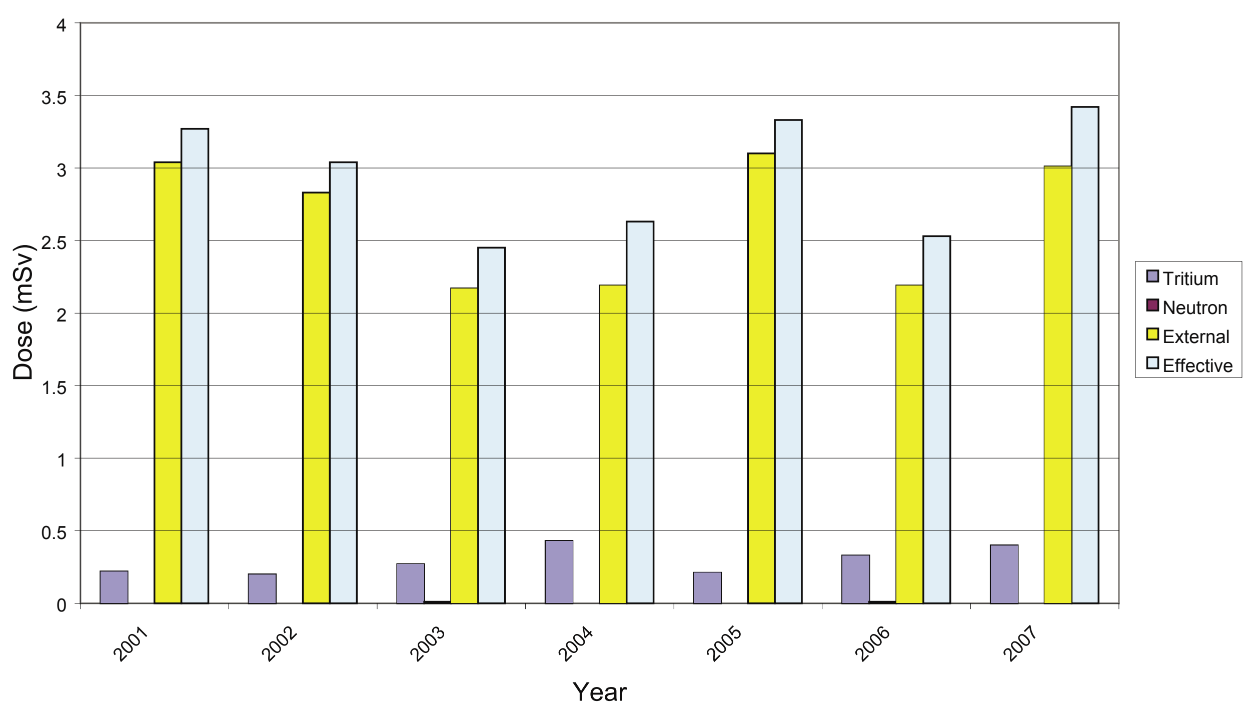


Figure 2.2. Average Dose Trends for Bruce Nuclear Generating Station (Based on All Monitoring Results)

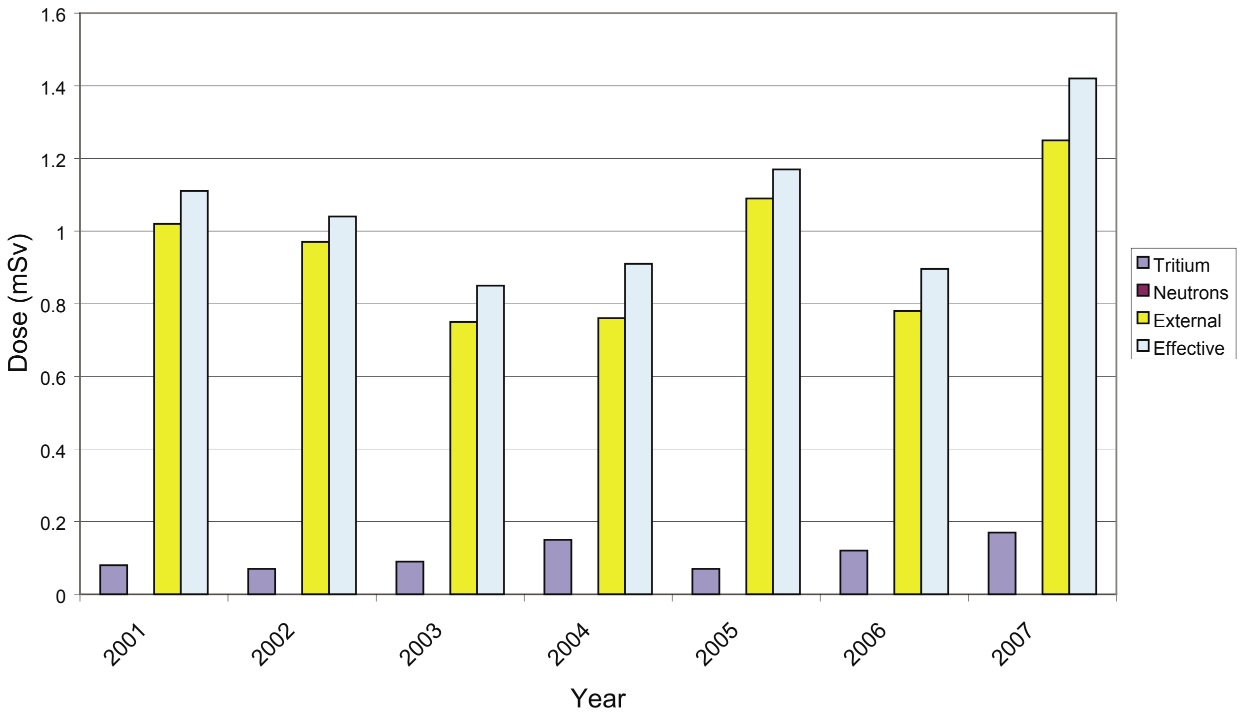


Figure 2.3. Collective Dose Trends for Bruce Nuclear Generating Station

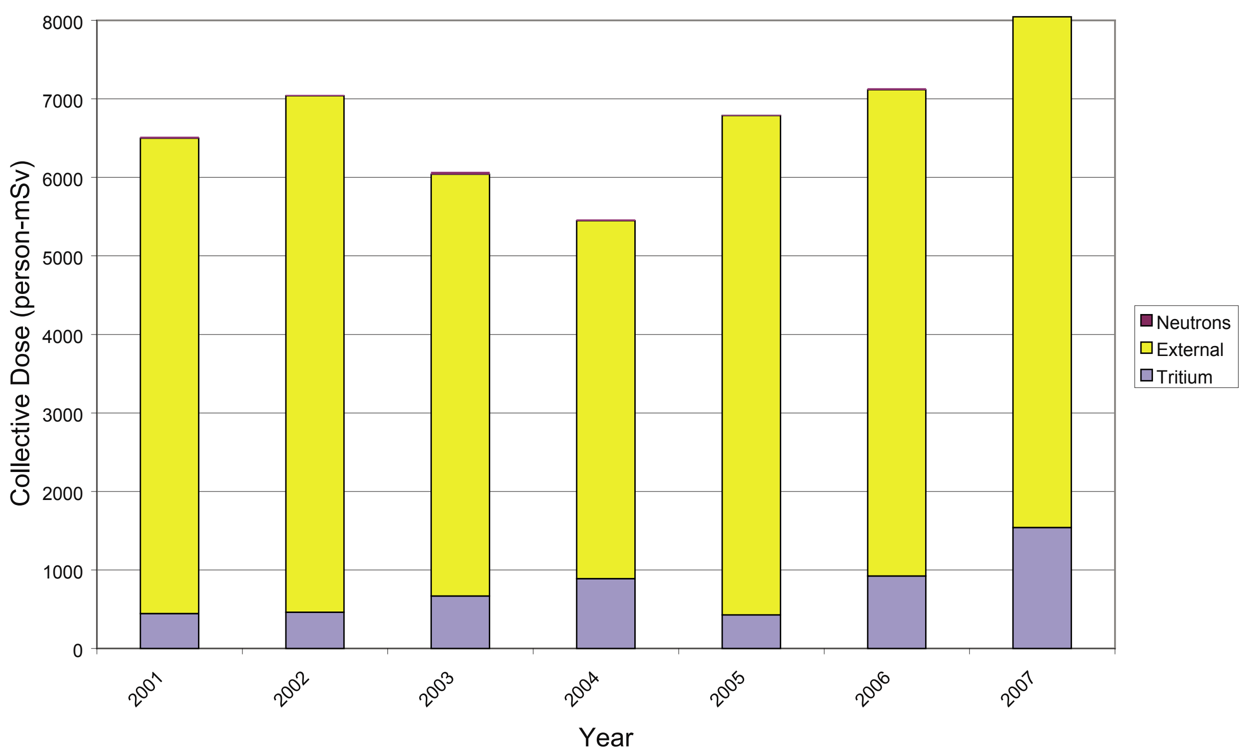
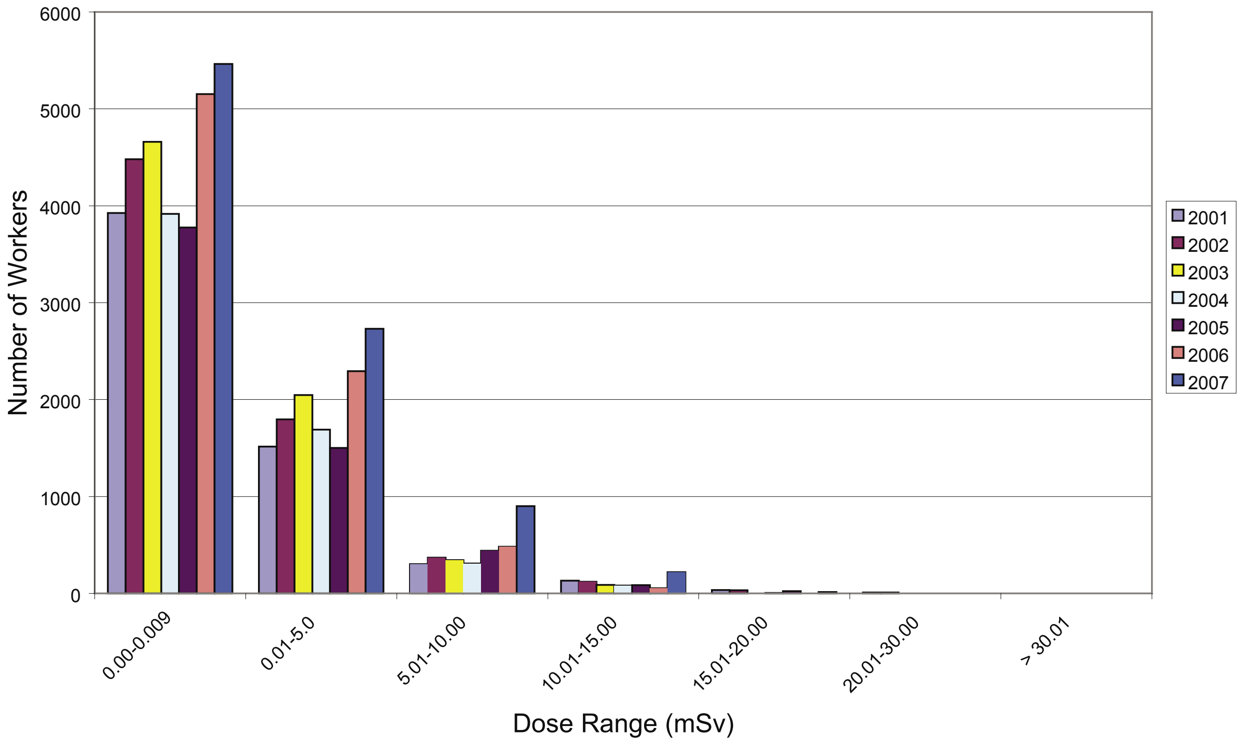


Figure 2.4. Distribution of Effective Doses Among All Workers at Bruce Nuclear Generating Station



2.1.2 Pickering Nuclear Generating Stations

Located in Pickering, Ontario, the Pickering Nuclear Generating Stations are owned and operated by Ontario Power Generation. Two generating stations are located within one enclosure:

- Pickering A consists of four nuclear reactors (units 1 to 4) that began operating in 1971
- Pickering B consists of four nuclear reactors (units 5 to 8) that began operating in 1982

As part of its extensive recovery program, Ontario Hydro (now Ontario Power Generation) temporarily shut down all Pickering A reactors in 1997 and maintained them in a guaranteed shutdown state. Unit 4 was restarted in September 2003, and Unit 1 was restarted in March 2005. Units 2 and 3 remain in a guaranteed shutdown state.

Figures 2.5–2.8 present dose information for the Pickering Nuclear Generating Stations from 2001 to 2007. Graphs do not distinguish between doses received at Pickering A versus those received at Pickering B.

Figure 2.5. Average Dose Trends for Pickering Nuclear Generating Station (Based on Non-Zero Results)

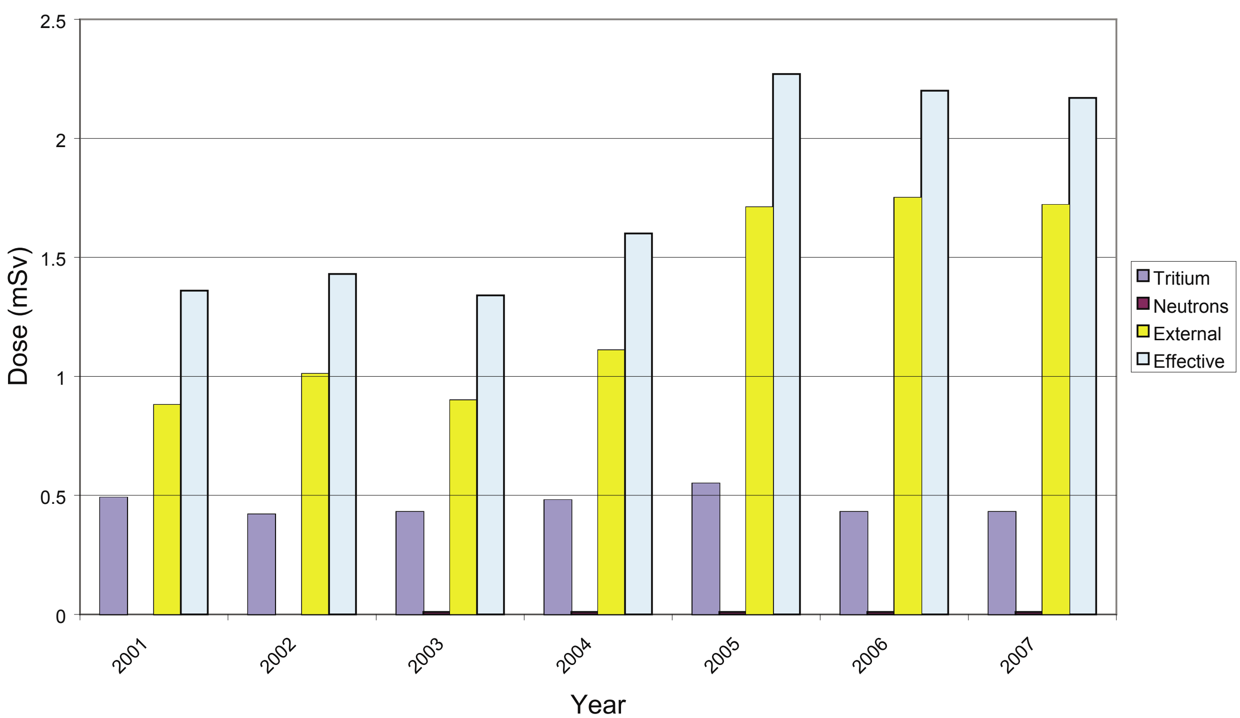


Figure 2.6. Average Dose Trends for Pickering Nuclear Generating Station (Based on All Monitoring Results)

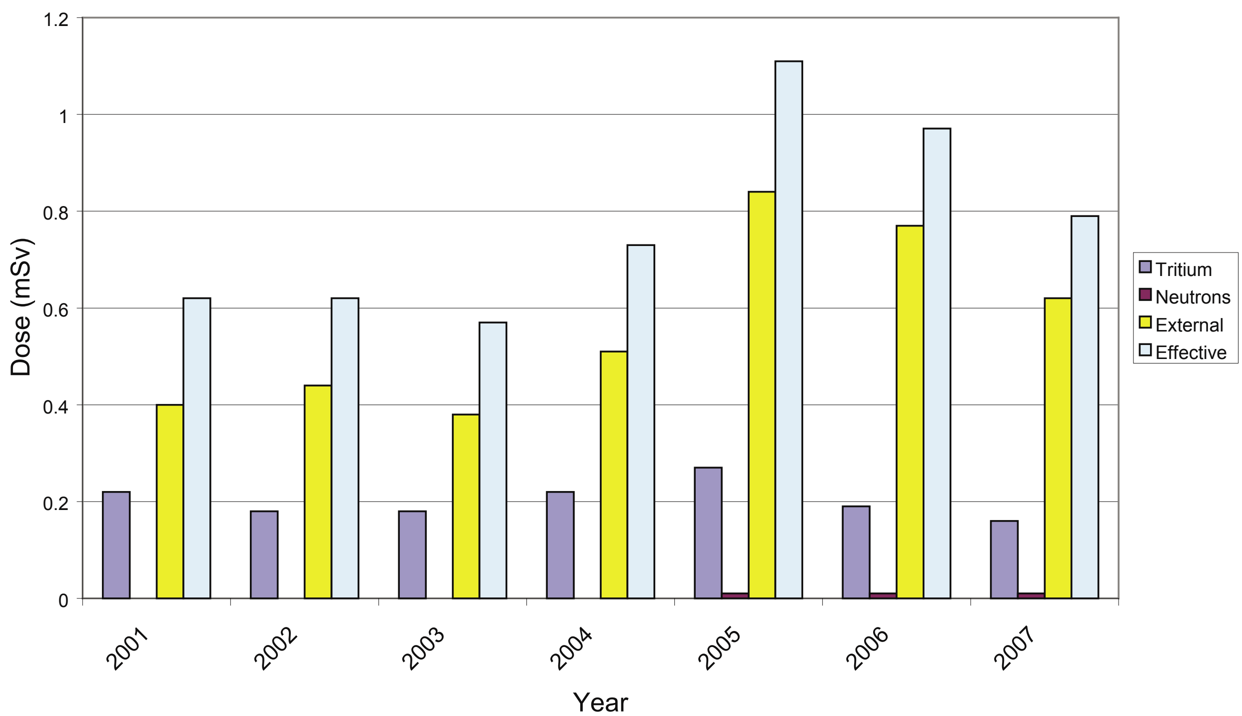


Figure 2.7. Collective Dose Trends for Pickering Nuclear Generating Station

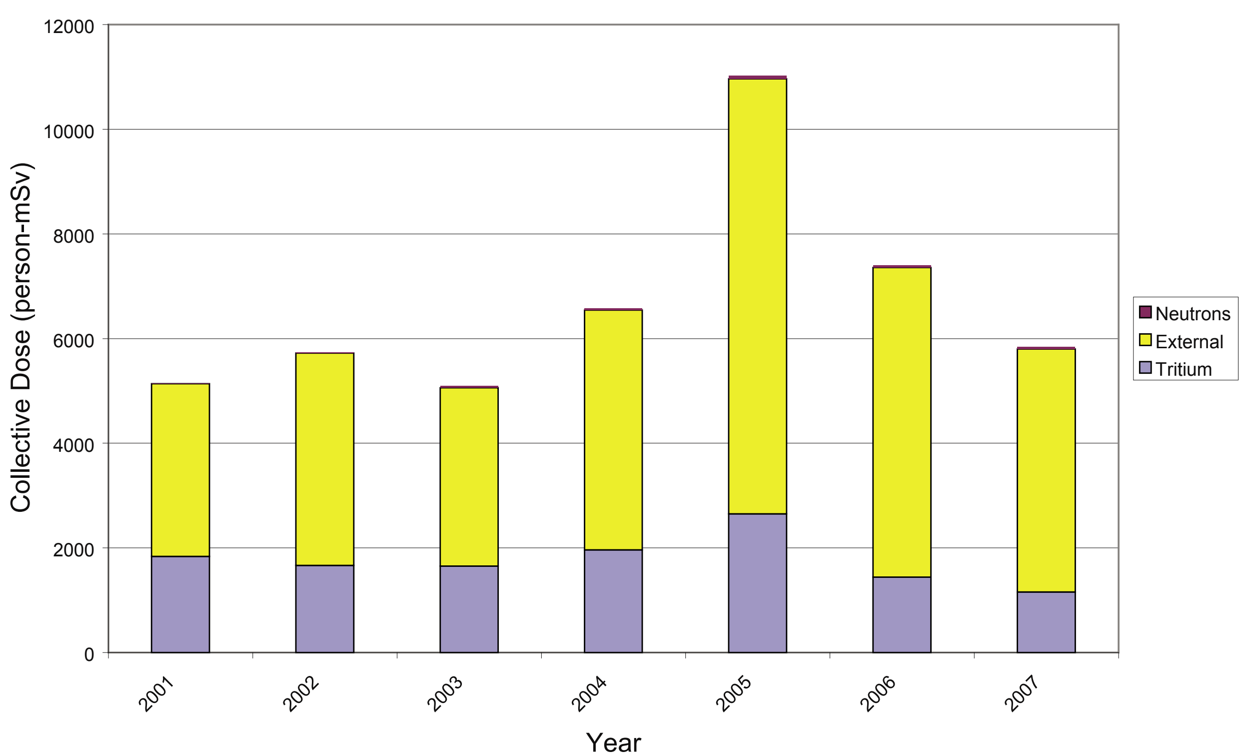
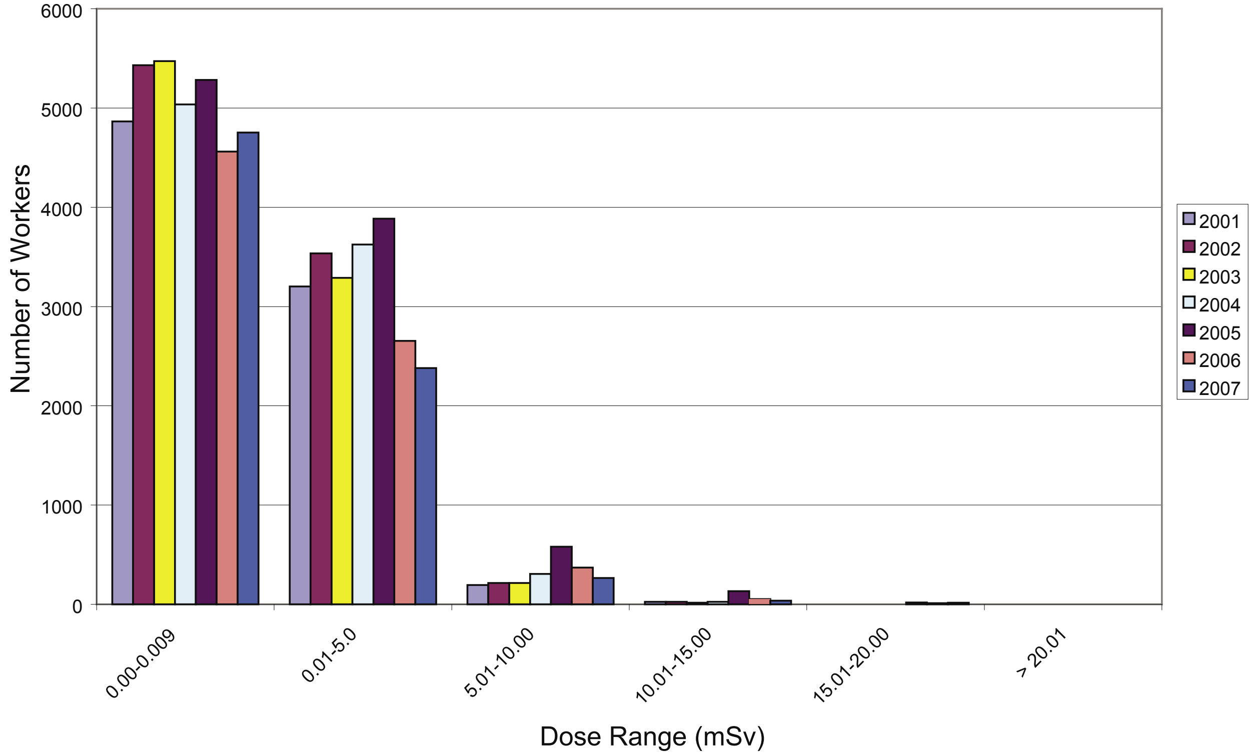


Figure 2.8. Distribution of Effective Doses Among All Workers at Pickering Nuclear Generating Station



2.1.3 Darlington Nuclear Generating Station

Owned and operated by Ontario Power Generation, the Darlington Nuclear Generating Station has four nuclear reactors, the first of which began operating in 1989. The facility is located near Bowmanville, on the shore of Lake Ontario.

Figures 2.9–2.12 present dose information for the Darlington Nuclear Generating Station, from 2001 to 2007.

Figure 2.9. Average Dose Trends for Darlington Nuclear Generating Station (Non- Zero Results Only)

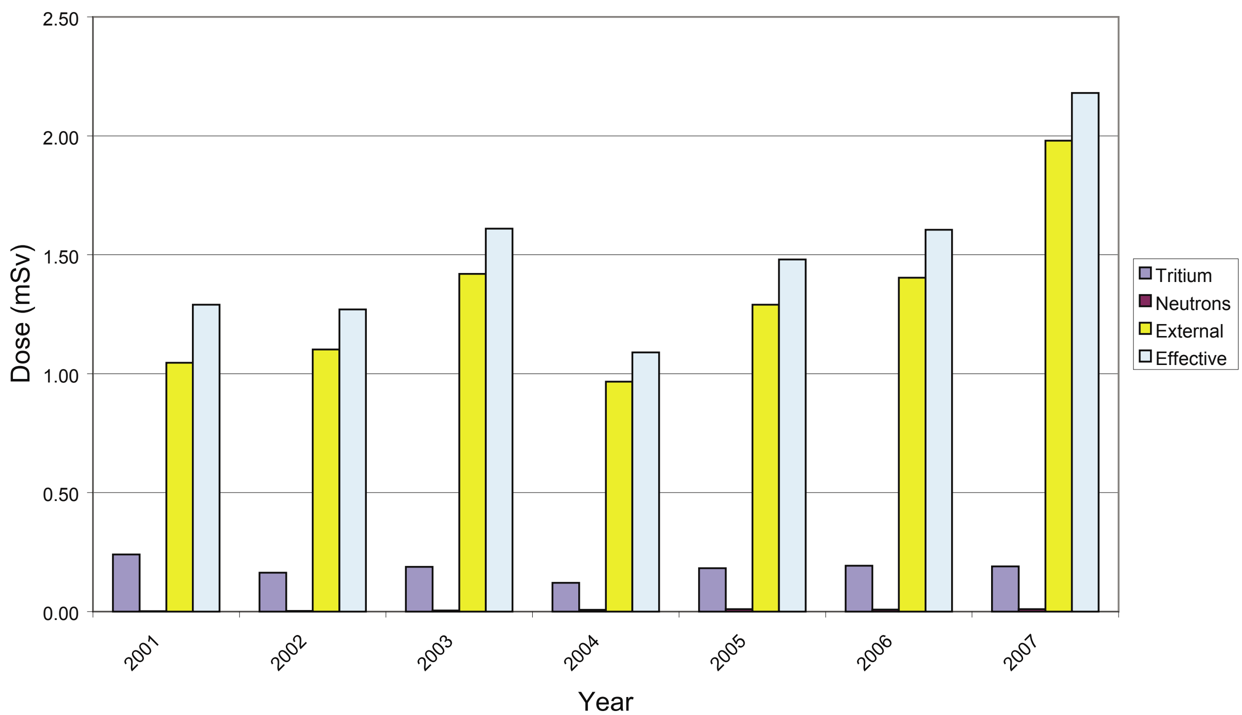


Figure 2.10. Average Dose Trends for Darlington Nuclear Generating Station (All Monitoring Results)

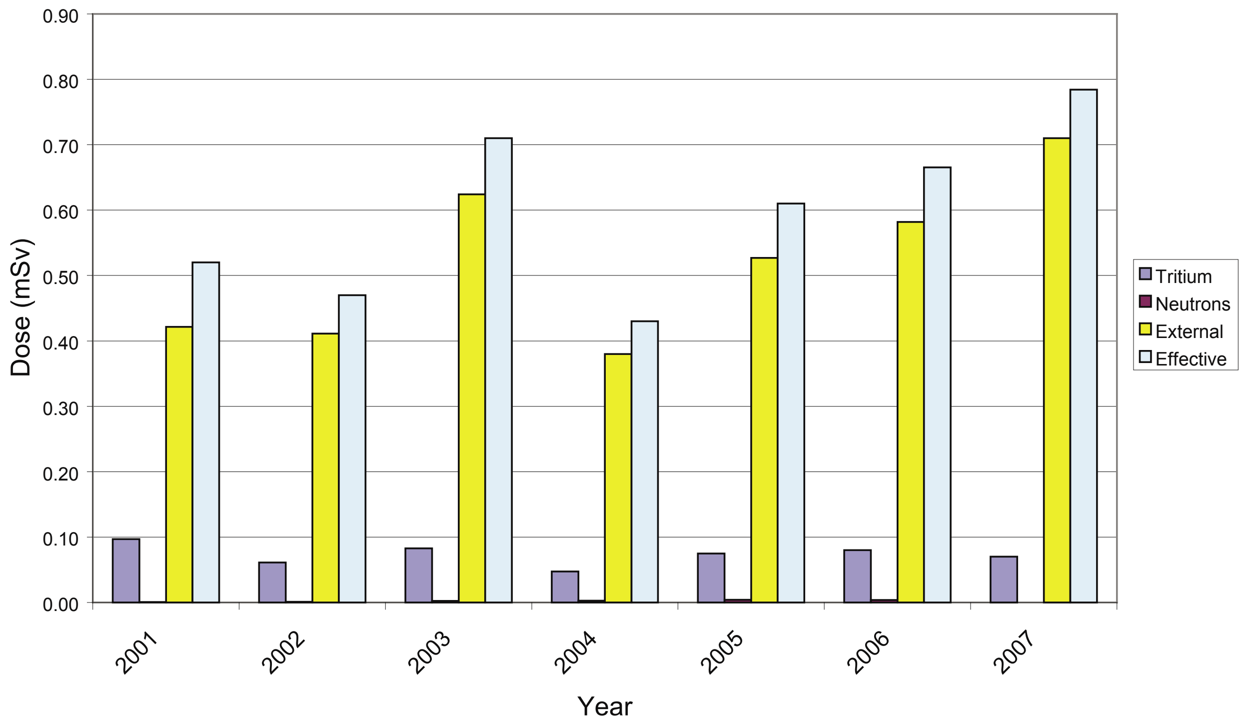


Figure 2.11. Collective Dose Trends for Darlington Nuclear Generating Station

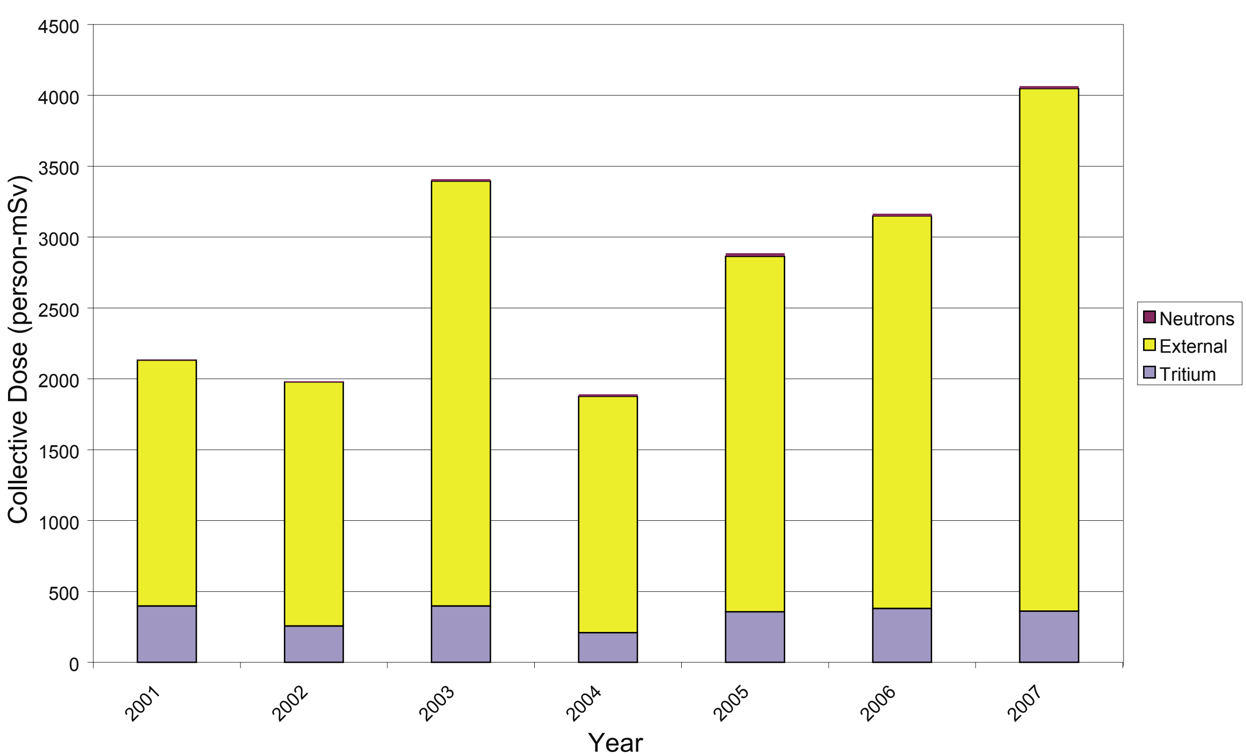
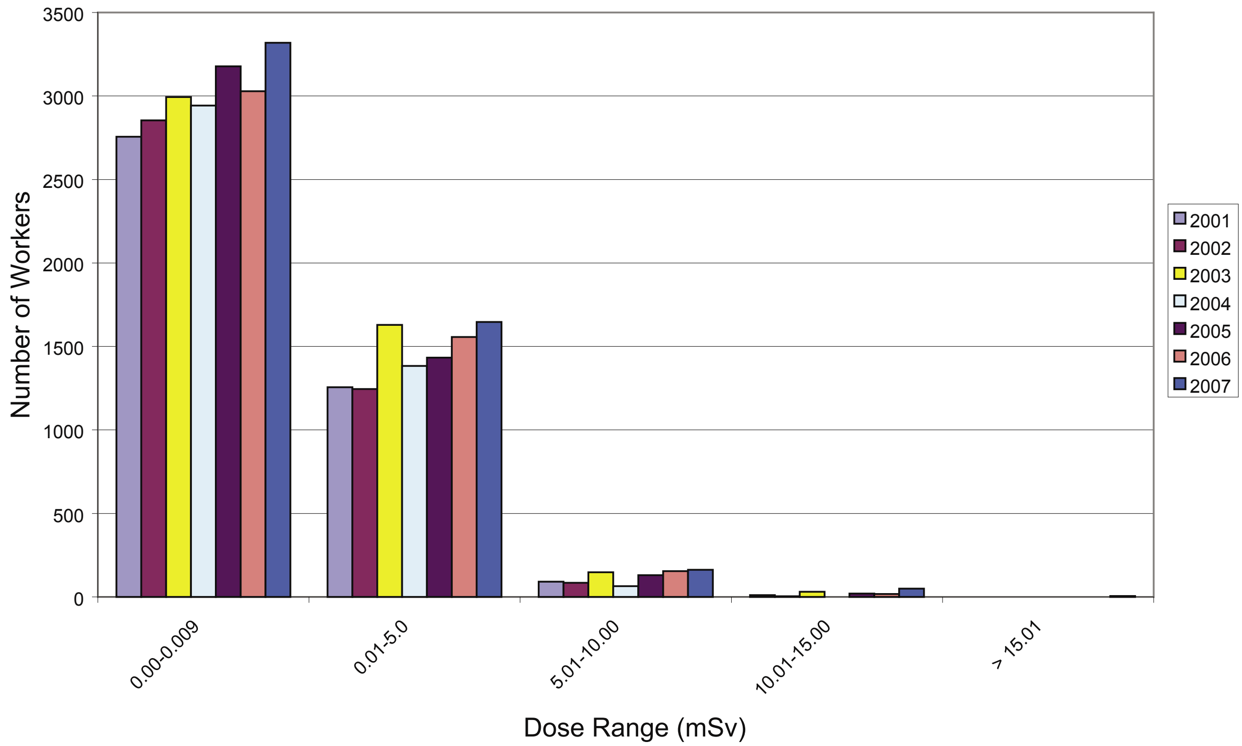


Figure 2.12. Distribution of Effective Doses Among All Workers at Darlington Nuclear Generating Station



2.1.4 Gentilly-2 Nuclear Generating Station

The Gentilly-2 Nuclear Generating Station, owned and operated by Hydro-Québec, has a single reactor that began operating in 1982. The facility is located on the south shore of the St. Lawrence River, near Trois-Rivières, Québec.

Figures 2.13–2.16 present dose information for the Gentilly-2 Nuclear Generating Station, from 2001 to 2007.

Figure 2.13. Average Dose Trends for Gentilly-2 Nuclear Generating Station (Based on Non-Zero Results)

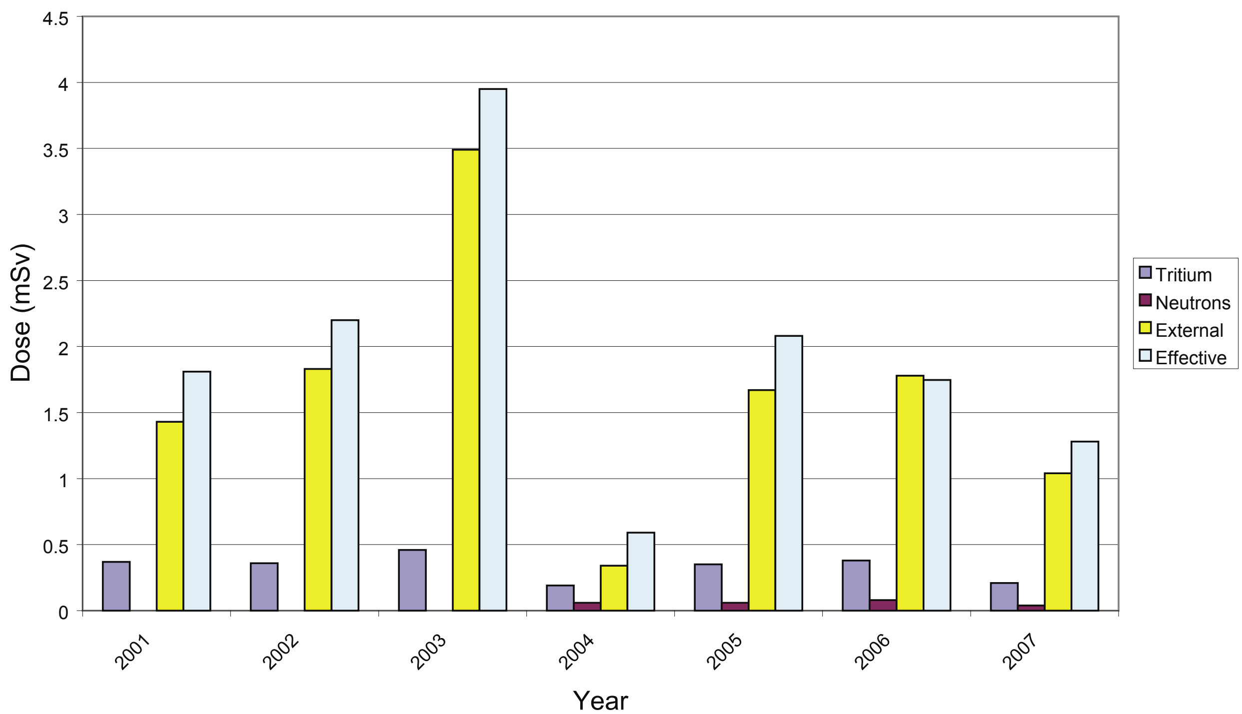


Figure 2.14. Average Dose Trends for Gentilly-2 Nuclear Generating Station (Based on All Monitoring Results)

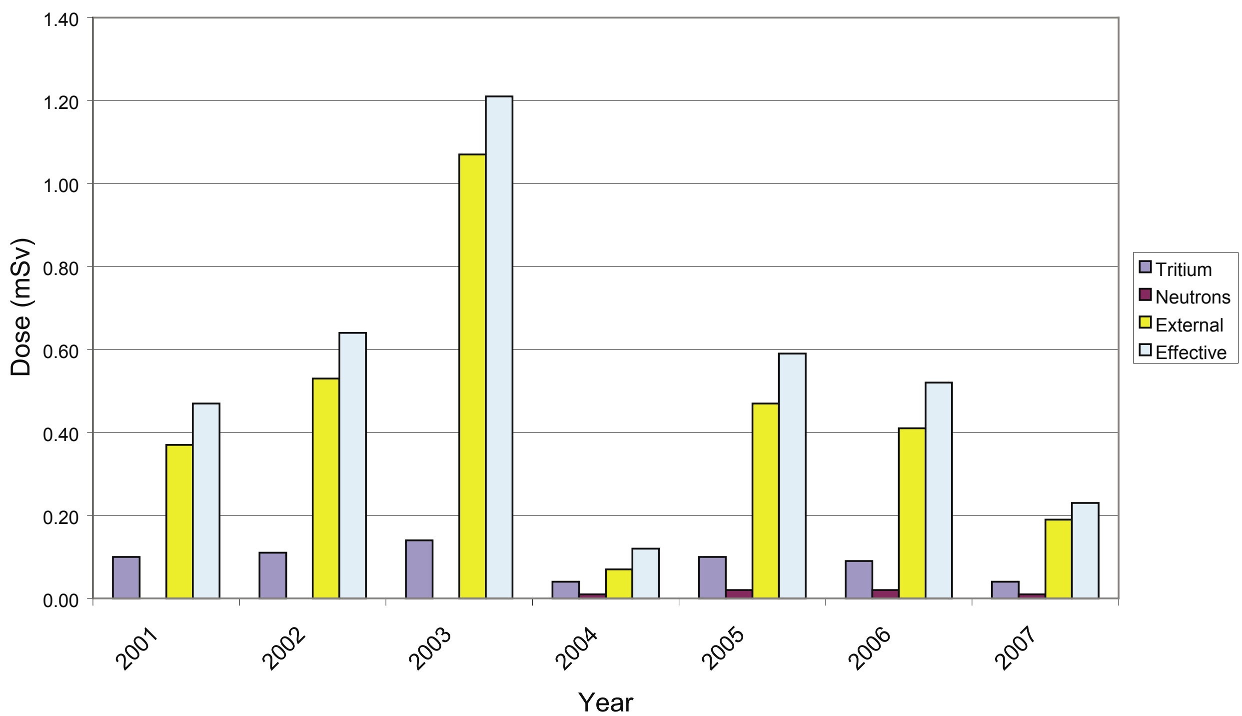


Figure 2.15. Collective Dose Trends for Gentilly-2 Nuclear Generating Station

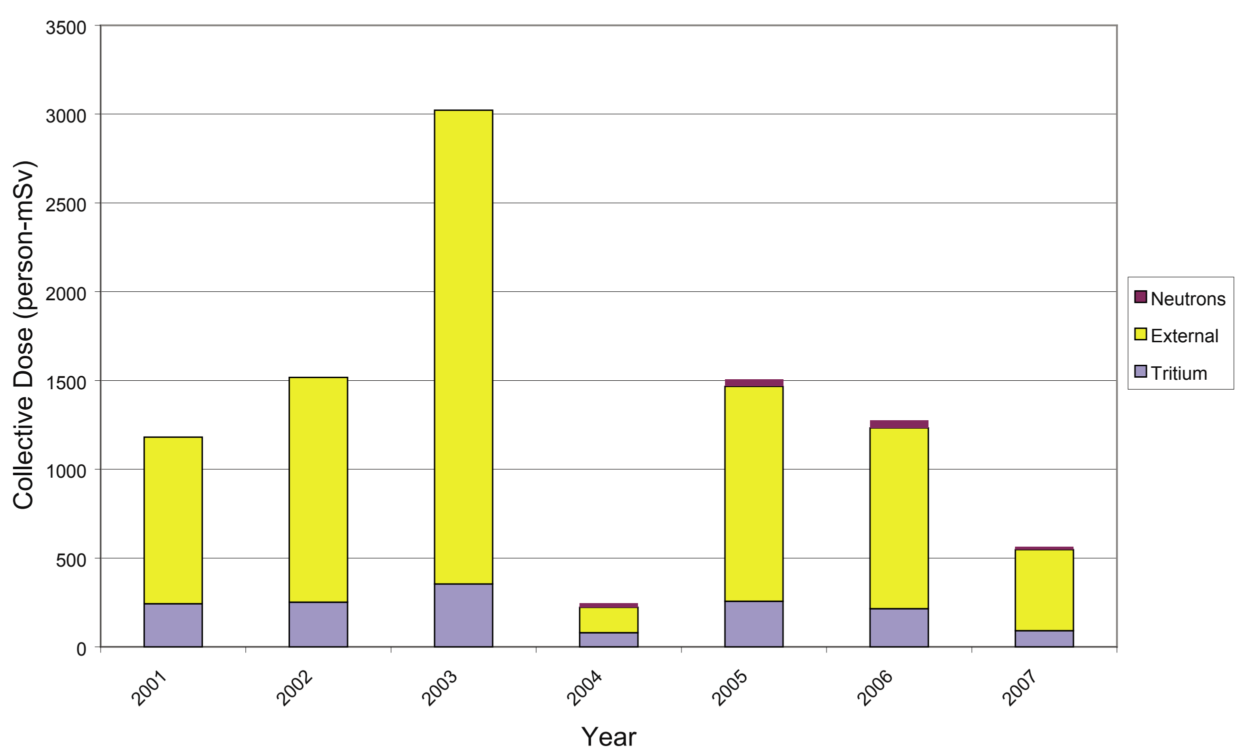
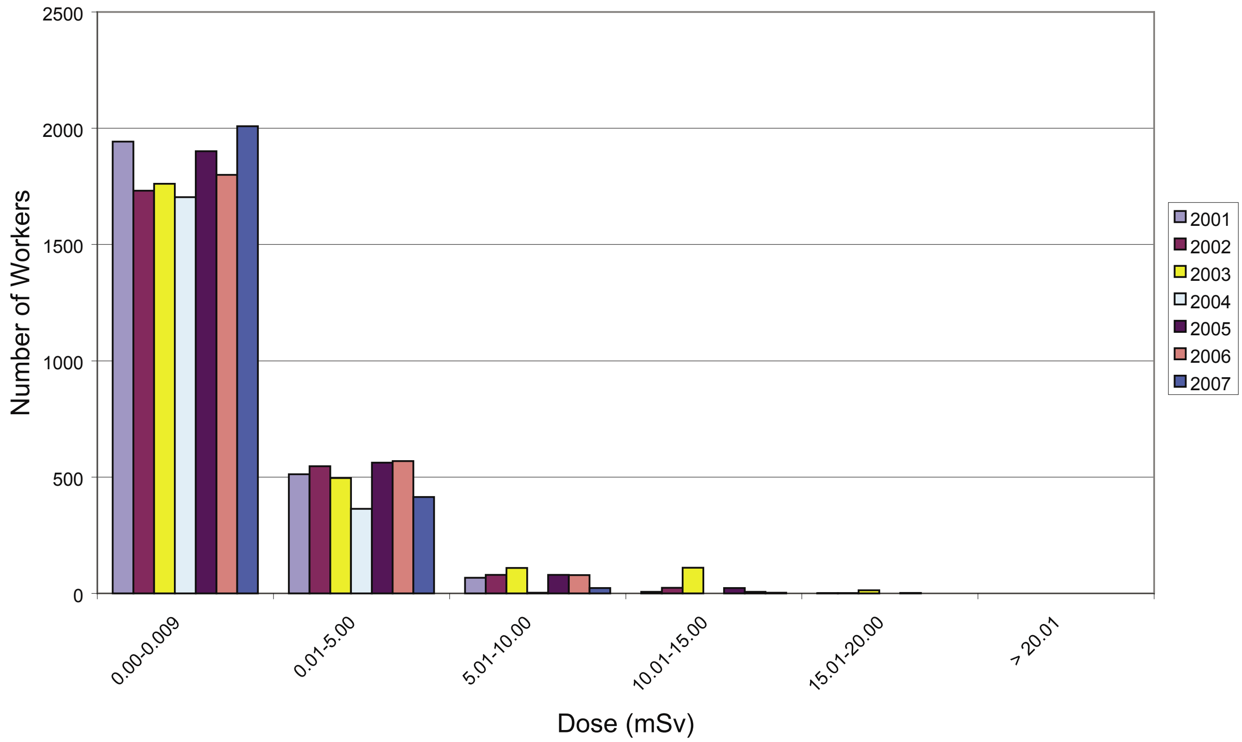


Figure 2.16. Distribution of Effective Doses Among All Workers at Gentilly-2 Nuclear Generating Station



2.1.5 Point Lepreau Nuclear Generating Station

The Point Lepreau Nuclear Generating Station has one reactor that began operating in 1982. Owned and operated by New Brunswick Power Nuclear, the station is located in Point Lepreau, New Brunswick, about 40 km west of Saint John, on the shores of the Bay of Fundy.

Figures 2.17–2.20 present dose information for the Point Lepreau Nuclear Generating Station, from 2001 to 2007.

Figure 2.17. Average Dose Trends for Point Lepreau Nuclear Generating Station (Based on Non-Zero Results)

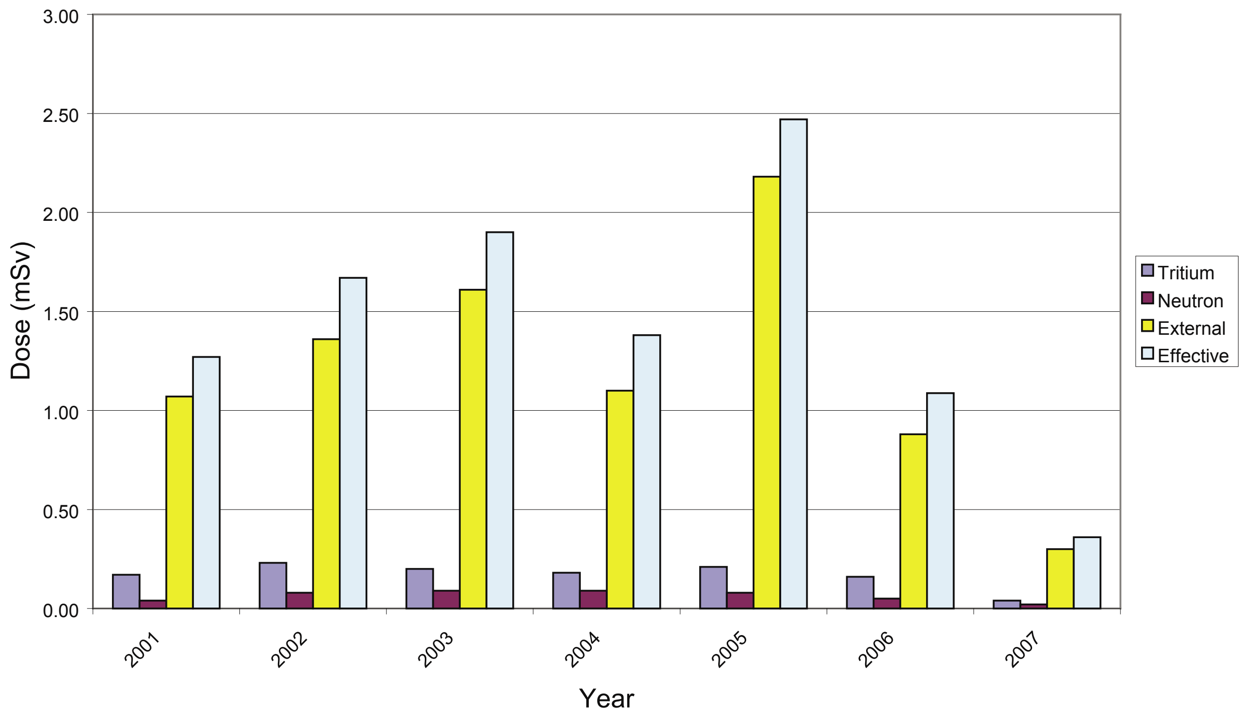


Figure 2.18. Average Dose Trends for Point Lepreau Nuclear Generating Station (Based on All Monitoring Results)

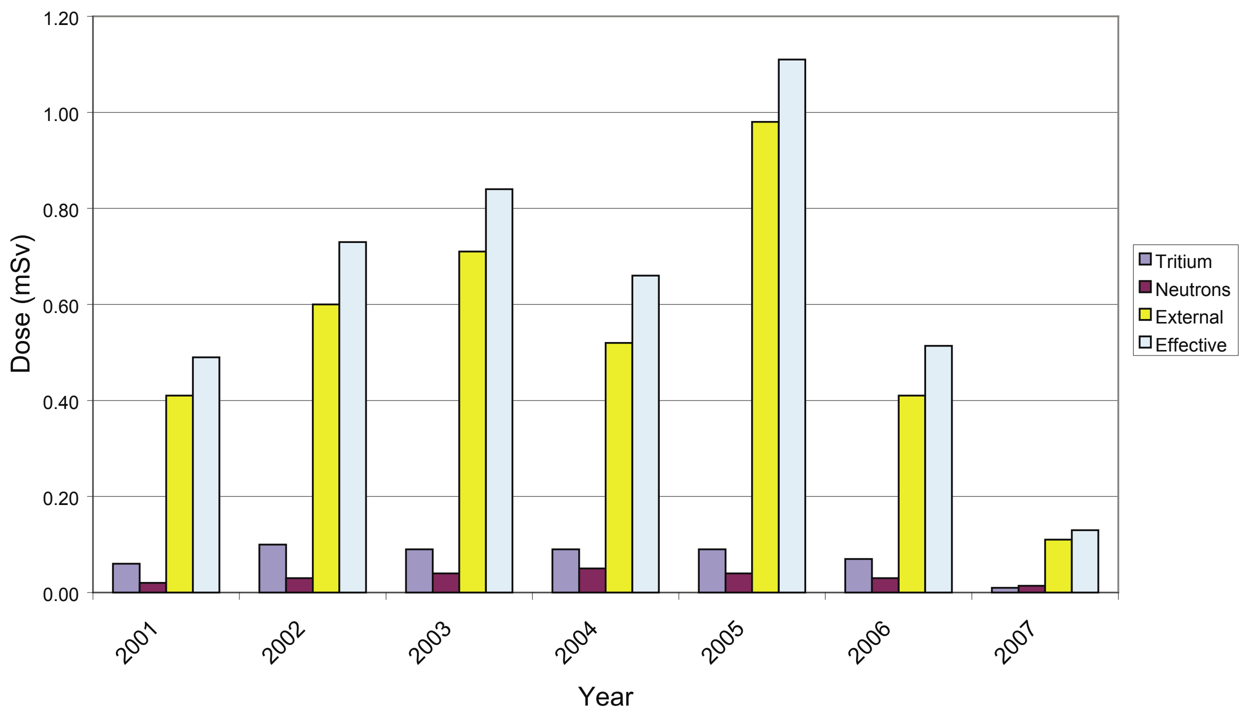


Figure 2.19. Collective Dose Trends for Point Lepreau Nuclear Generating Station

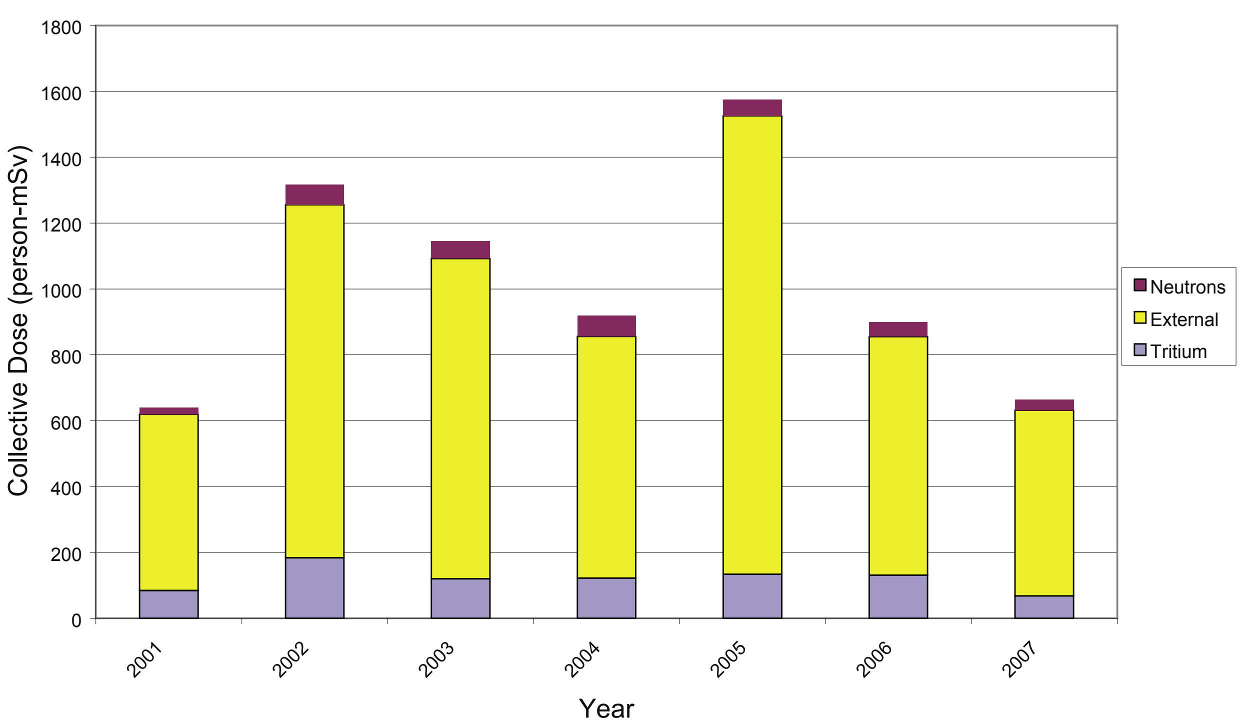
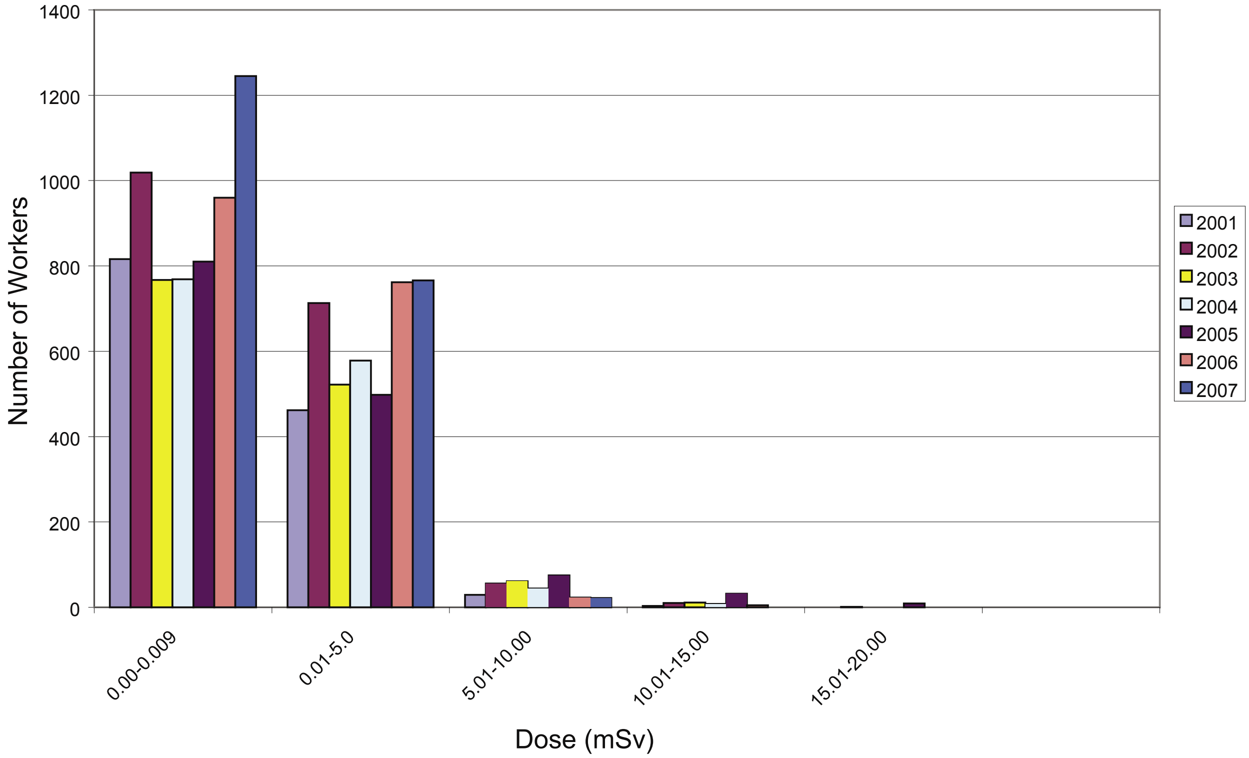


Figure 2.20. Distribution of Effective Doses Among All Workers at Point Lepreau Nuclear Generating Station



2.2 Uranium Mines and Mills

This section presents dose information for mine and mill sites in the following regions:

- Cluff Lake (Section 2.2.1)
- McClean Lake (Section 2.2.2)
- McArthur River (Section 2.2.3)
- Key Lake (Section 2.2.4)
- Cigar Lake (Section 2.2.5)
- Rabbit Lake (Section 2.2.6)

Graphs indicate the following data for each site, from 2001 to 2007:

1. average doses based on non-zero (positive) results
2. average doses based on all monitoring results
3. collective doses
4. distribution of average effective doses

Notes on data for uranium mines and mills:

1. Effective doses are composed of the following reported components:
   - doses from photons (labelled on the charts as “external”)
   - doses from radon progeny
   - doses from long-lived radioactive dust
   - doses from radon gas (in some cases)

2. Collective dose data is presented in stacked bar graphs, where total effective doses are the sum of their respective components of photon, radon progeny, long-lived radioactive dust and radon gas doses.

3. The NDR lists radon progeny in working level months (WLM). For this report, radon progeny exposures were converted[4] to doses expressed in mSv.

2.2.1 Cluff Lake Operation

The Cluff Lake mining facilities, operated by AREVA Resources Canada Inc., are located in northwestern Saskatchewan. Work began in 1980 and ended in 2002, with the site now being decommissioned. The site consisted of three open-pit and two underground mines, a mill, and a tailings management facility. During 2005 and 2006, most of the infrastructure was removed and the affected areas were remediated.

Figures 2.21–2.24 present dose information for the Cluff Lake operation, from 2001 to 2007.

4 Doses were converted using the International Commission on Radiation Protection (ICRP)’s conversion convention of 1 WLM = 5 mSv. This convention was established in the ICRP publication *Protection against Radon at Home and at Work* (ICRP 65).

Figure 2.21. Average Dose Trends for the Cluff Lake Operation (Based on Non-Zero Results)

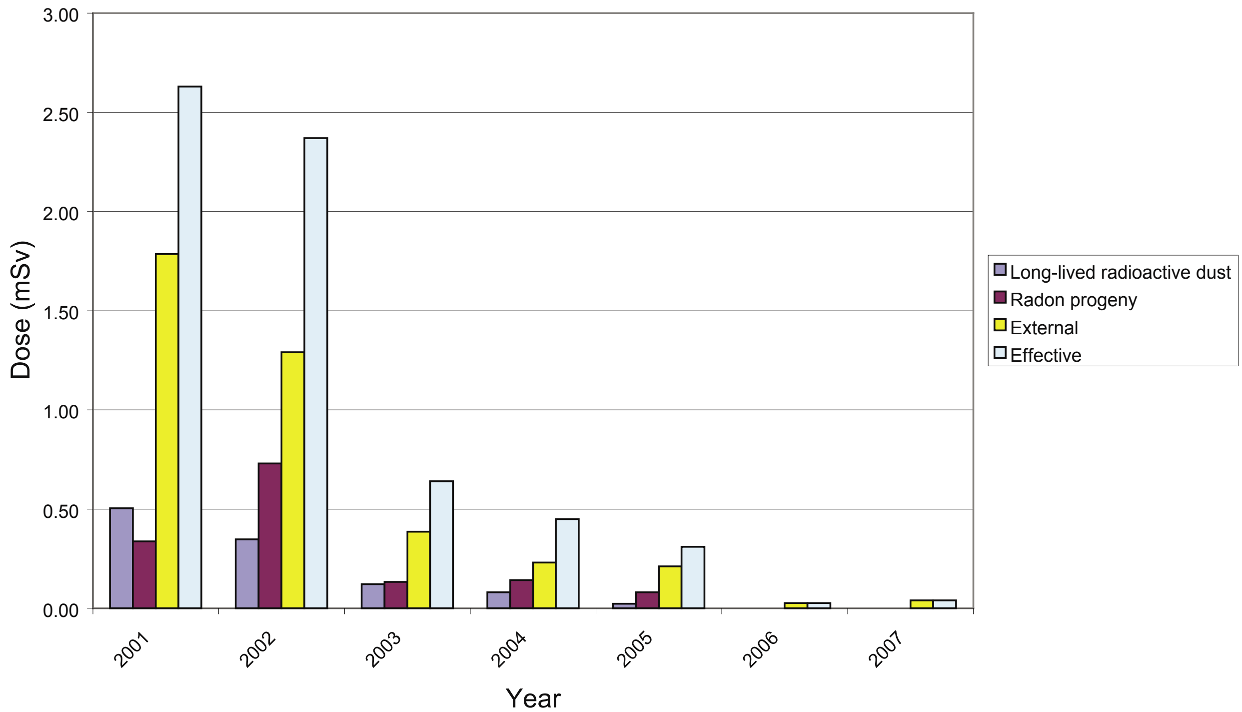


Figure 2.22 Average Dose Trends for the Cluff Lake Operation (Based on All Monitoring Results)

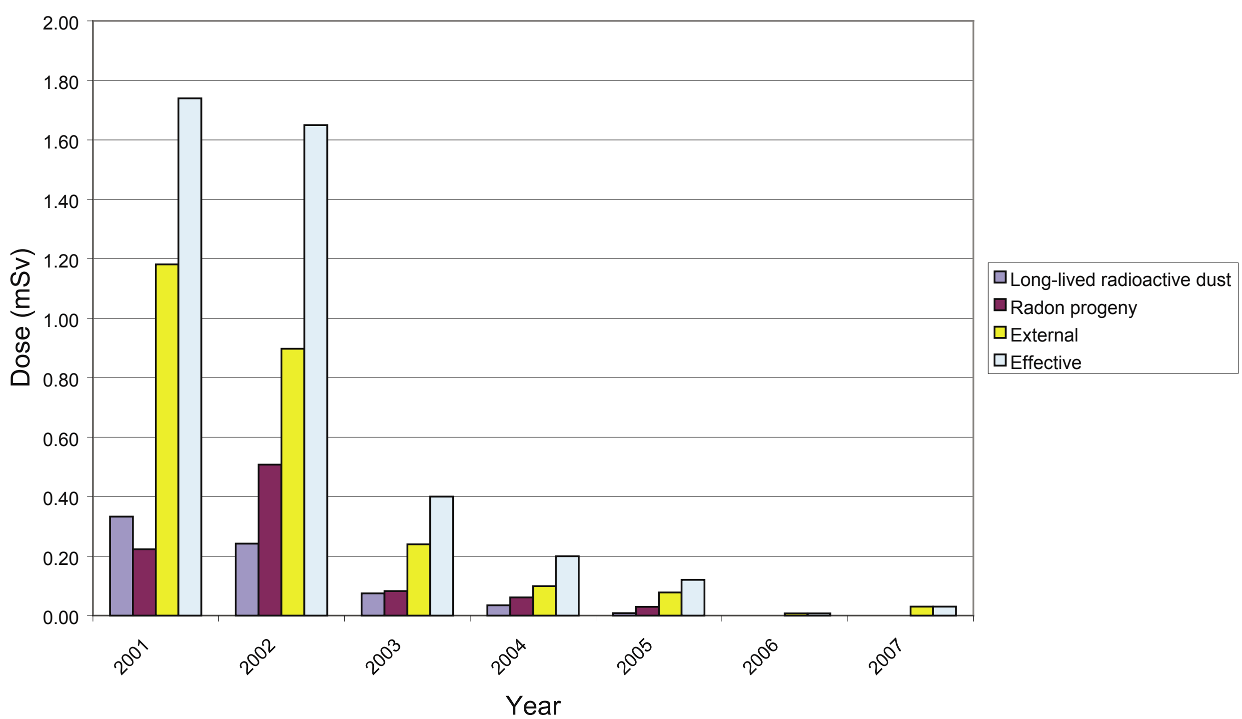


Figure 2.23. Collective Dose Trends for the Cluff Lake Operation

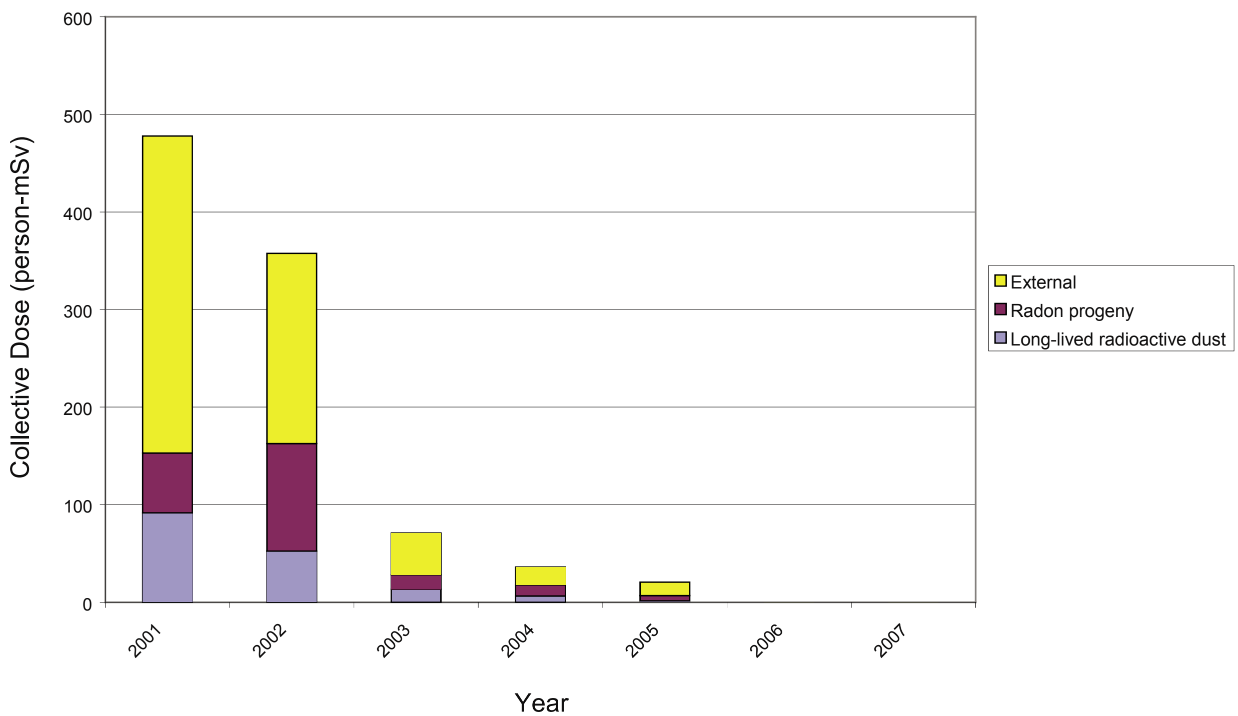
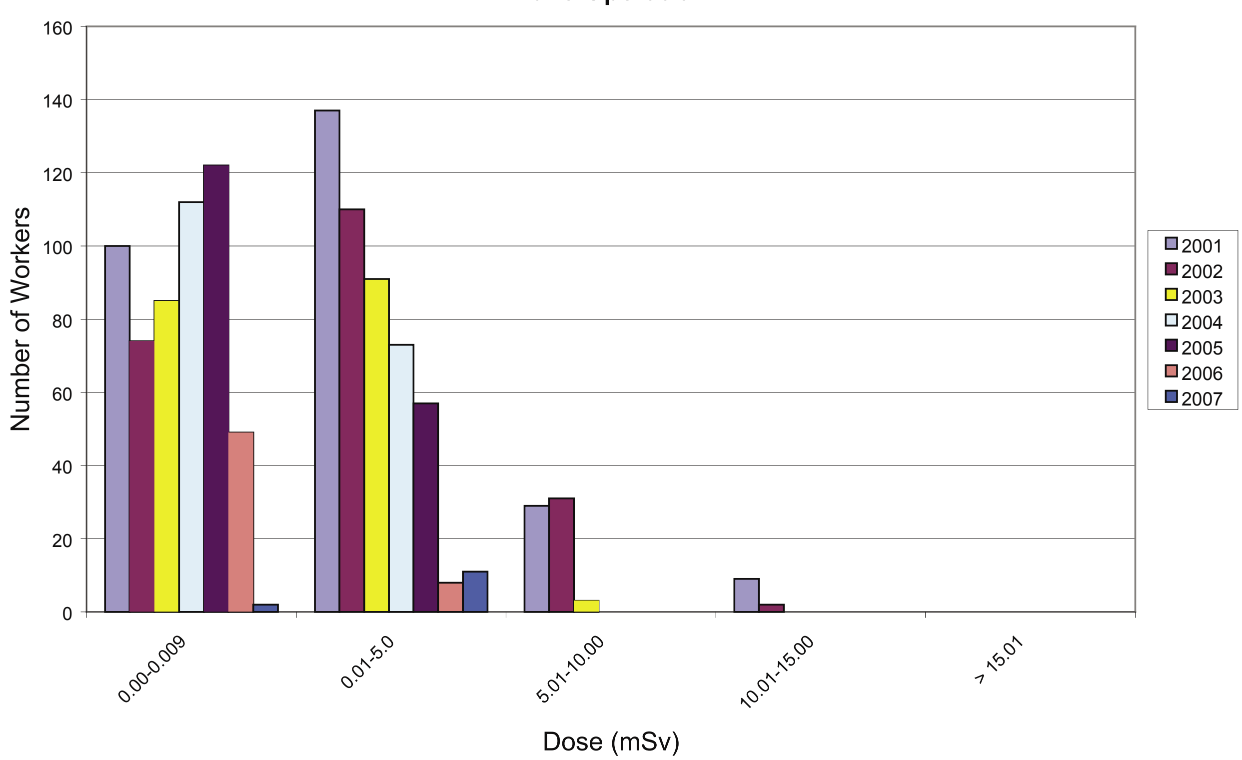


Figure 2.24. Distribution of Effective Doses Among All Workers at the Cluff Lake Operation



2.2.2 McClean Lake Operation

AREVA Resources Canada Inc. runs the McClean Lake mining operation in northeastern Saskatchewan. It comprises open pit mines, a mill and a tailings management facility. Mining began in 1995, while milling started in 1999.

Figures 2.25–2.28 present dose information for the McClean Lake operation, from 2001 to 2007.

Figure 2.25. Average Dose Trends for the McClean Lake Operation (Based on Non-Zero Results)

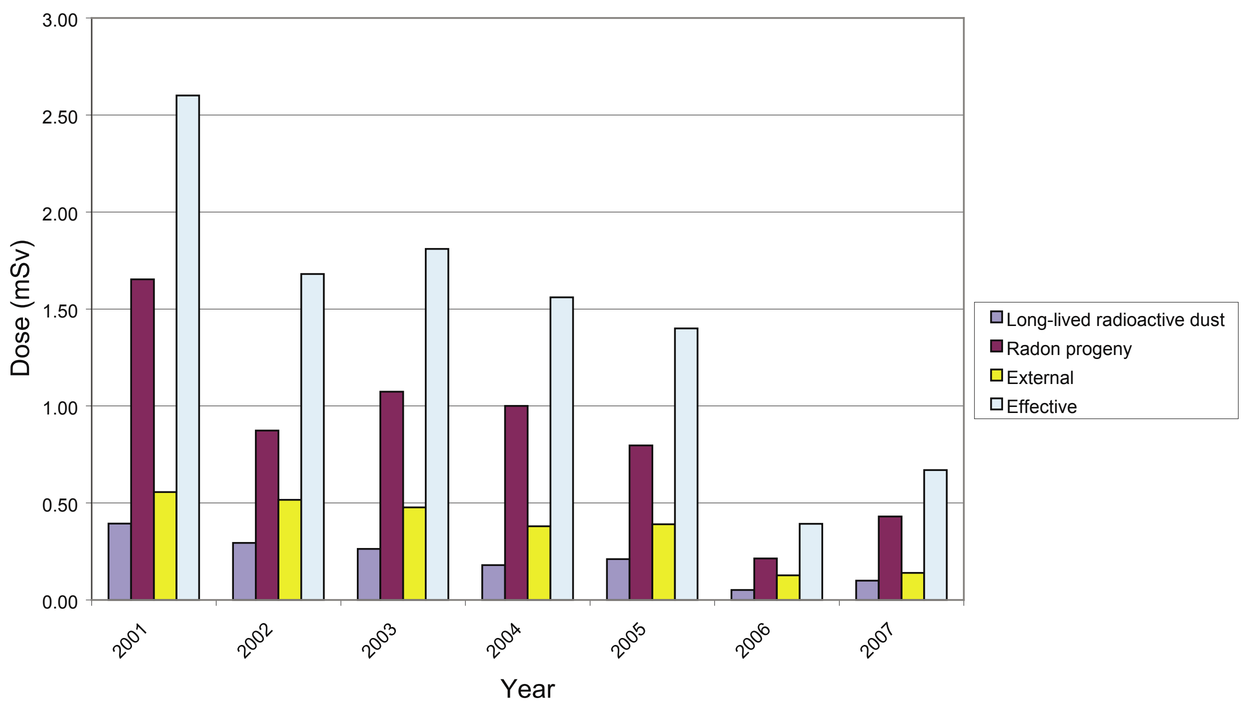


Figure 2.26. Average Dose Trends for the McClean Lake Operation (Based on All Monitoring Results)

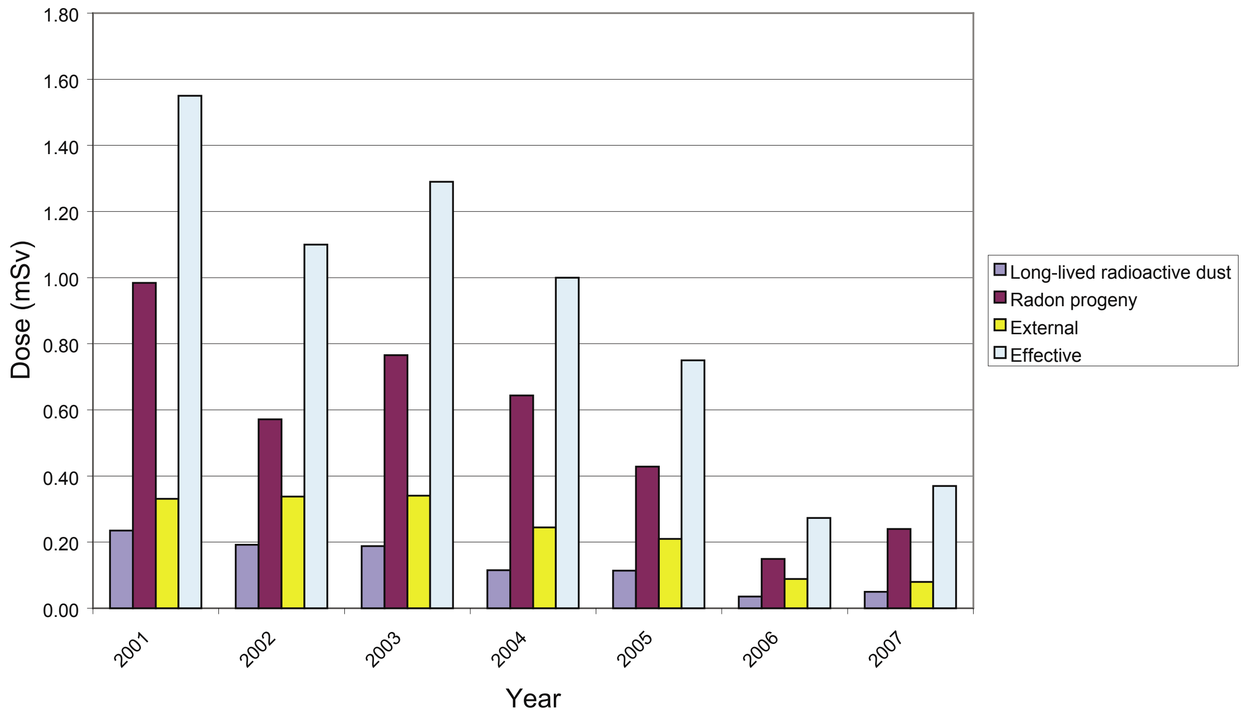


Figure 2.27. Collective Dose Trends for the McClean Lake Operation

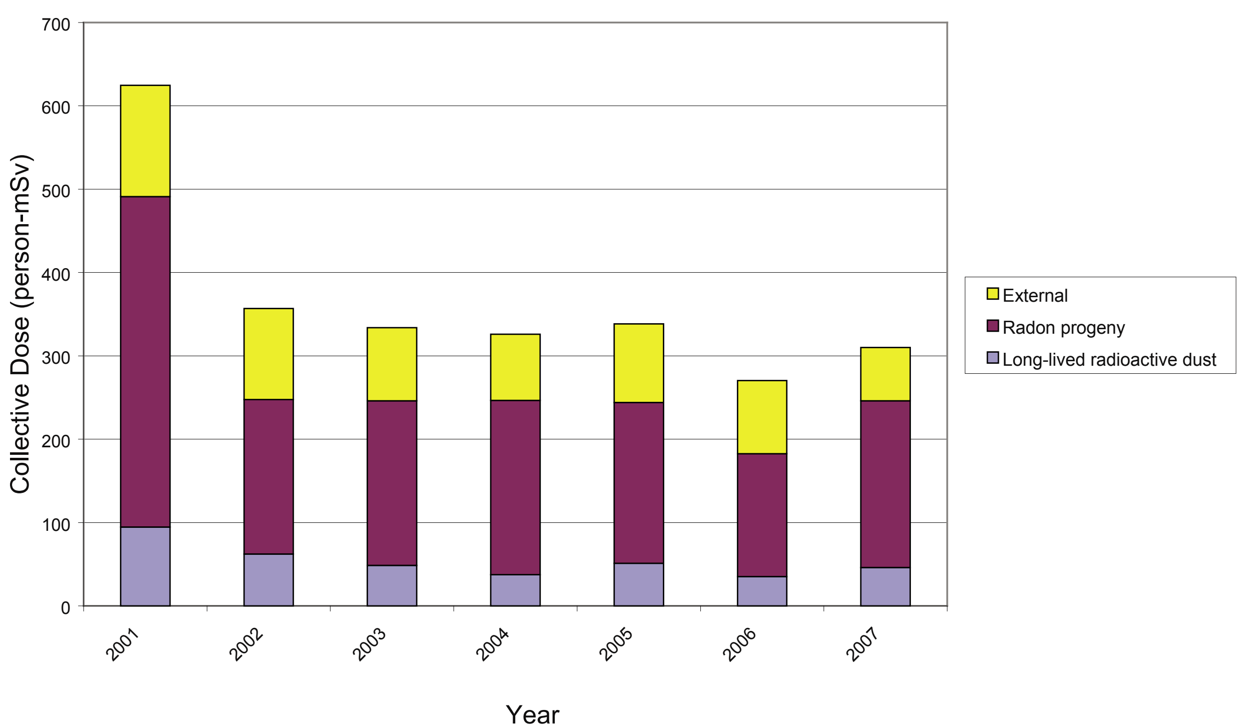
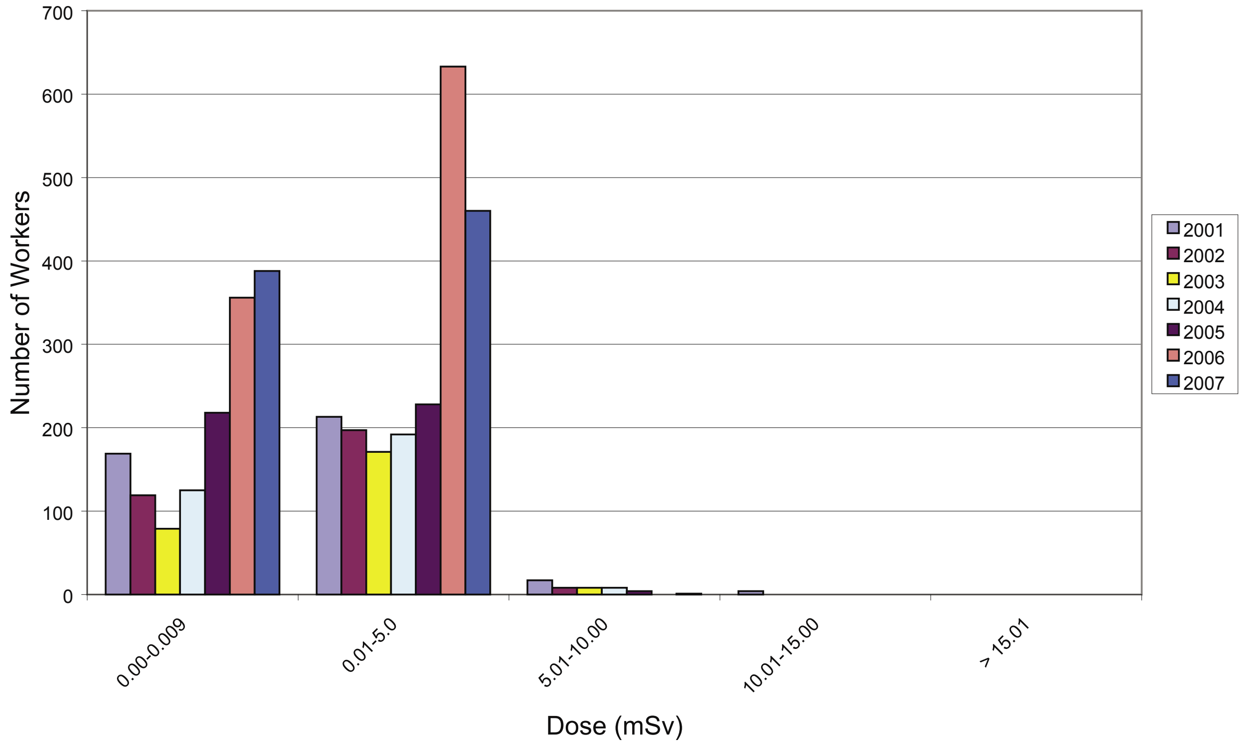


Figure 2.28. Distribution of Effective Doses Among All Workers at the McClean Lake Operation



2.2.3 McArthur River Operation

Cameco Corporation operates the McArthur River underground mine in north-central Saskatchewan. Ore from the mine, which began production in 1999, is processed at the Key Lake Mill, located 80 km south of McArthur River.

Figures 2.29–2.32 present dose information for the McArthur River operation, from 2001 to 2007.

Figure 2.29. Average Dose Trends for the McArthur River Operation (Based on Non-Zero Results)

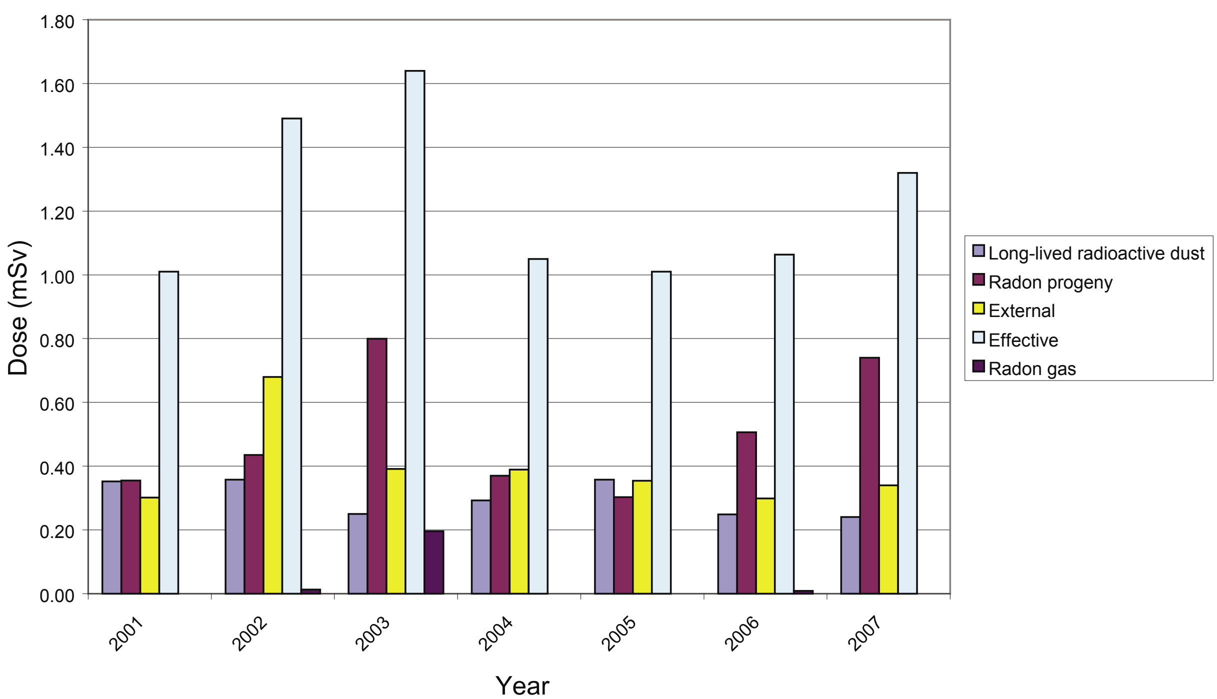


Figure 2.30. Average Dose Trends for the McArthur River Operation (Based on All Monitoring Results)

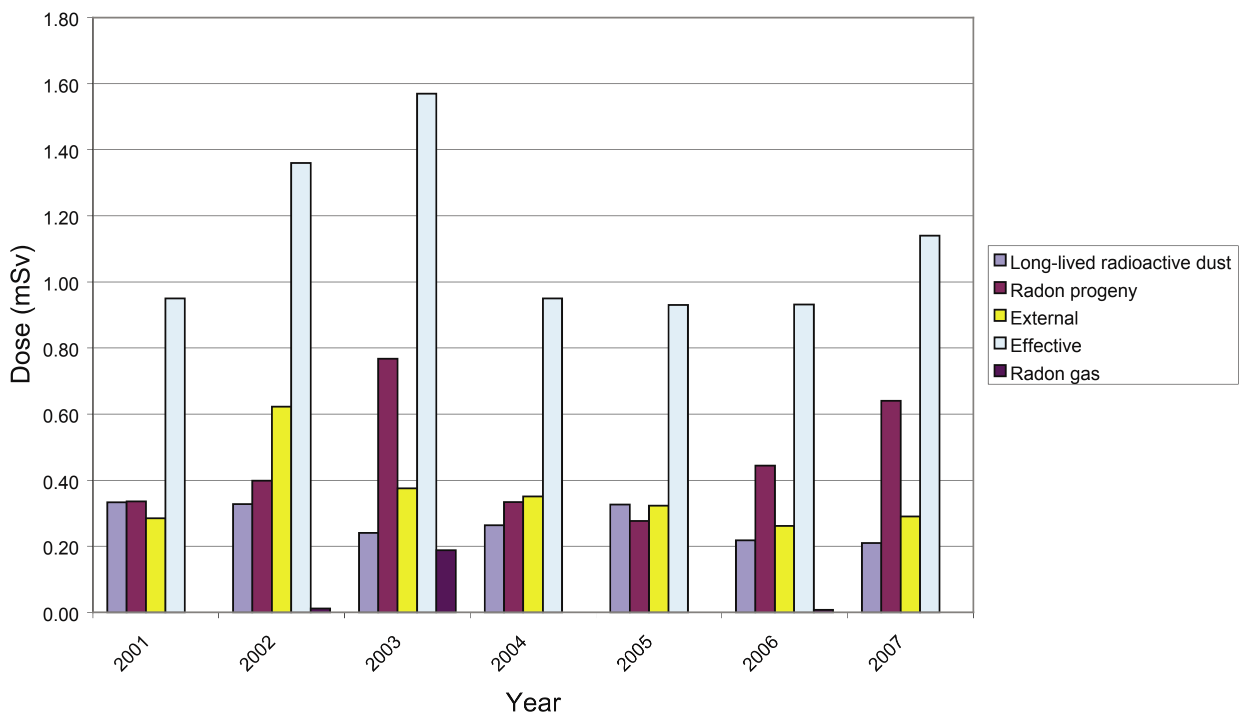


Figure 2.31. Collective Dose Trends for the McArthur River Operation

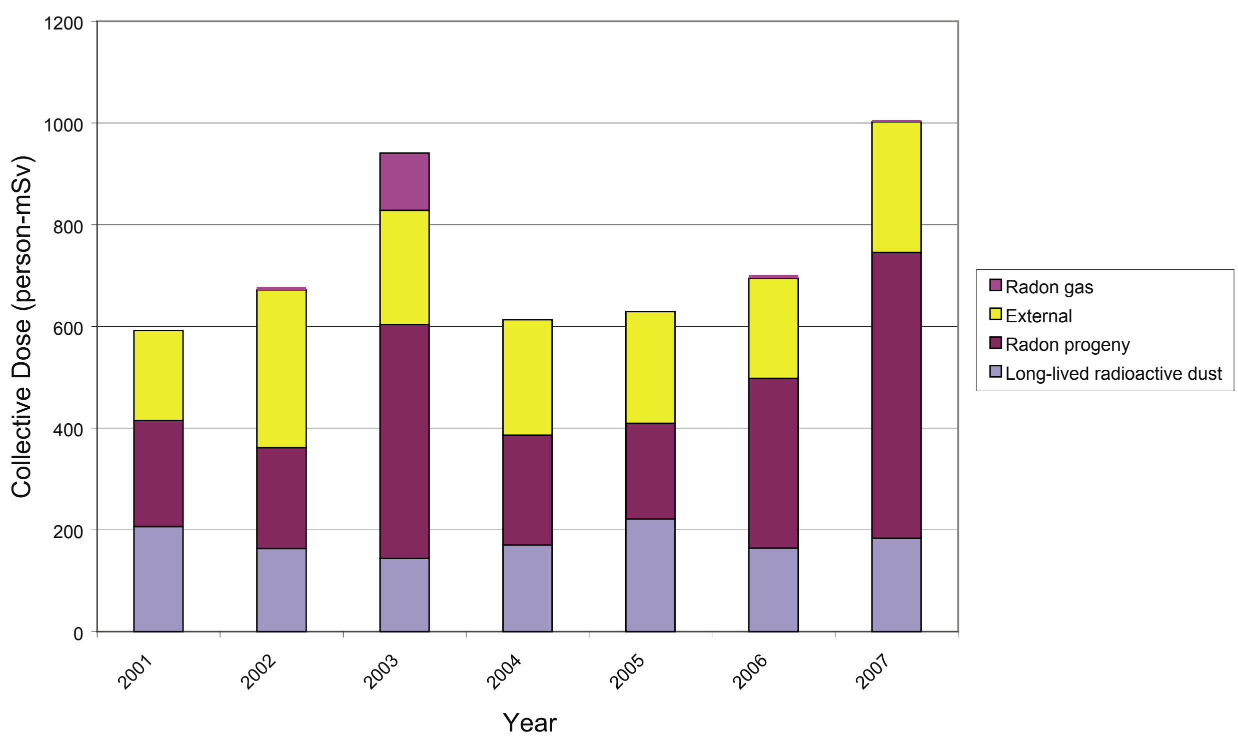
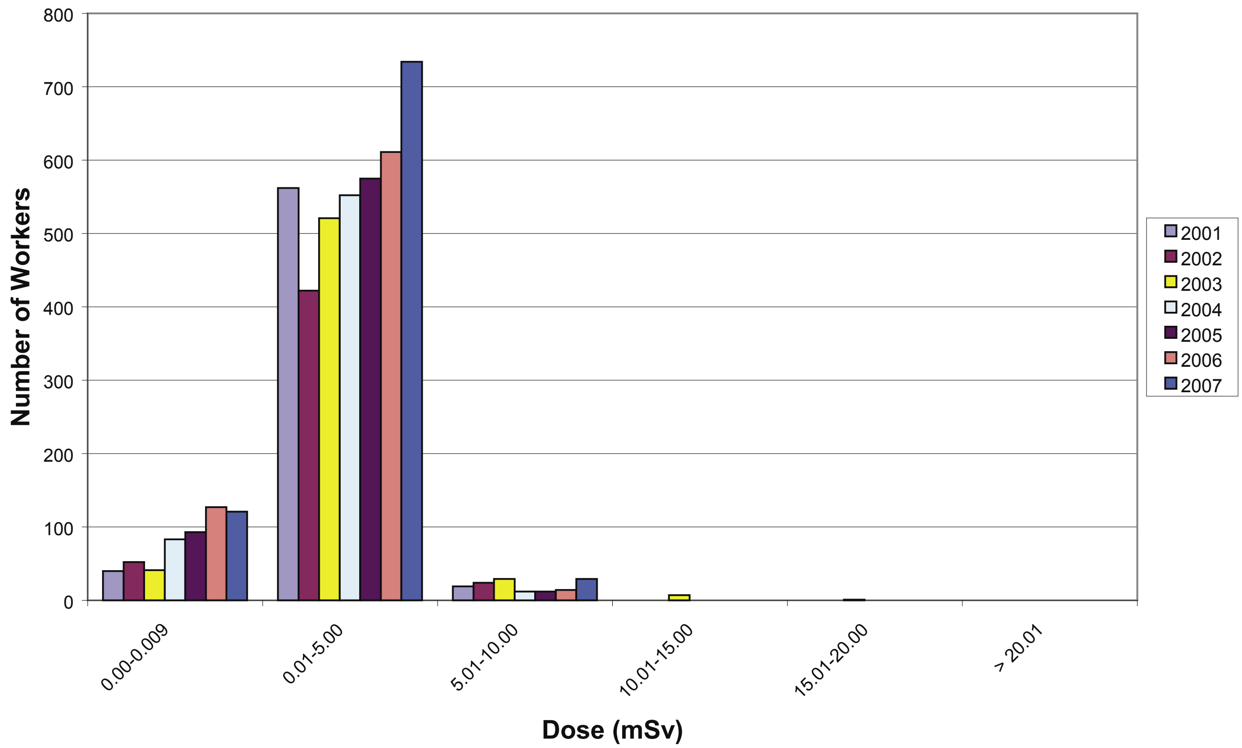


Figure 2.32. Distribution of Effective Doses Among All Workers at the McArthur River Operation



2.2.4 Key Lake Operation

Cameco Corporation operates mining facilities in Key Lake, located in north-central Saskatchewan. The Key Lake operation includes two mined-out open pit mines (used for tailings management), a mill and two dry tailings management facilities. Mining began in 1983 and ceased in 1997; the mill continued to process ore from the McArthur River mine during the reporting period.

Figures 2.33–2.36 present dose information for the Key Lake operation, from 2001 to 2007.

Figure 2.33. Average Dose Trends for the Key Lake Operation (Based on Non-Zero Results)

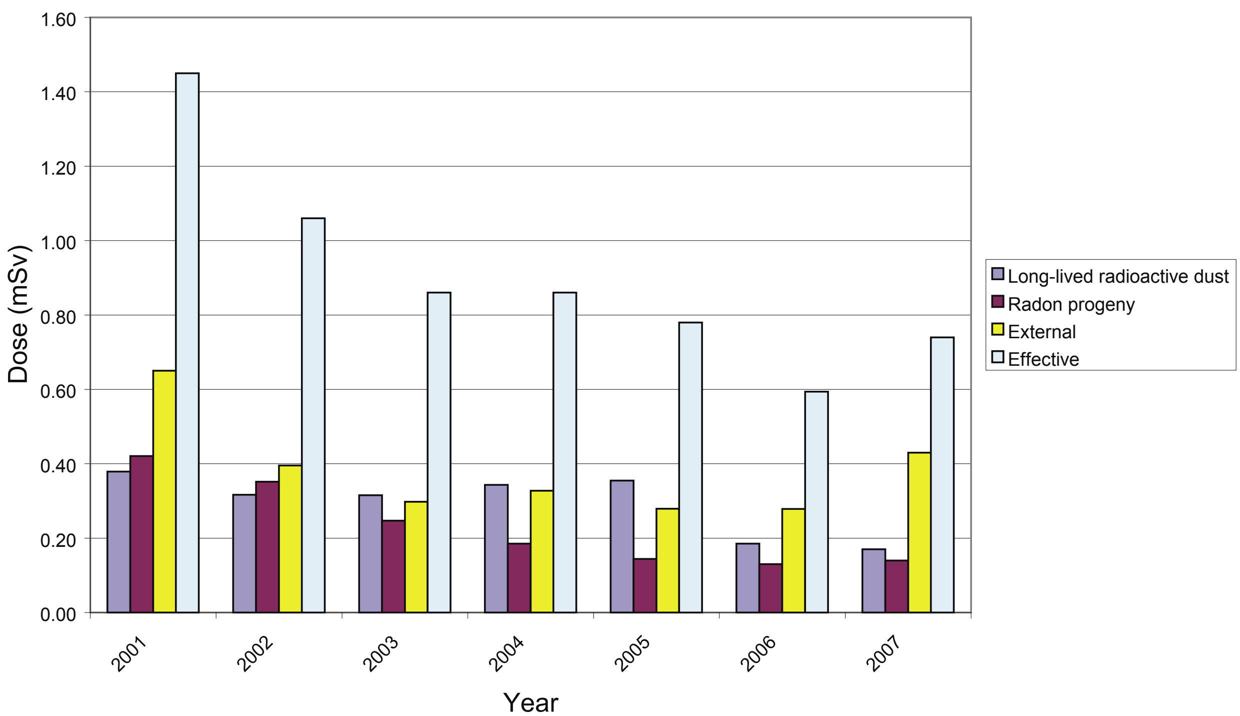


Figure 2.34. Average Dose Trends for the Key Lake Operation (Based on All Monitoring Results)

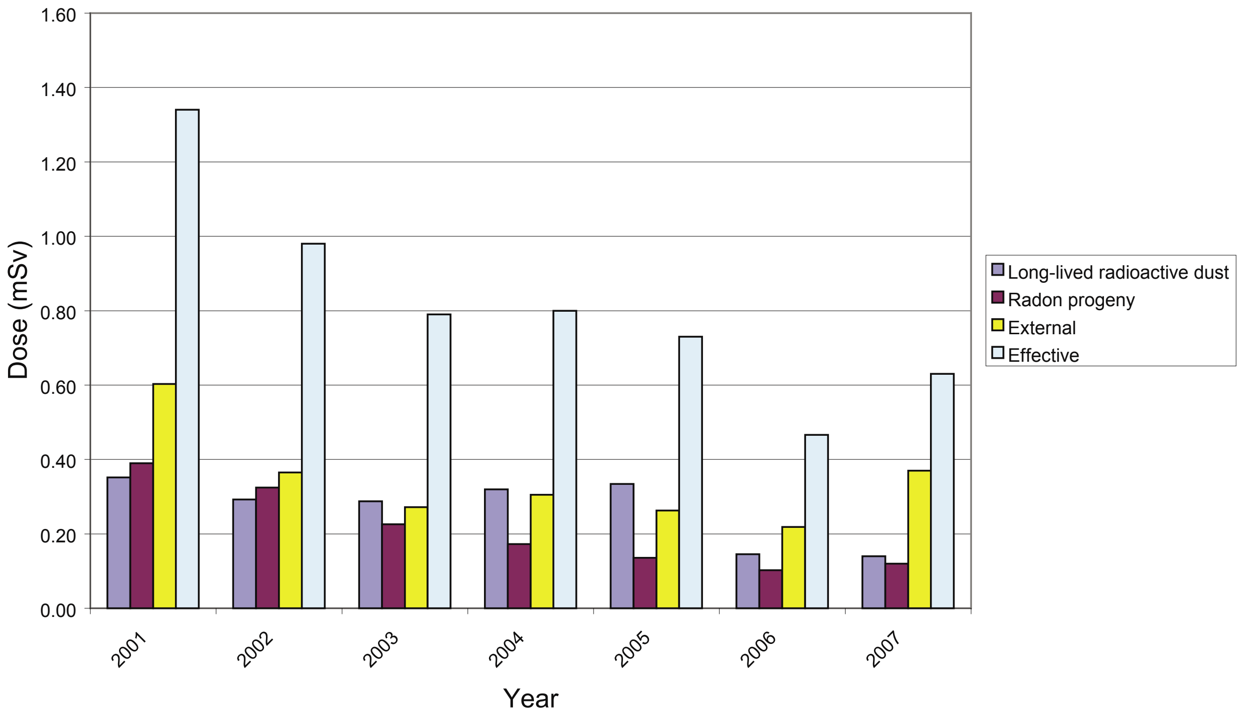


Figure 2.35. Collective Dose Trends for the Key Lake Operation

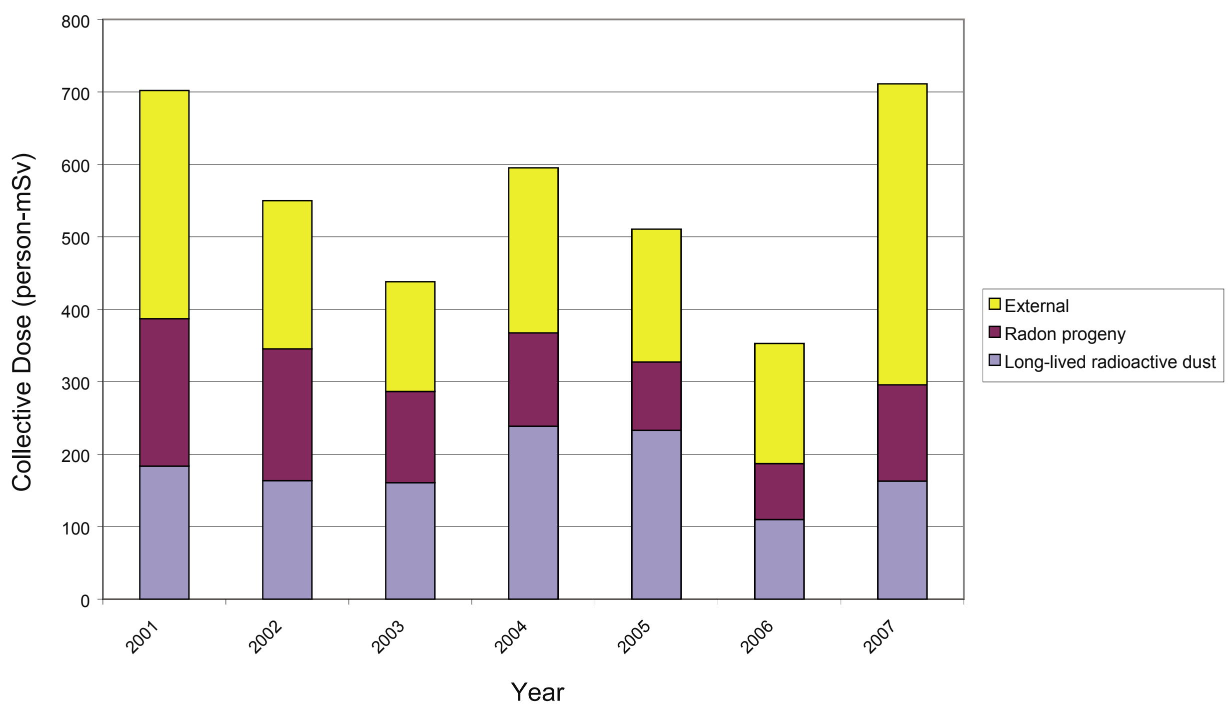
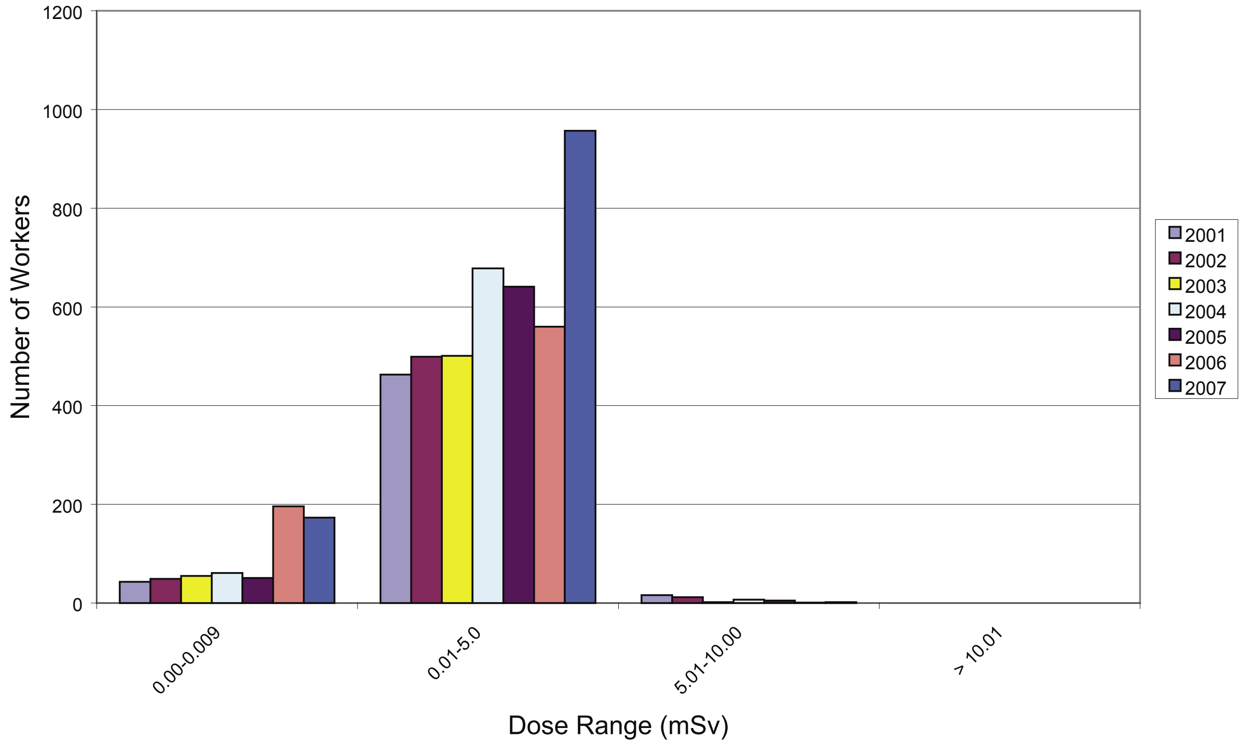


Figure 2.36. Distribution of Effective Doses Among All Workers at the Key Lake Operation



2.2.5 Cigar Lake Operation

Cameco Corporation manages the Cigar Lake underground mine, located in northern Saskatchewan at the southern end of Waterbury Lake. The mine was under construction at the time of this report's publication. Test mining in ore was carried out in 1991, 1992 and 2000.

Figures 2.37–2.40 present dose information for the Cigar Lake operation, from 2001 to 2007.

Figure 2.37. Average Dose Trends for the Cigar Lake Operation (Based on Non-Zero Results)

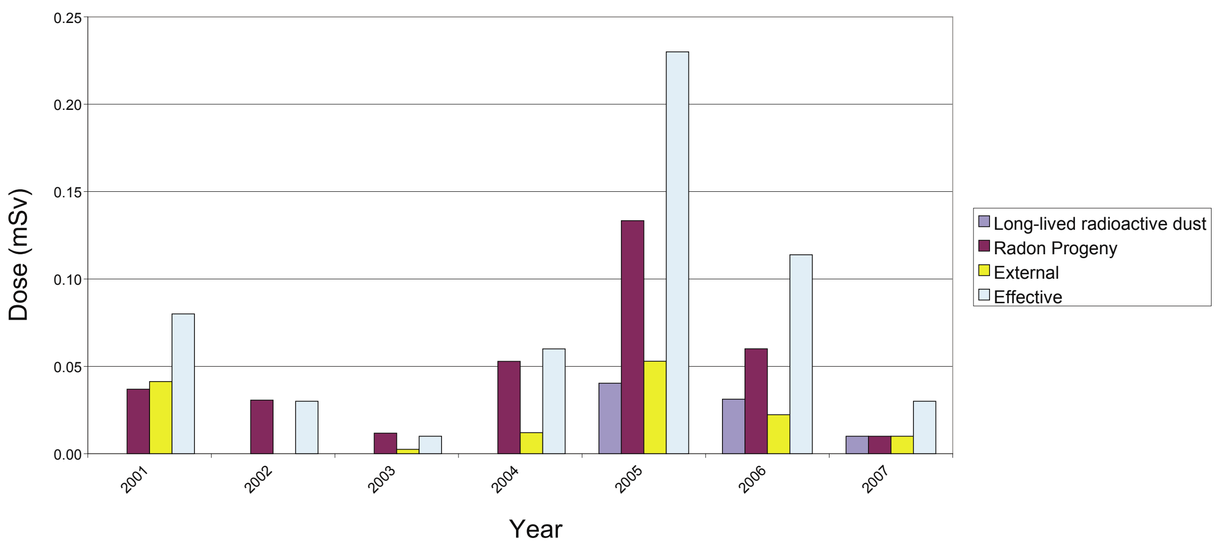


Figure 2.38. Average Dose Trends for the Cigar Lake Operation (Based on All Monitoring Results)

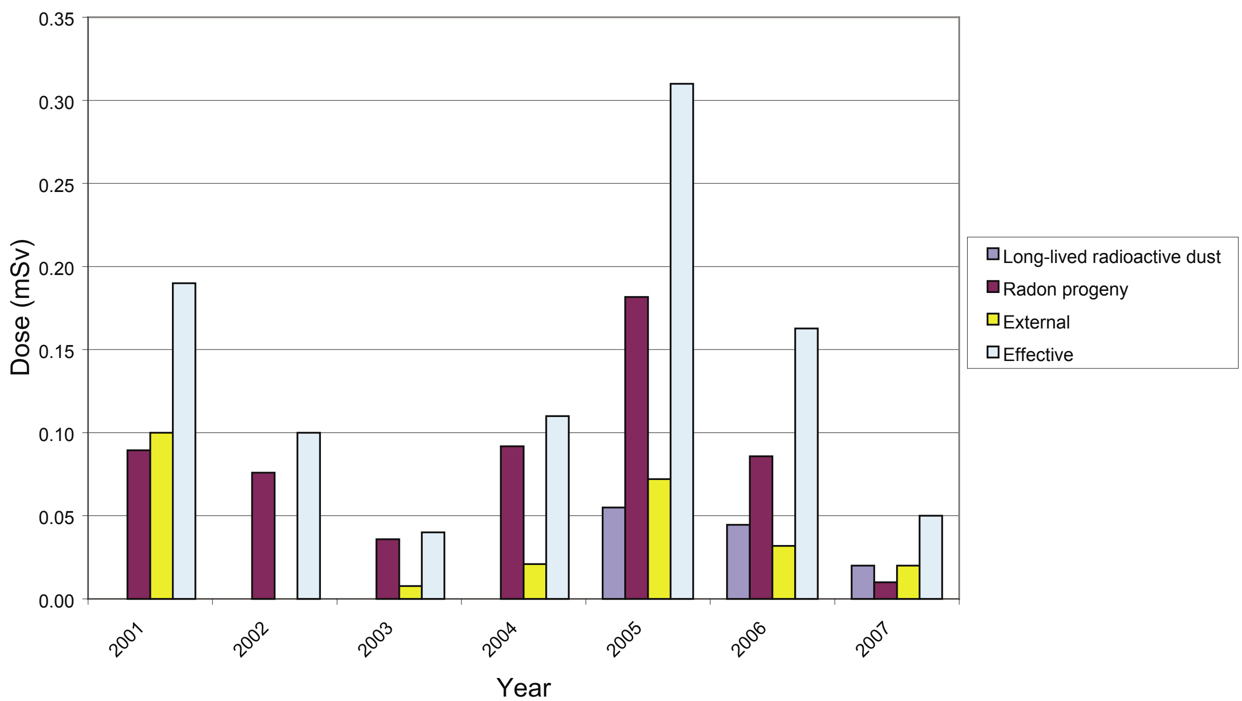


Figure 2.39. Collective Dose Trends for the Cigar Lake Operation

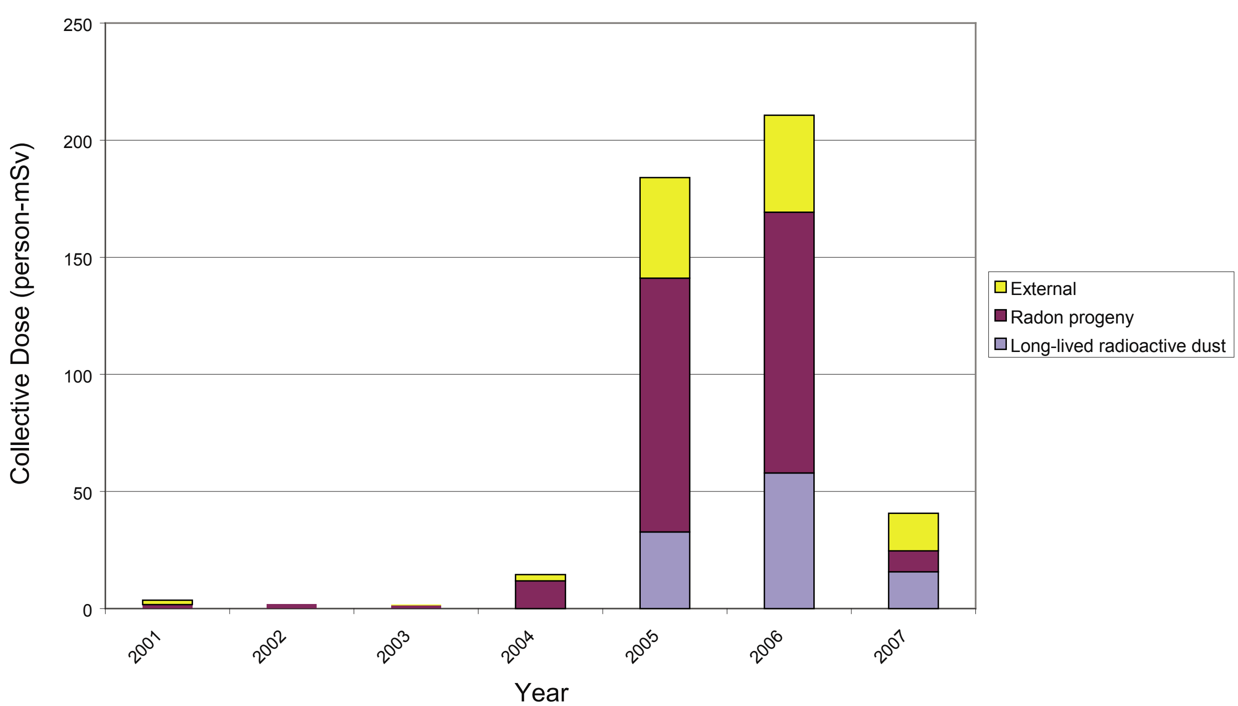
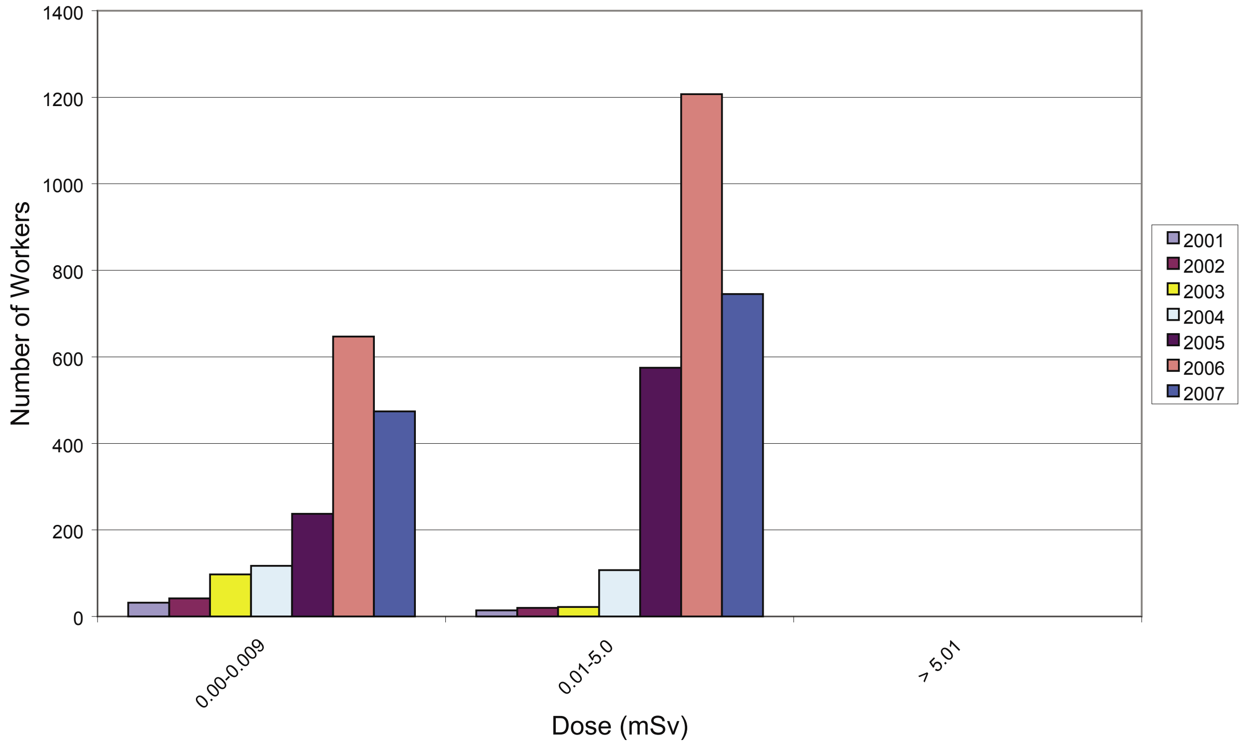


Figure 2.40. Distribution of Effective Doses Among All Workers at the Cigar Lake Operation



2.2.6 Rabbit Lake Operation

Cameco Corporation owns and operates mining facilities in Rabbit Lake, located in north-eastern Saskatchewan. Facilities include an underground mine, four mined-out open-pit mines, a mill and two tailings management facilities. Mining and milling began in 1975.

Figures 2.41–2.44 present dose information for the Rabbit Lake operation, from 2001 to 2007.

Figure 2.41. Average Dose Trends for the Rabbit Lake Operation (Based on Non-Zero Results)

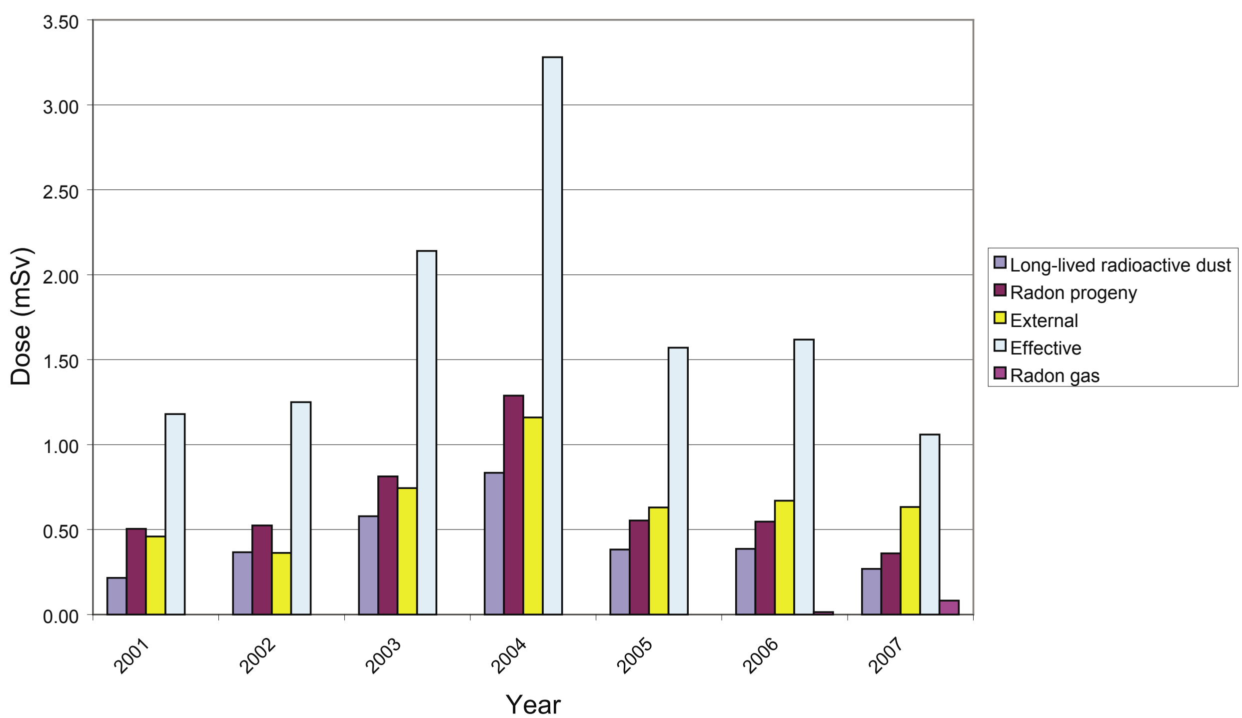


Figure 2.42. Average Dose Trends for the Rabbit Lake Operation (Based on All Monitoring Results)

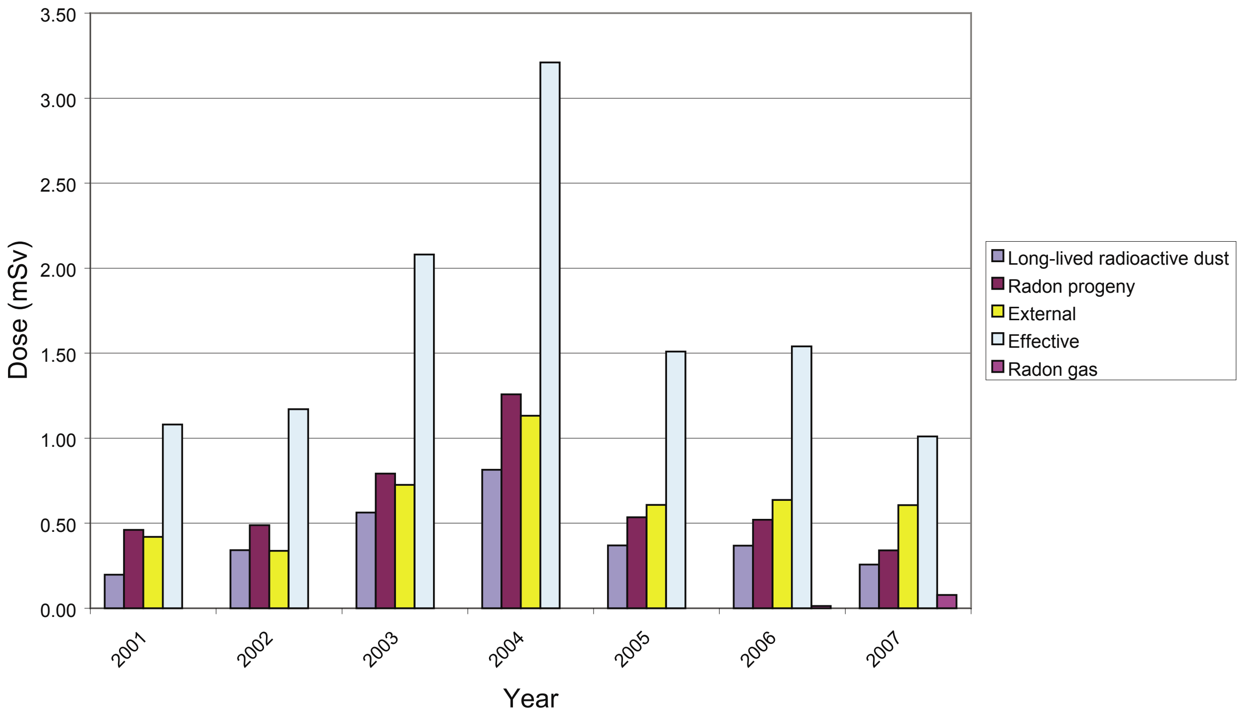


Figure 2.43. Collective Dose Trends for the Rabbit Lake Operation

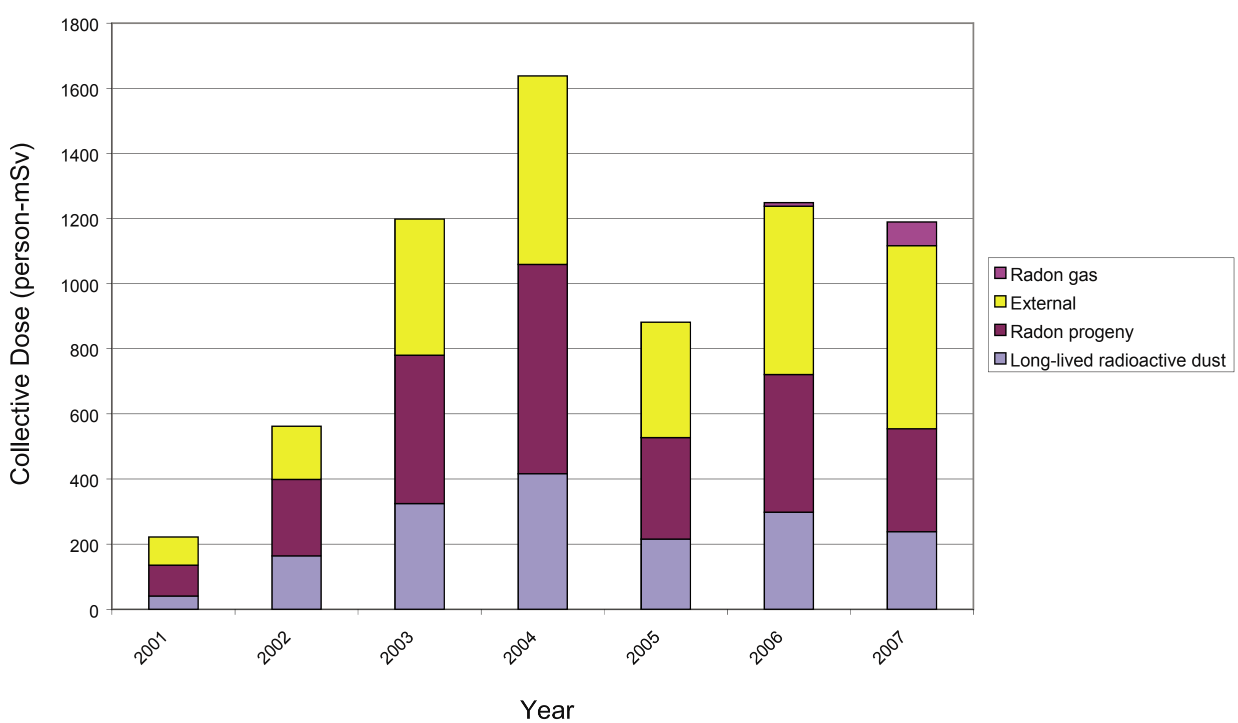
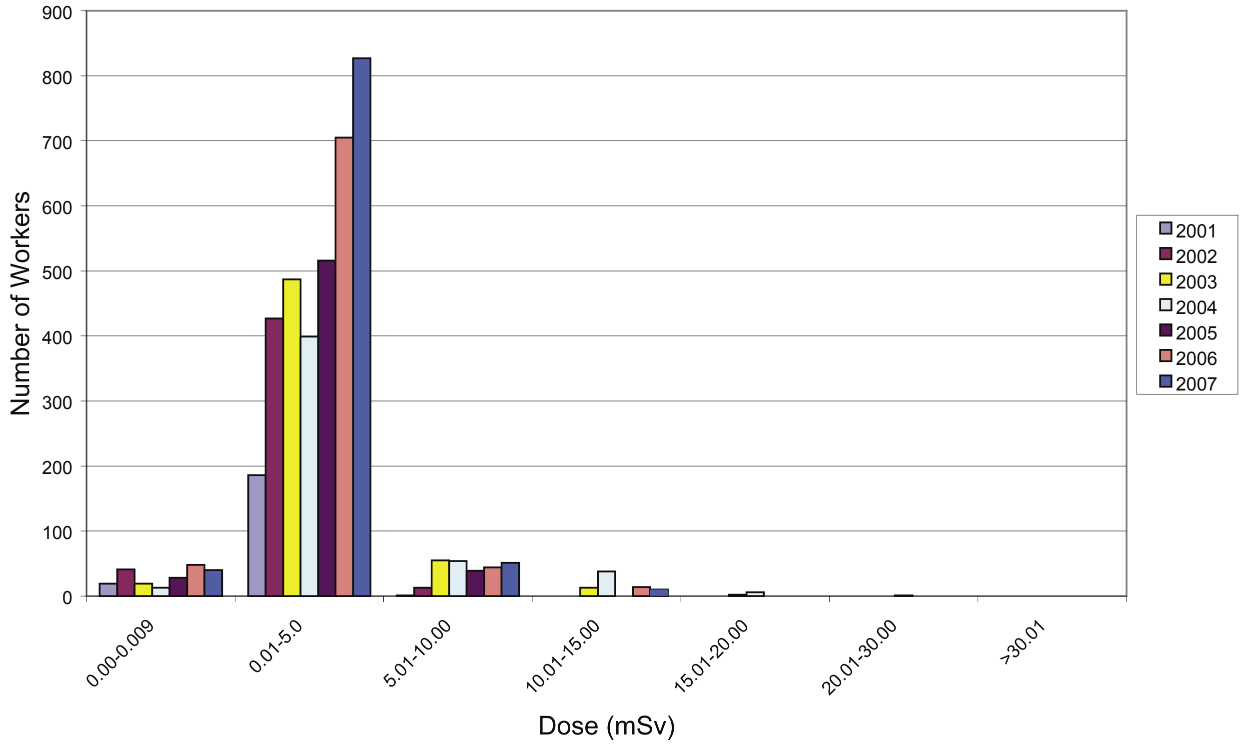


Figure 2.44. Distribution of Effective Doses Among All Workers at the Rabbit Lake Operation



2.3 Uranium Refineries

This section presents data for the following two facilities:

- a uranium refining facility in Blind River (Section 2.3.1)
- a uranium conversion facility in Port Hope (Section 2.3.2)

Graphs indicate the following average doses at each facility, from 2001 to 2007:

1. average doses based on non-zero (positive) results
2. average doses based on all monitoring results
3. collective doses
4. distribution of average effective doses

Note on data for uranium refineries:

1. Doses from photons from external sources are measured and reported to the NDR. However, doses from internal intakes of uranium are measured through urine bioassay and lung counting. Historically, while these internal doses have been measured, they have not been submitted to the NDR. For the purposes of this report, only the external component of the effective dose (as found in the NDR) is provided. In the future, both internal and external doses will be reported to the NDR.

2.3.1 Blind River Refinery

Cameco Corporation owns and is licensed to operate a uranium refinery in Blind River, Ontario. The facility, which began operating in 1983, converts uranium ore concentrate to uranium trioxide. The uranium trioxide is shipped to Cameco's uranium conversion facility in Port Hope, Ontario, where it is processed into uranium dioxide (for use in the fabrication of fuel for nuclear reactors in Canada) or uranium hexafluoride (exported for enrichment and fabrication into fuel for nuclear power reactors around the world).

Figures 2.45–2.48 present dose information for the Blind River refinery, from 2001 to 2007.

Figure 2.45. Average Dose Trends for the Blind River Refinery (Based on Non-Zero Results)

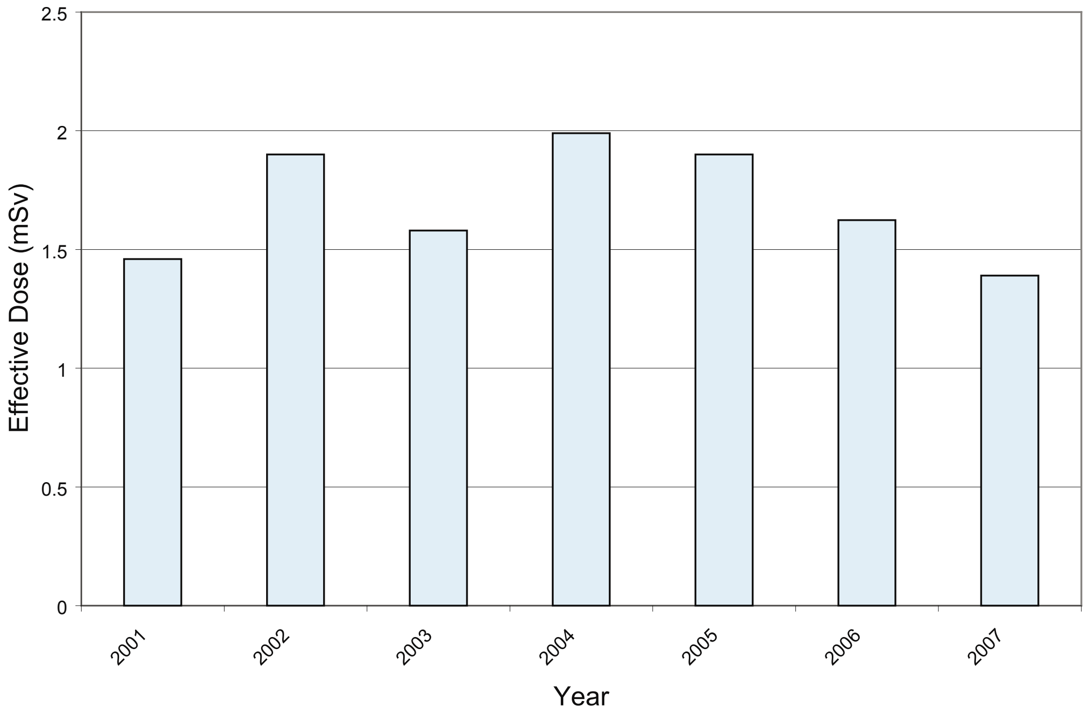


Figure 2.46. Average Dose Trends for the Blind River Refinery (Based on All Monitoring Results)

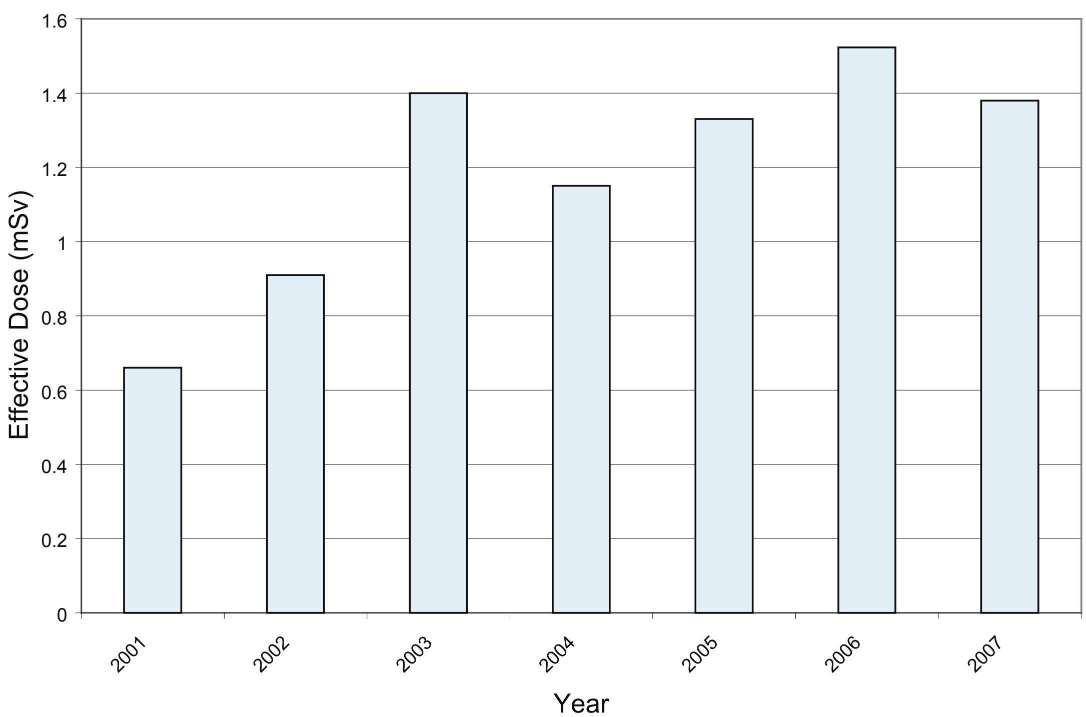


Figure 2.47. Collective Dose Trends for the Blind River Refinery

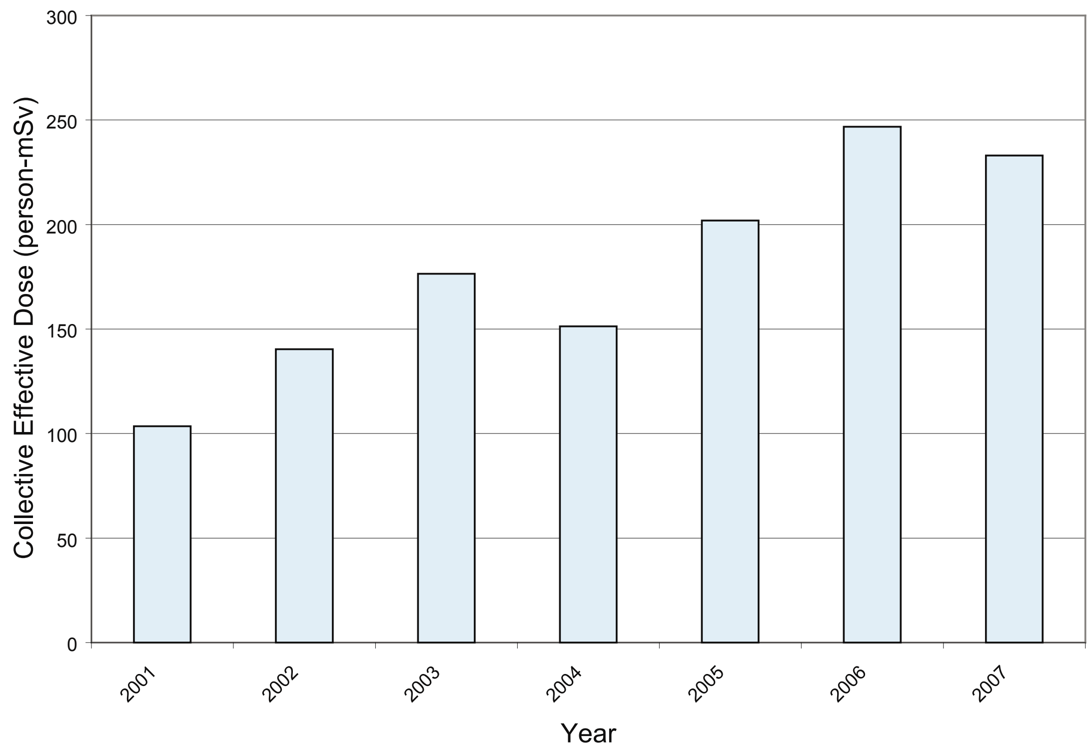
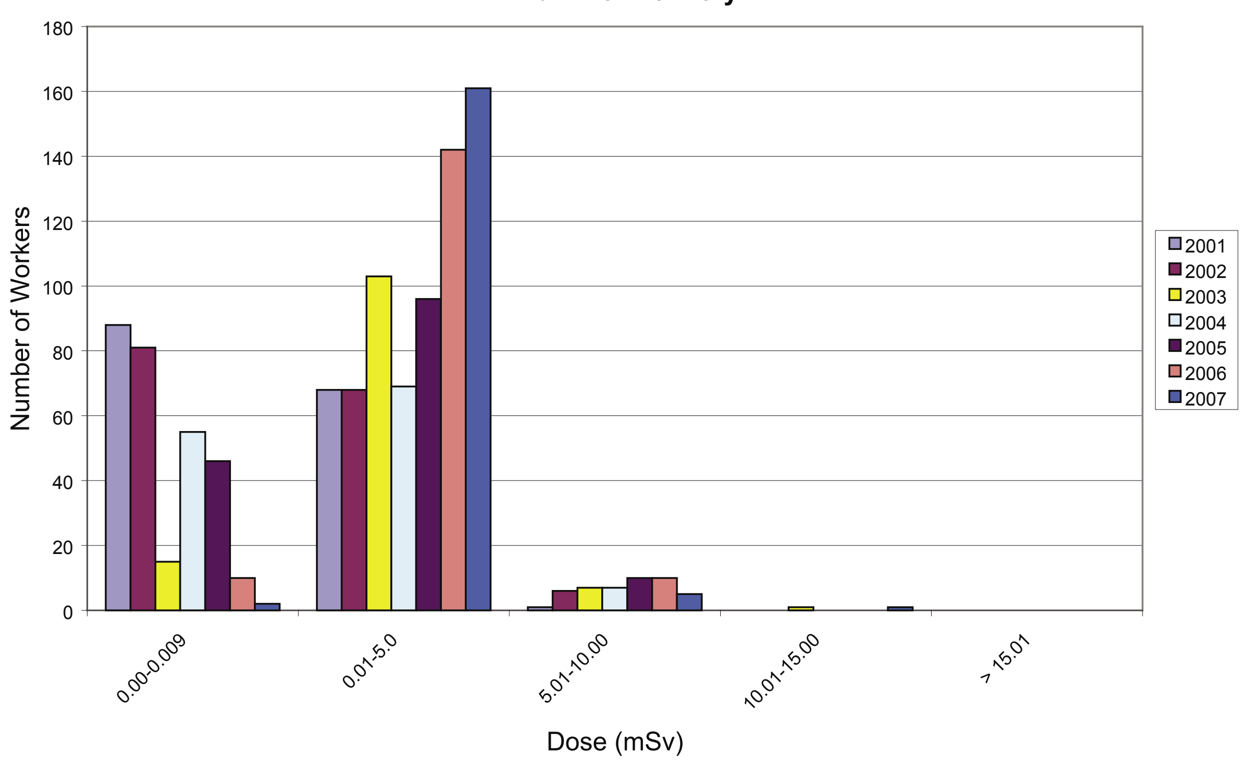


Figure 2.48. Distribution of Effective Doses Among All Workers at the Blind River Refinery



2.3.2 Port Hope Conversion Facility

Cameco Corporation owns and is licensed to operate a uranium conversion facility in Port Hope, Ontario. The facility processes uranium trioxide, received from the refinery in Blind River, into uranium dioxide and uranium hexafluoride.

Figures 2.49–2.52 present dose information for the Port Hope uranium conversion facility, from 2001 to 2007.

Figure 2.49. Average Dose Trends for the Port Hope Conversion Facility (Based on Non-Zero Results)

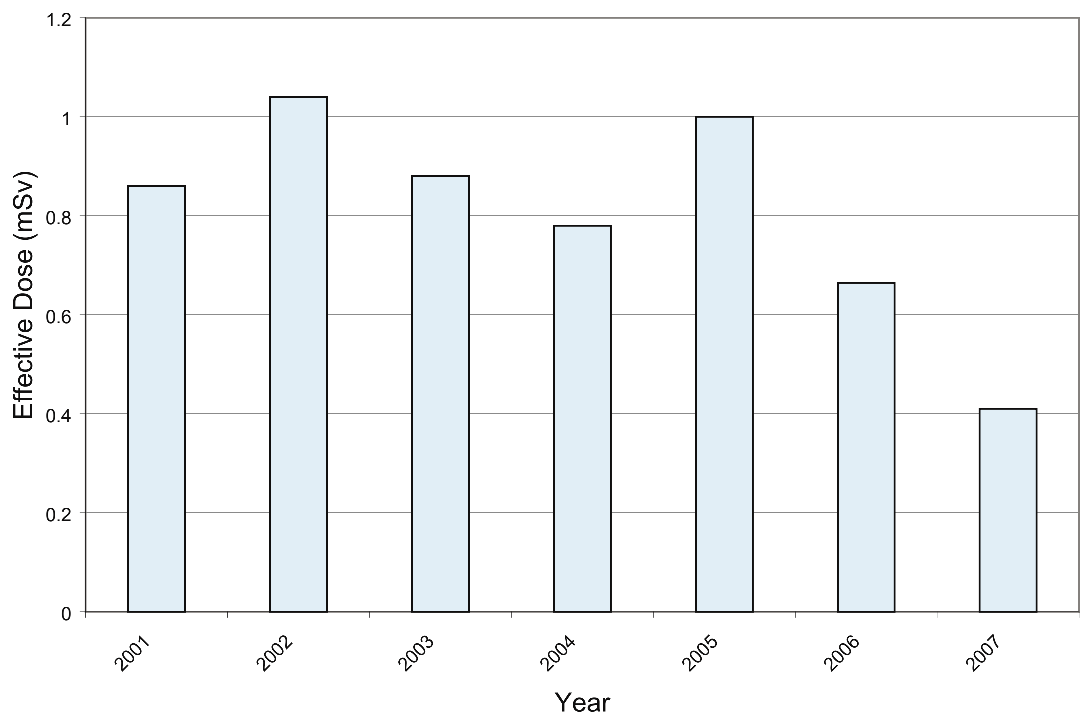


Figure 2.50. Average Dose Trends for the Port Hope Conversion Facility (Based on All Monitoring Results)

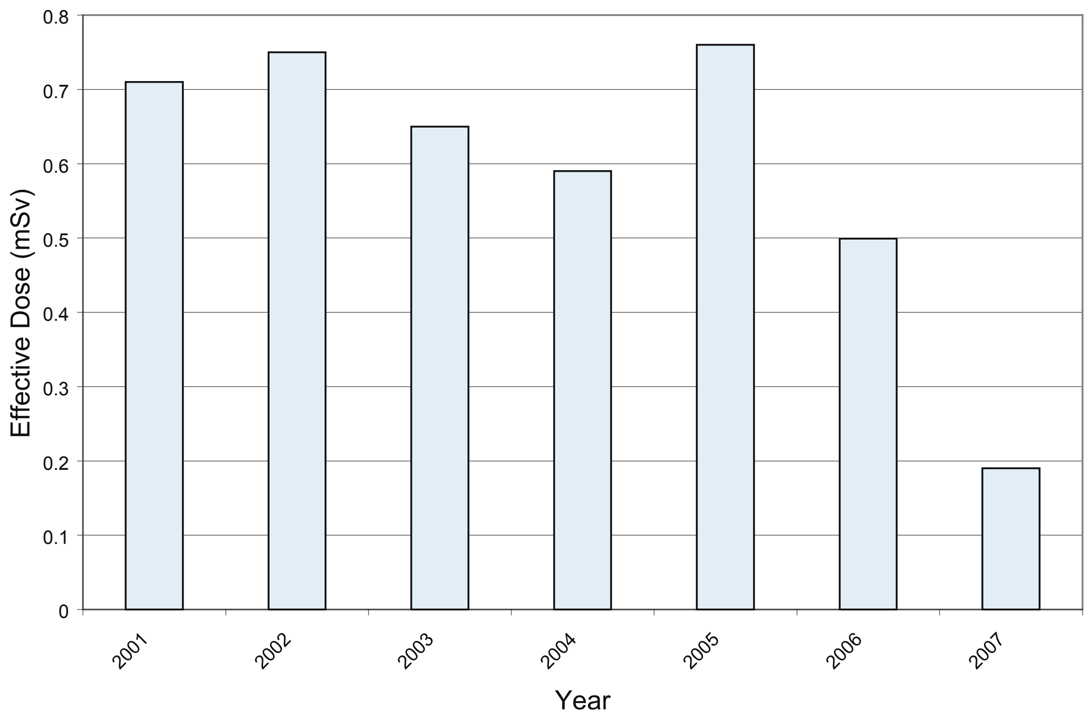


Figure 2.51. Collective Dose Trends for the Port Hope Conversion Facility

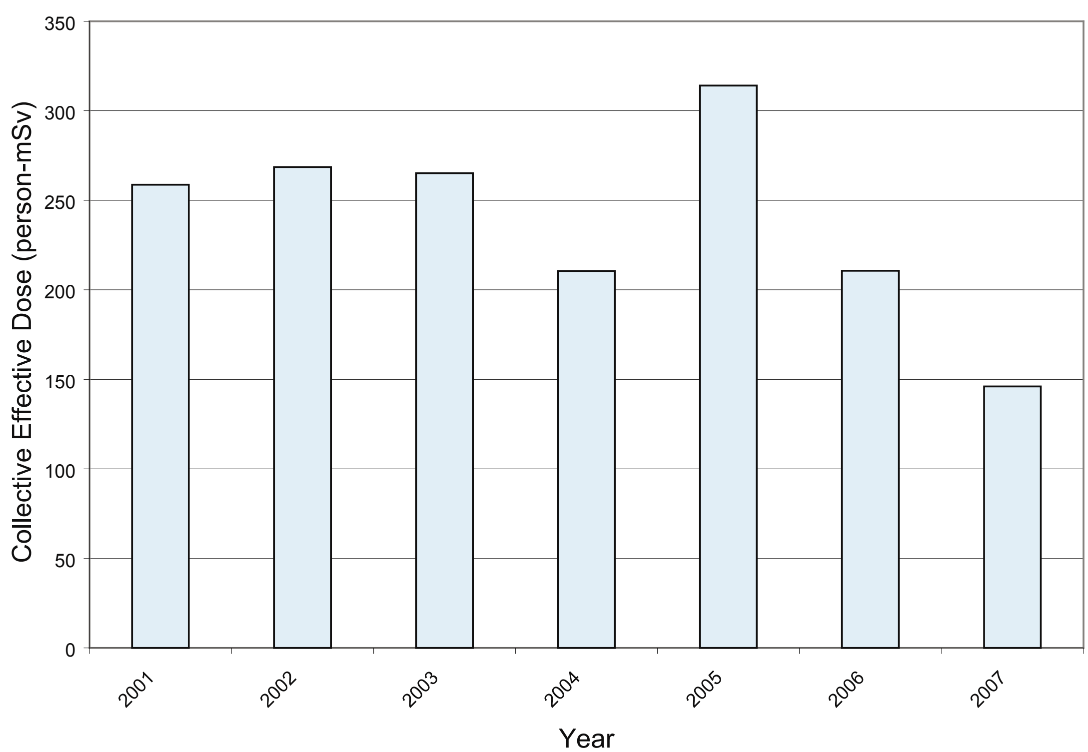
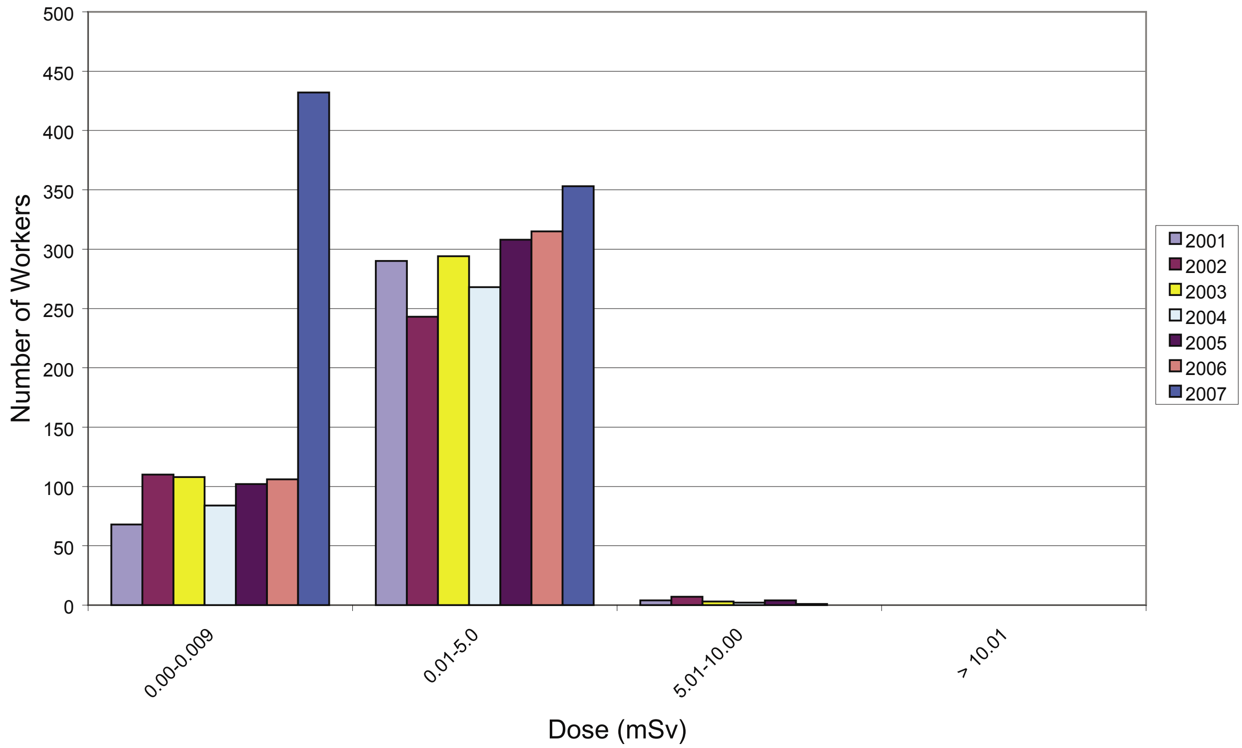


Figure 2.52. Distribution of Effective Doses Among All Workers at the Port Hope Conversion Facility



2.4 Fuel Fabrication Facilities

This section presents data for three nuclear fuel fabrication facilities:

- Two facilities owned and operated by General Electric Canada Inc. (Section 2.4.1)
- One facility in Port Hope, operated by Zircatec Precision Industries (Section 2.4.2)

Graphs indicate the following data for each facility:

1. average doses based on non-zero (positive) results
2. average doses based on all monitoring results
3. collective doses
4. distribution of average doses

Notes on data for fuel fabrication facilities:

1. Effective doses for the three facilities are composed of the following reported components:
   - dose from photons (labelled on the charts as “external”)
   - doses from internal intakes of uranium dust (long-lived radioactive dust), from uranium in air concentrations (for General Electric’s Toronto facility only)

2. Collective dose data is presented in stacked bar graphs, where total effective doses are the sum of their respective components: photon doses and doses from long-lived radioactive dust.

2.4.1 General Electric Nuclear Fuel Facilities

General Electric Canada Inc. operates two nuclear fuel facilities in Ontario:

- At the Toronto facility, uranium dioxide pellets are produced from natural or depleted uranium dioxide powder
- At the Peterborough facility, uranium dioxide fuel bundles are created from the pellets produced at the Toronto facility

Figures 2.53–2.56 present dose information for General Electric Canada Inc.’s fuel fabrication facilities from 2001 to 2007. Graphs do not distinguish between the doses received at the Peterborough facility versus those at the Toronto facility.

Figure 2.53. Average Dose Trends for the General Electric Fuel Facility (Based on Non-Zero Results Only)

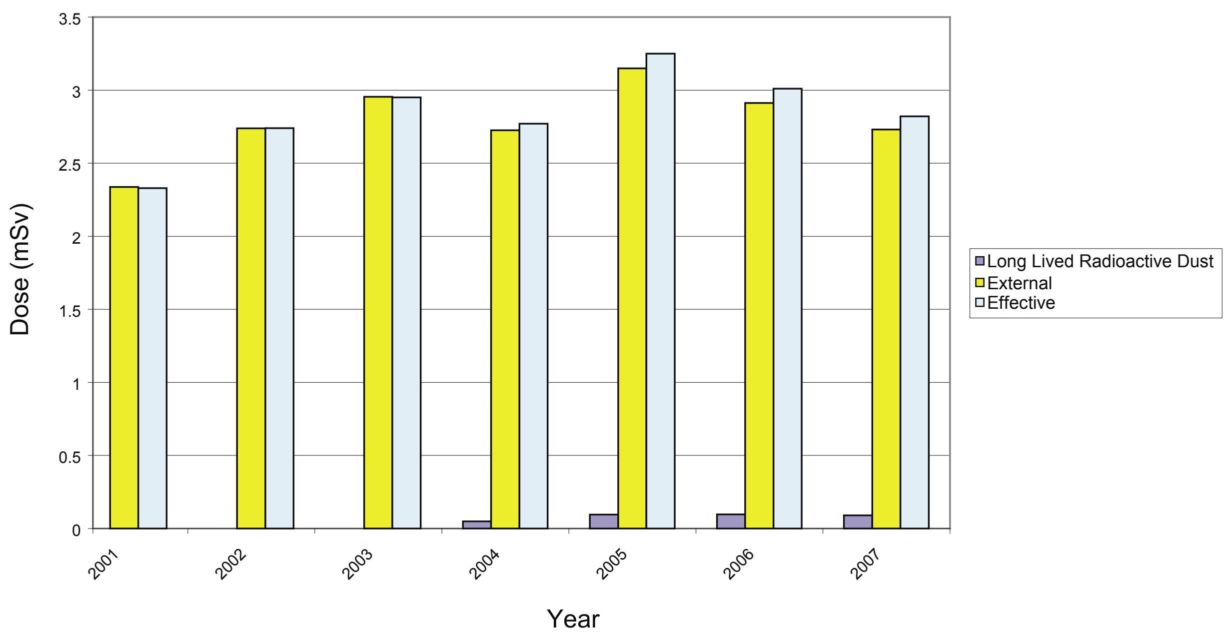


Figure 2.54. Average Dose Trends for the General Electric Fuel Facility (Based on All Monitoring Results)

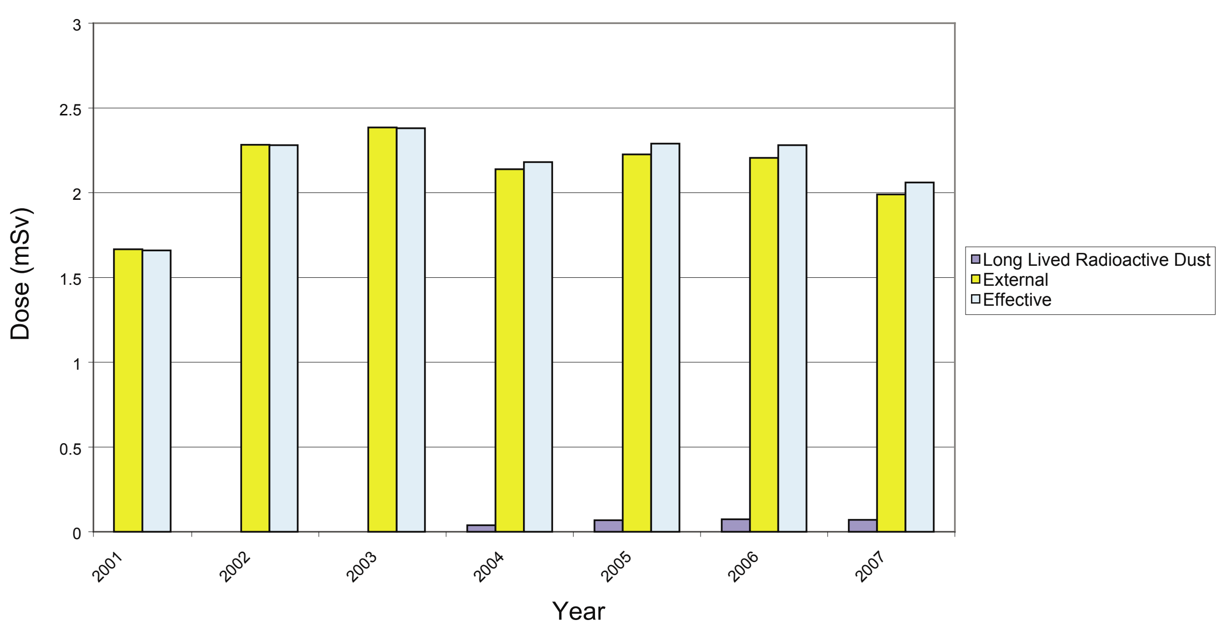


Figure 2.55. Collective Dose Trends for the General Electric Fuel Facility

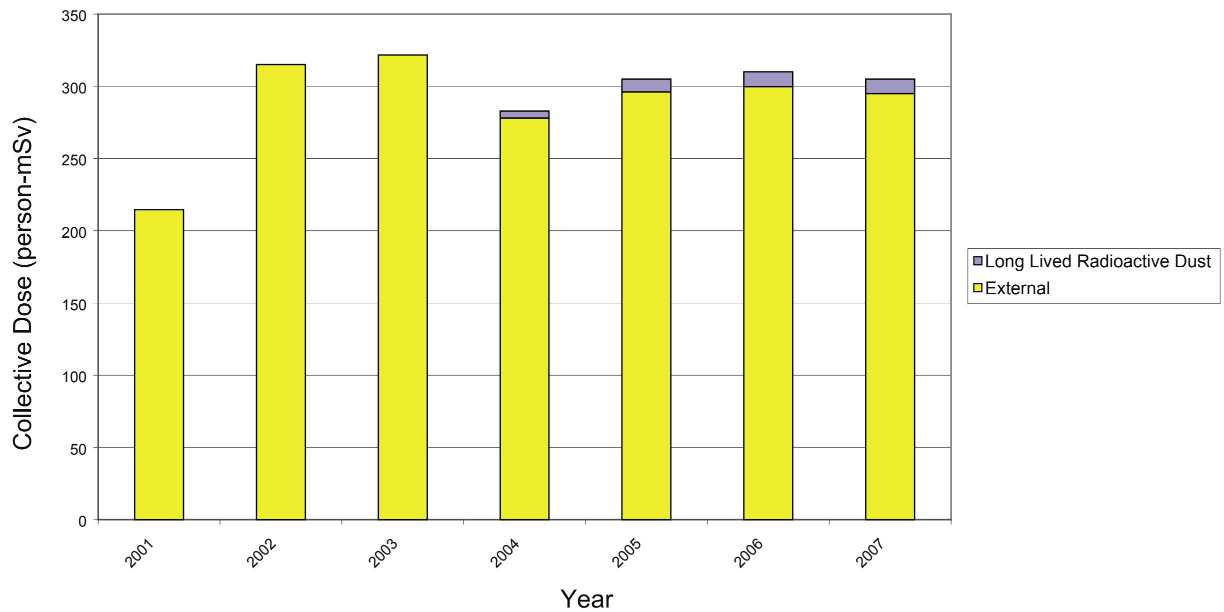
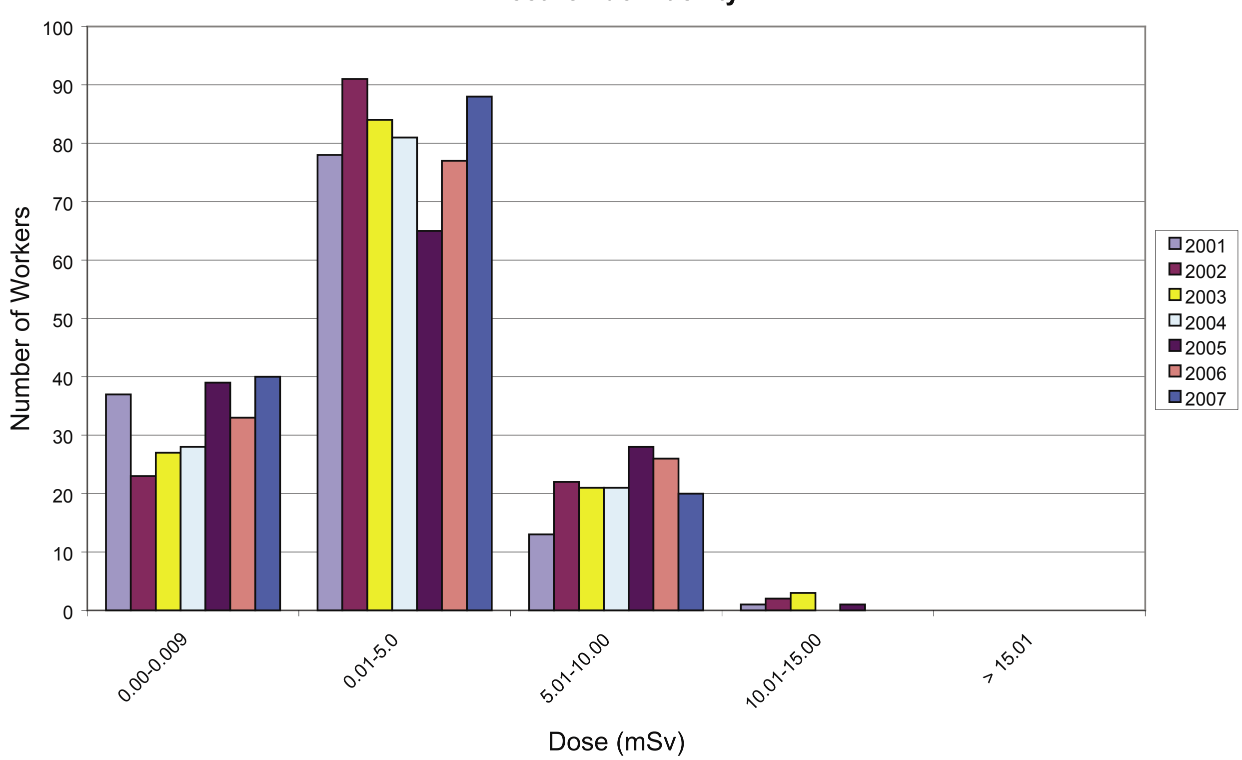


Figure 2.56. Distribution of Effective Doses among all Workers at the General Electric Fuel Facility



2.4.2 Zircatec Nuclear Fuel Facility

Zircatec Precision Industries Inc. operates a nuclear fuel facility in Port Hope, Ontario, where it makes fuel pellets from uranium dioxide powder received from Port Hope's uranium conversion facility. The nuclear fuel facility also manufactures fuel bundles for nuclear reactors in Canada.

Notes on data for the Zircatec nuclear fuel facility:

1. Graphs indicate the following data:
   - average doses based on non-zero (positive) results
   - average doses based on all monitoring results
   - collective doses
   - distribution of average effective doses

2. Doses from photons from external sources were measured and reported to the NDR. However, doses from internal intakes of uranium are measured through urine bioassay. Historically, although these internal doses have been measured and submitted to the CNSC, they have not been submitted to the NDR. For the purposes of this report, only the external component of the effective dose (as found in the NDR) is provided. In the future, both internal and external doses will be reported to the NDR.

Figures 2.57–2.60 present dose information for the Zircatec nuclear fuel facility, from 2001 to 2007.

Figure 2.57. Average Dose Trends for the Zircatec Nuclear Fuel Facility (Based on Non-Zero Results)

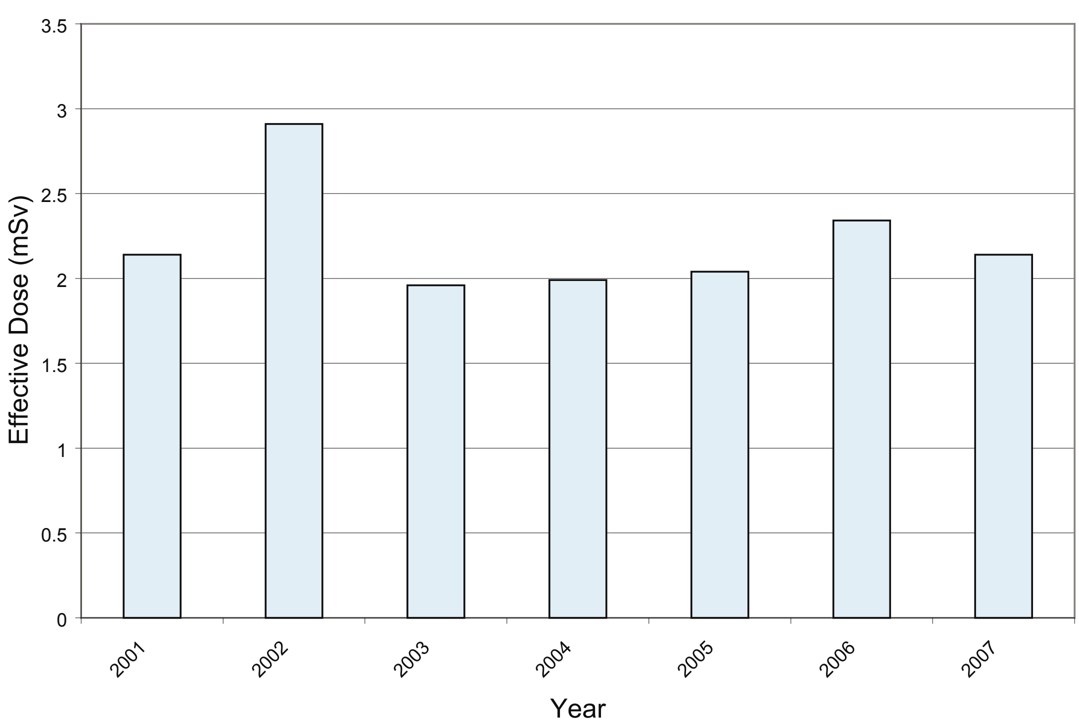


Figure 2.58. Average Dose Trends for the Zircatec Nuclear Fuel Facility (Based on All Monitoring Results)

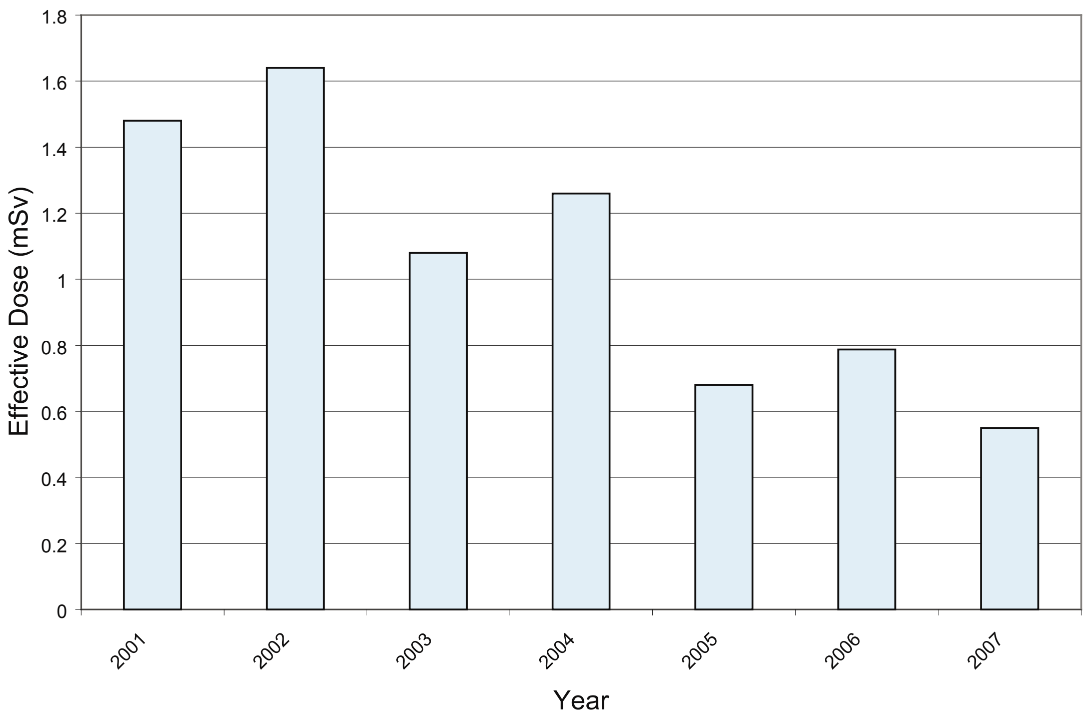


Figure 2.59. Collective Dose Trends for the Zircatec Nuclear Fuel Facility

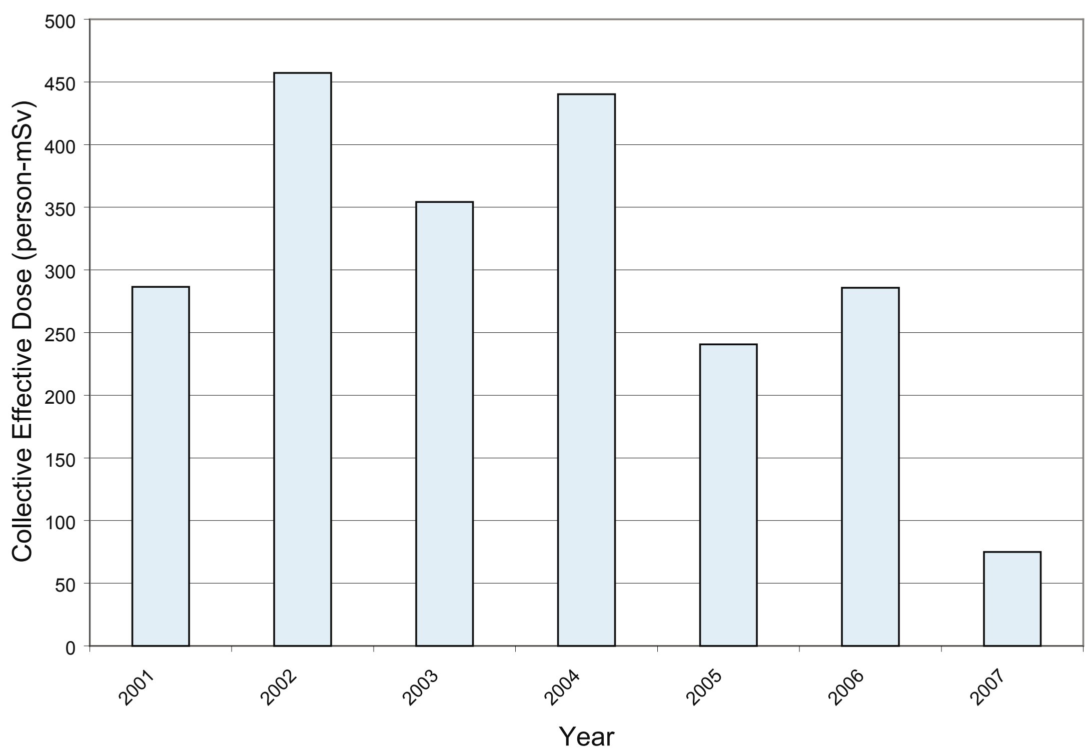
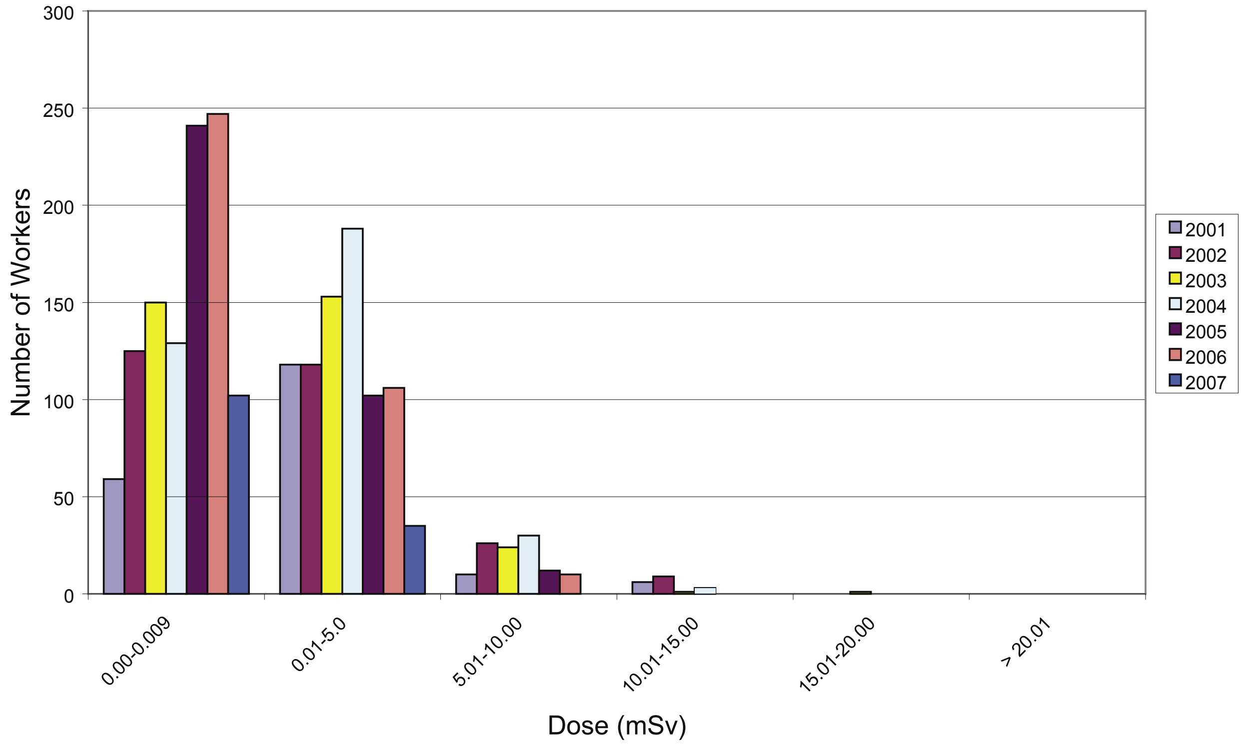


Figure 2.60. Distribution of Effective Doses Among All Workers at the Zircatec Nuclear Fuel Facility



2.5 Research and Radioisotope Production Facilities

This section presents dose information for the following research and radioisotope production facilities from 2001 to 2007:

- Chalk River Laboratories and Whiteshell Laboratories (Section 2.5.1)
- A radioisotope production facility operated by MDS Nordion (Section 2.5.2)
- The Tri-University Meson Facility (TRIUMF) (Section 2.5.3)

Note on data for research and radioisotope production facilities:

1. Graphs indicate the following data for each facility:
   - average doses based on non-zero (positive) results
   - average doses based on all monitoring results
   - collective doses
   - distribution of effective doses

2.5.1 Chalk River Laboratories and Whiteshell Laboratories

Atomic Energy of Canada Limited (AECL) owns and is licensed to operate Chalk River Laboratories and Whiteshell Laboratories.

Situated in Renfrew County on the south shore of the Ottawa River, the Chalk River Laboratories site hosts the National Research Universal Reactor, along with numerous other facilities, occupying some 160 buildings in an area of approximately 40 km^2. Activities consist of radioisotope production for nuclear medicine; testing and development of structural materials in support of power reactor operations; fuel fabrication; research; and radioactive waste management and storage.

The Whiteshell Laboratories site is located approximately 10 km west of Pinawa, Manitoba, and 100 km northeast of Winnipeg, on the east bank of the Winnipeg River. AECL established the laboratories for nuclear research and testing during the early 1960s, and has since discontinued operations, which are being decommissioned under a licence from the CNSC.

Figures 2.61–2.64 present dose information for Chalk River Laboratories and Whiteshell Laboratories, from 2001 to 2007.

Notes on data for Chalk River Laboratories and Whiteshell Laboratories:

1. Effective doses are composed of the following reported components:
   - external doses[5] (*from both photon and neutron doses*)
   - tritium doses

5 Due to issues with AECL's in-house dosimetry management system, neutron doses were not reported separately to the NDR during the reporting period. As a result, external doses from photons and neutrons were totaled. The reporting discrepancy has since been rectified.

2. Collective dose data is presented in stacked bar graphs, where total effective doses are the sum of their respective components of external (photon and neutron), and tritium doses. Intakes of other radionuclides occasionally occur, and these radionuclides are not included here because their associated doses are very small. For this reason, certain collective doses in this report may have values slightly lower than the sum of their respective components as listed.

Figure 2.61. Average Dose Trends for Chalk River and Whiteshell Laboratories (Non-Zero Results Only)

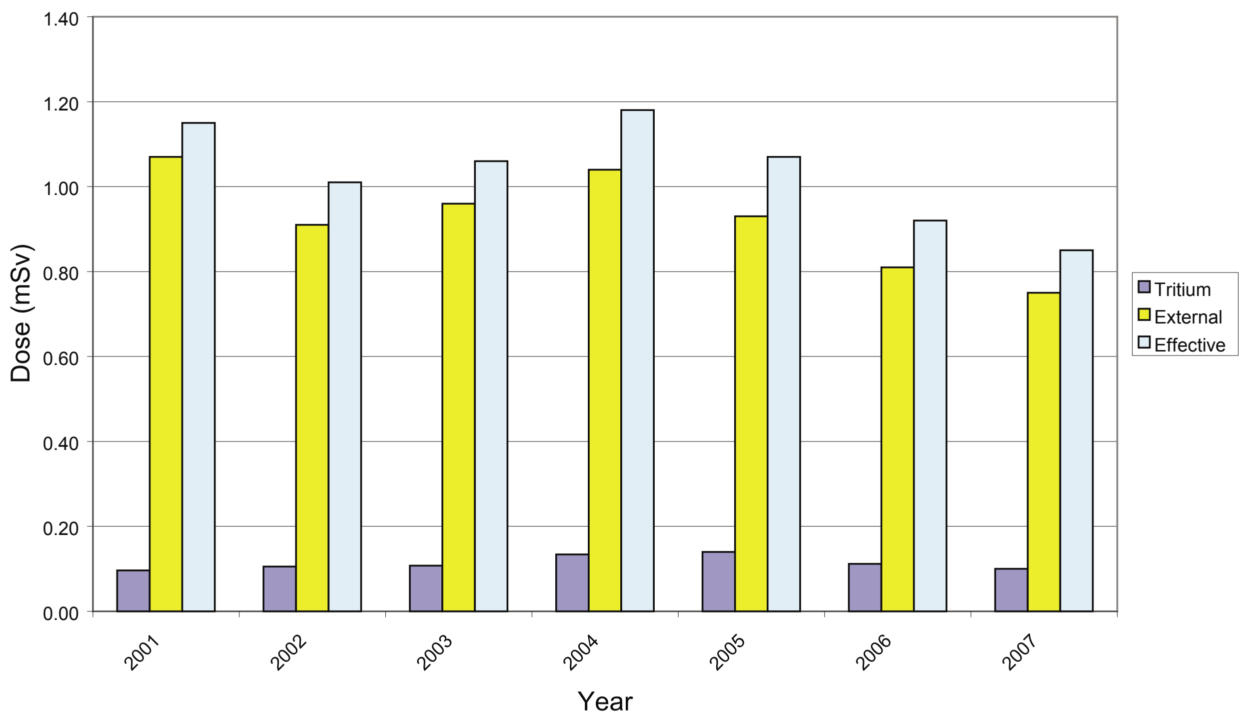


Figure 2.62. Average Dose Trends for Chalk River and Whiteshell Laboratories (All Monitoring Results)

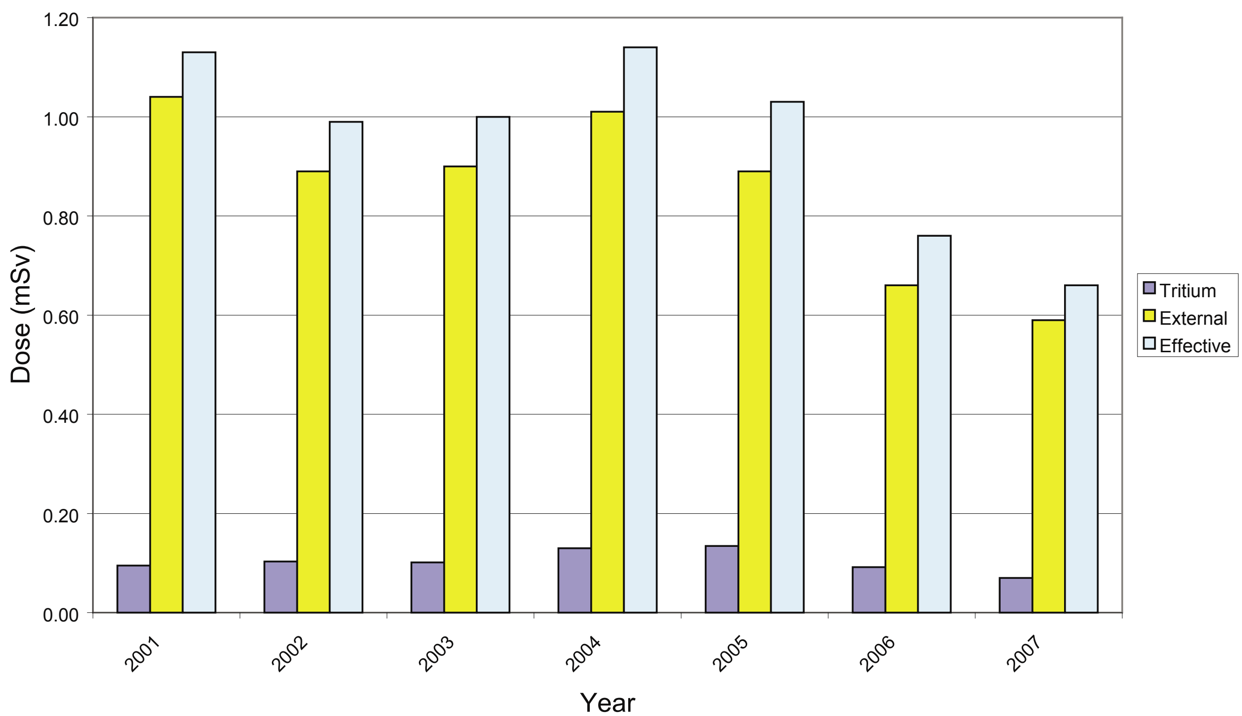


Figure 2.63. Collective Dose Trends for Chalk River and Whiteshell Laboratories

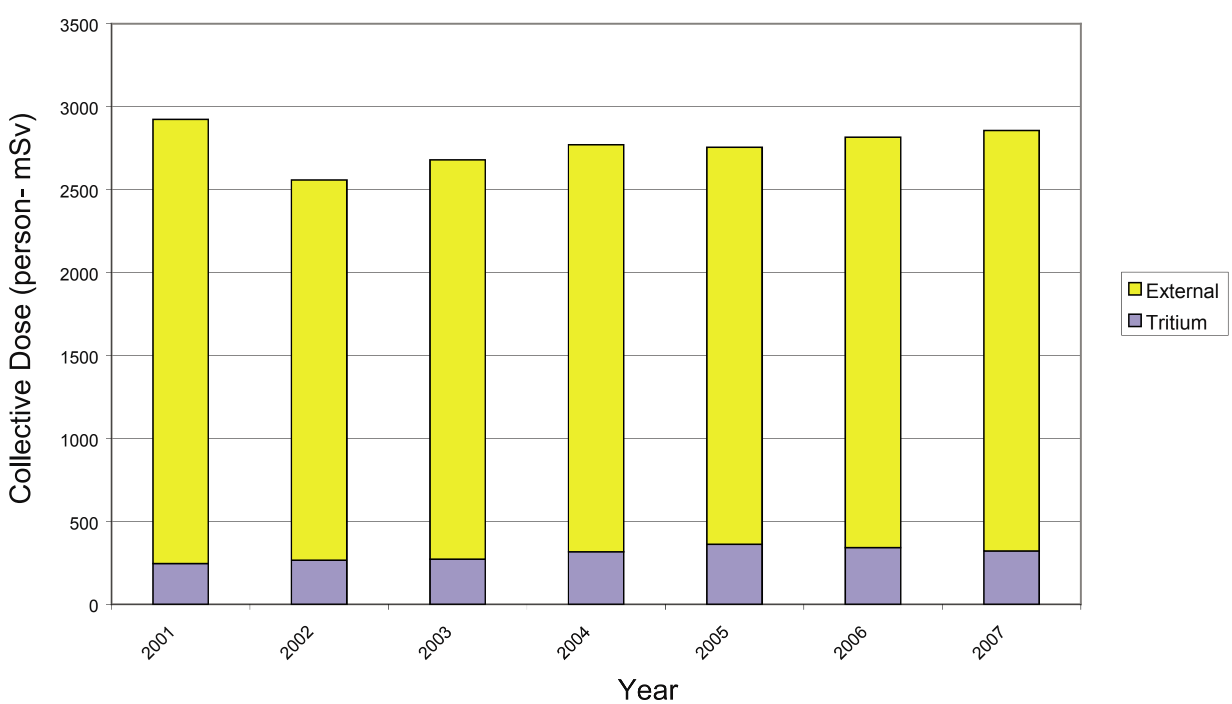
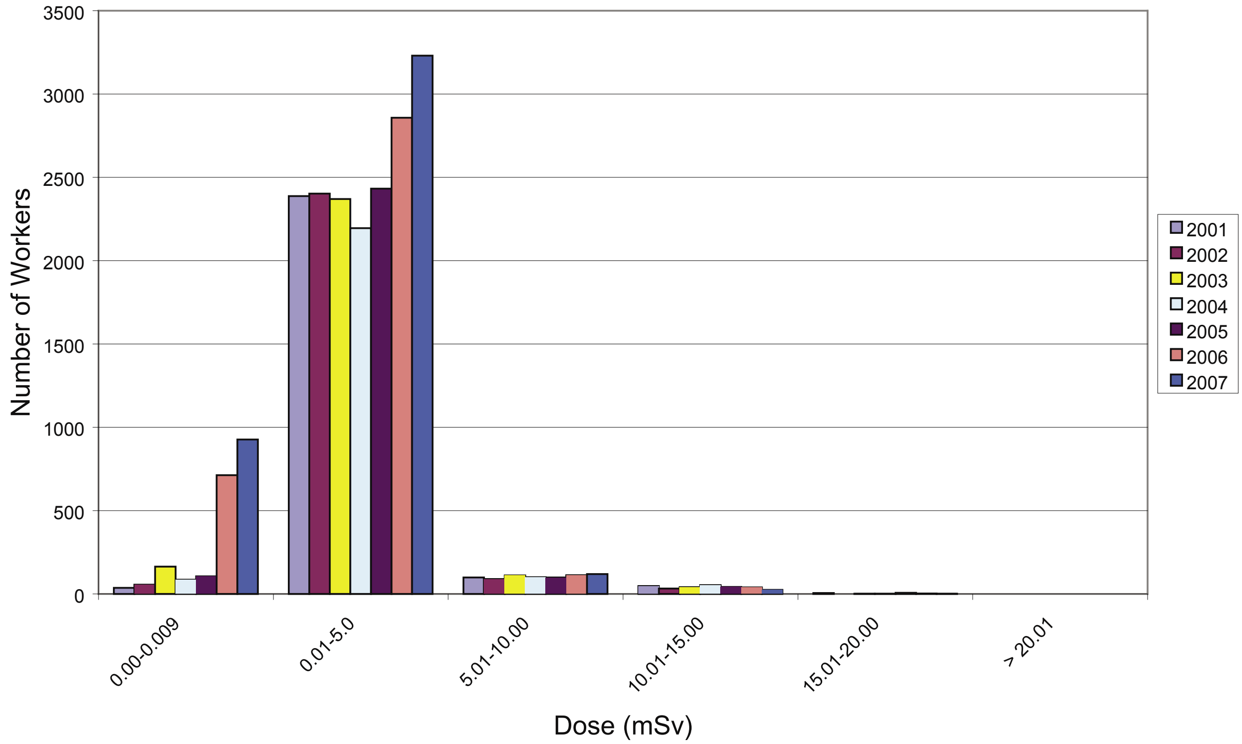


Figure 2.64. Distribution of Effective Doses Among All Workers at Chalk River and Whiteshell Laboratories



2.5.2 MDS Nordion (Nuclear Substance Processing Facility and Canadian Irradiation Centre)

MDS Nordion owns and operates a nuclear substance processing facility in Ottawa, Ontario, where it processes unsealed radioisotopes and manufactures sealed radiation sources. In operation since the early 1970s, the facility was purchased by Nordion International in 1991.

In cooperation with the Université du Québec's Institut Armand-Frappier, MDS Nordion also operates the Canadian Irradiation Centre, which conducts various irradiation services which include training, testing and development. The centre is located in Laval, Quebec, on the Université du Québec campus.

Figures 2.65–2.68 present dose information for MDS Nordion's Ottawa nuclear substance processing facility and for the Canadian Irradiation Centre, from 2001 to 2007.

Notes on data for MDS Nordion's nuclear substance processing facility and the Canadian Irradiation Centre:

1. Doses from photons from external sources were measured and reported to the NDR. MDS Nordion also has a routine thyroid monitoring program; very occasionally, small recordable doses of radiation have occurred from thyroid uptake of iodine. The resulting doses have not been historically submitted to the NDR. For the purposes of this report, only the external component of the effective dose (as found in the NDR) is provided.

Figure 2.65. Average Dose Trends for MDS Nordion (Based on Non-Zero Results)

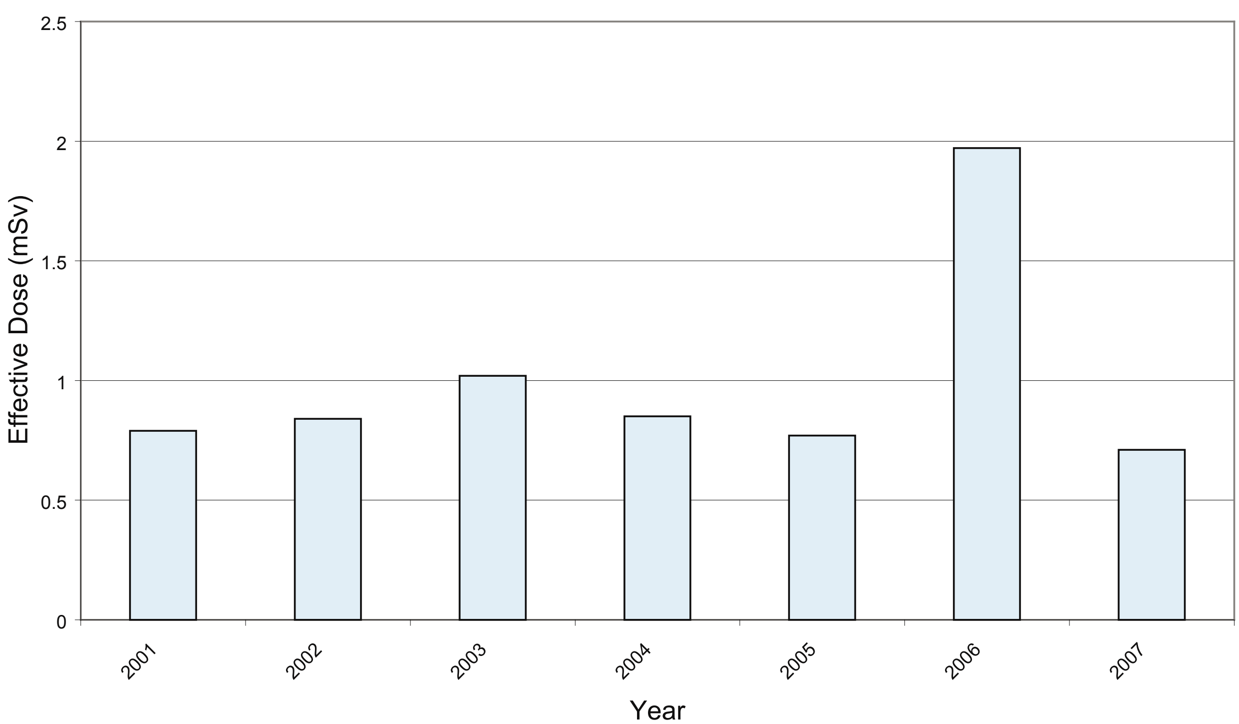


Figure 2.66. Average Dose Trends for MDS Nordion (Based on All Monitoring Results)

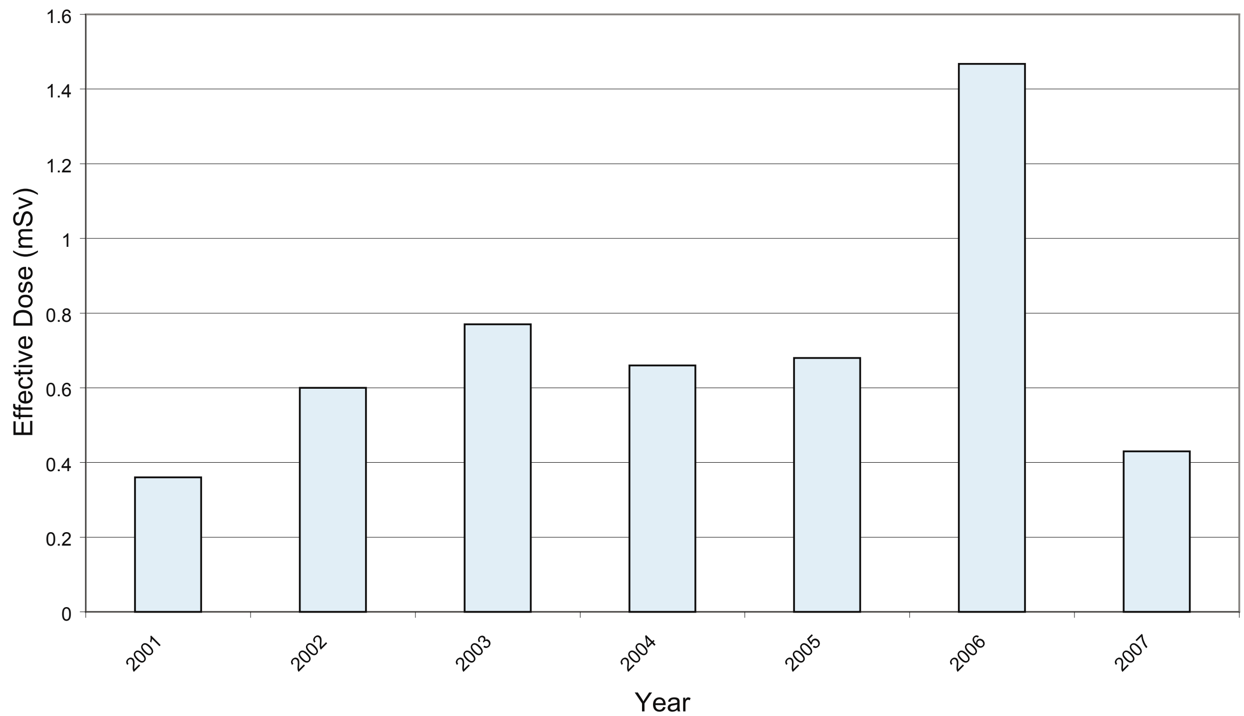


Figure 2.67. Collective Dose Trends for MDS Nordion

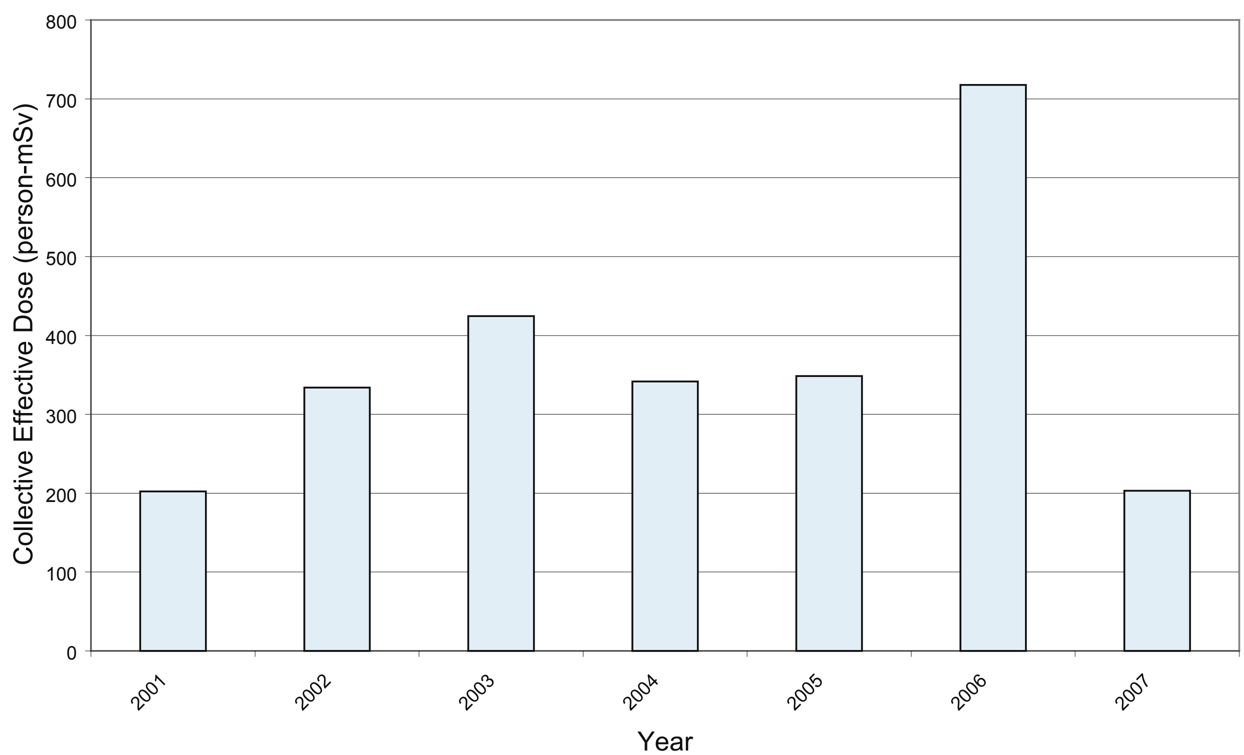
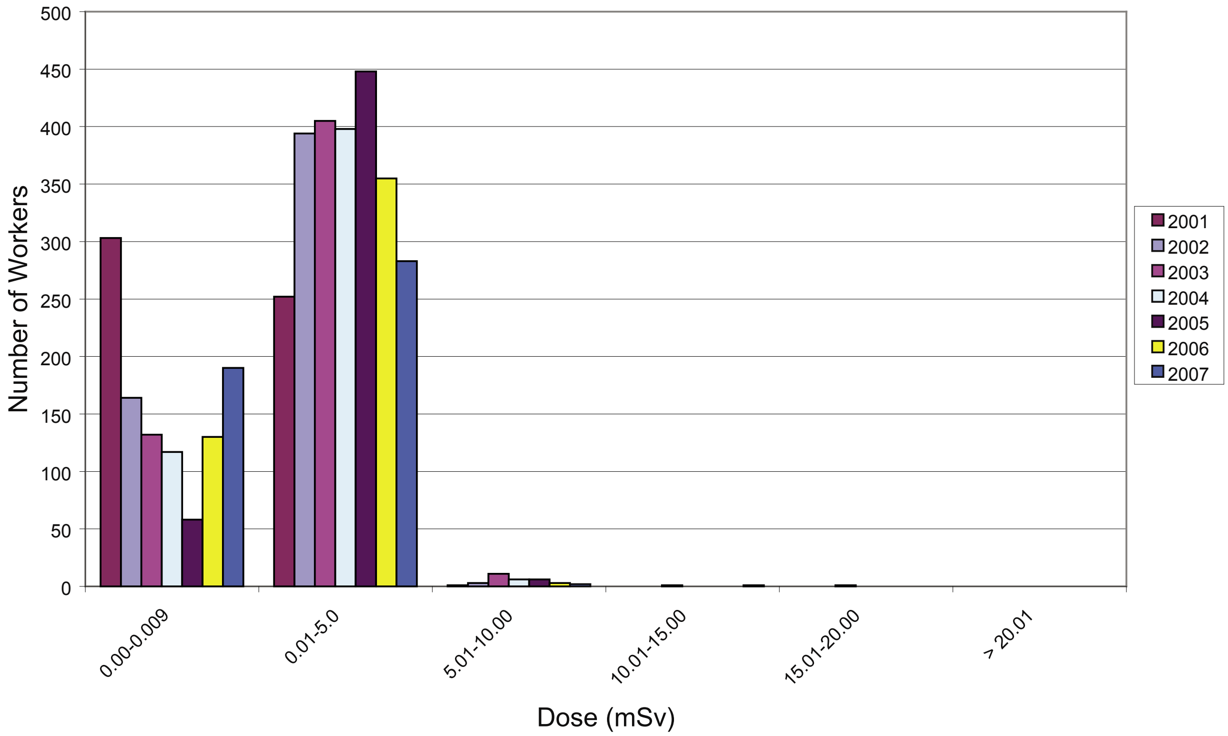


Figure 2.68. Distribution of Effective Doses Among All Workers at MDS Nordion



2.5.3 Tri-University Meson Facility

The Tri-University Meson facility (TRIUMF) is situated in Vancouver, on the campus of the University of British Columbia. TRIUMF, which began operating in the early 1970s with one cyclotron, now has two cyclotrons and associated laboratories for research and radioisotope production. The laboratory provides research facilities for Canadian and international users, and also produces radioisotopes, which are used by medical facilities and by a commercial organization (MDS Nordion). MDS Nordion staff also work at the TRIUMF site; however, MDS Nordion oversees this work and has its own radiation protection program.

Figures 2.69–2.72 present dose information for the TRIUMF facility from 2001 to 2007. Please note that data sets do not distinguish between doses received by TRIUMF staff and MDS Nordion staff who work on the site, as the data for these two groups was submitted collectively to the NDR for the reporting period shown. Future data for each group will be submitted separately to the NDR.

Note on data for TRIUMF:

1. Effective doses are composed of the following reported components:
   - doses from photons (labeled as “external” in the charts)
   - neutron doses

Figure 2.69. Average Dose Trends for TRIUMF (Non-Zero Results Only)

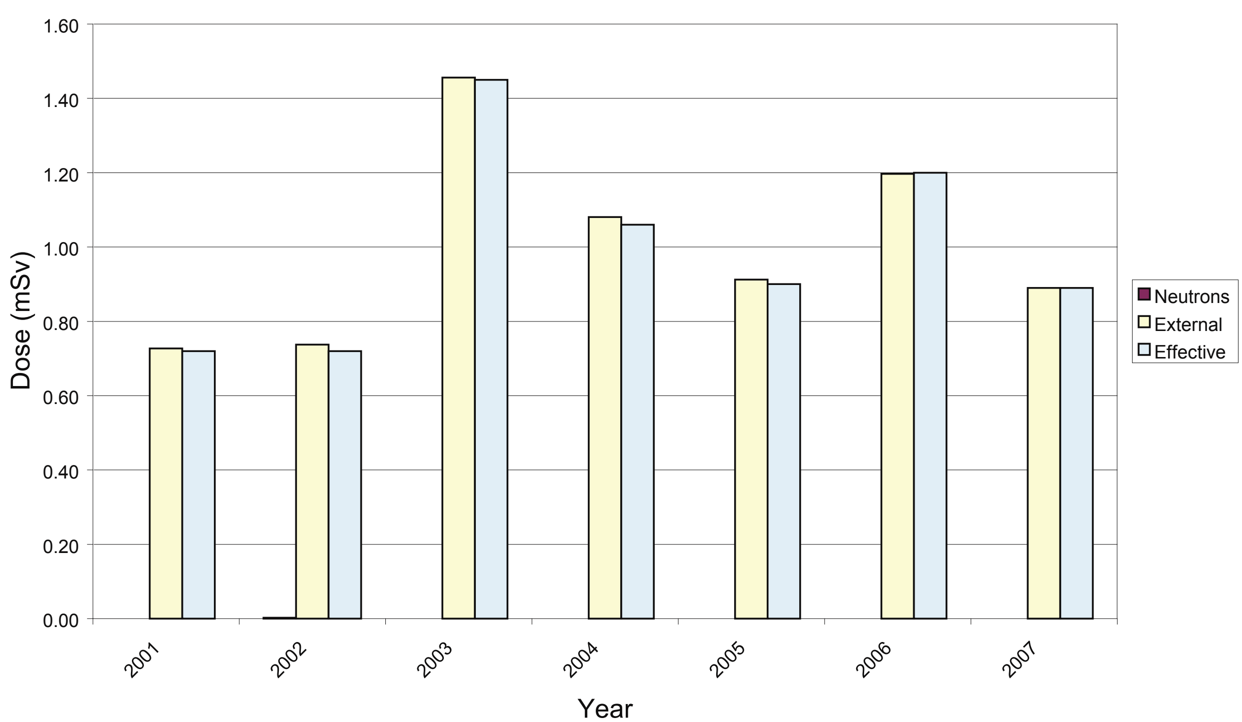


Figure 2.70. Average Dose Trends for TRIUMF (All Monitoring Results)

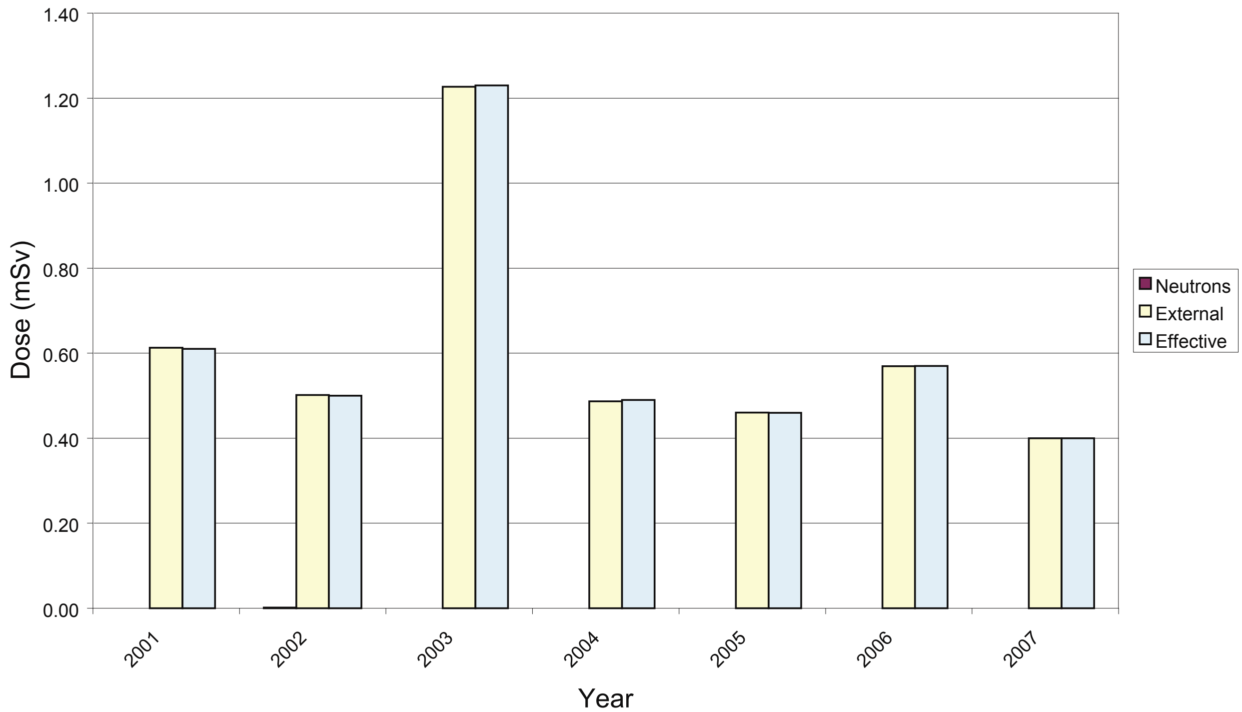


Figure 2.71. Collective Dose Trends for TRIUMF

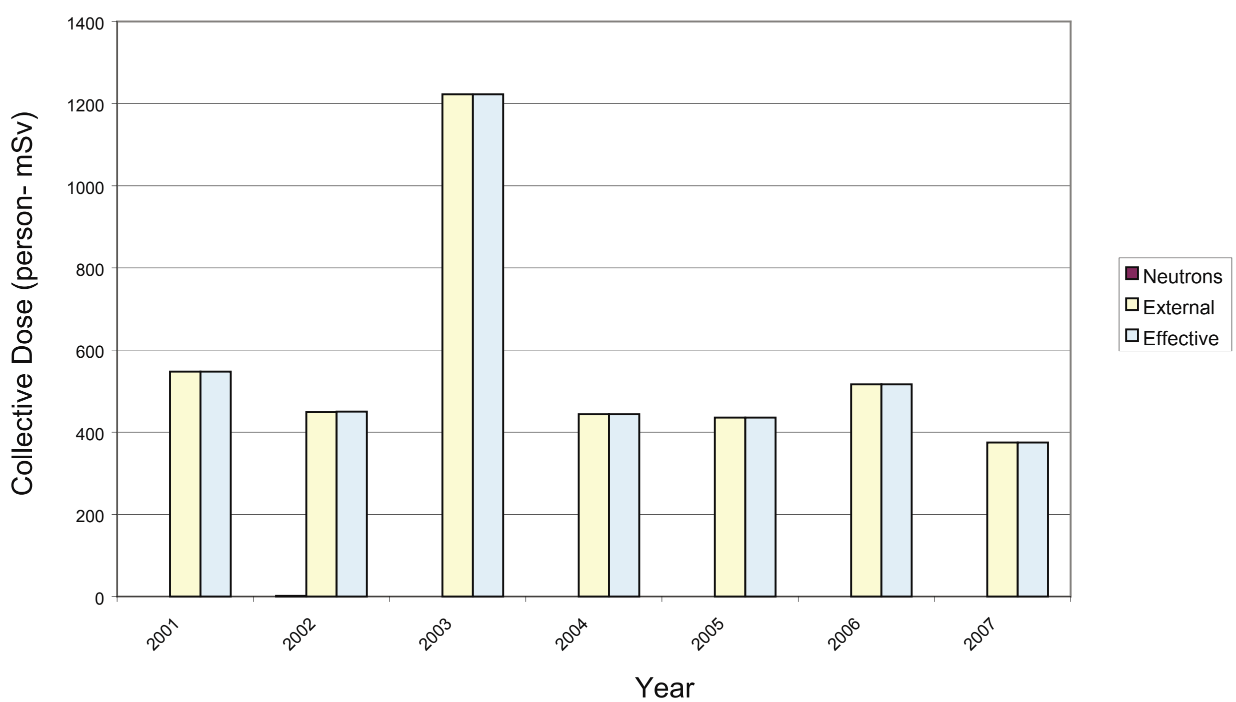
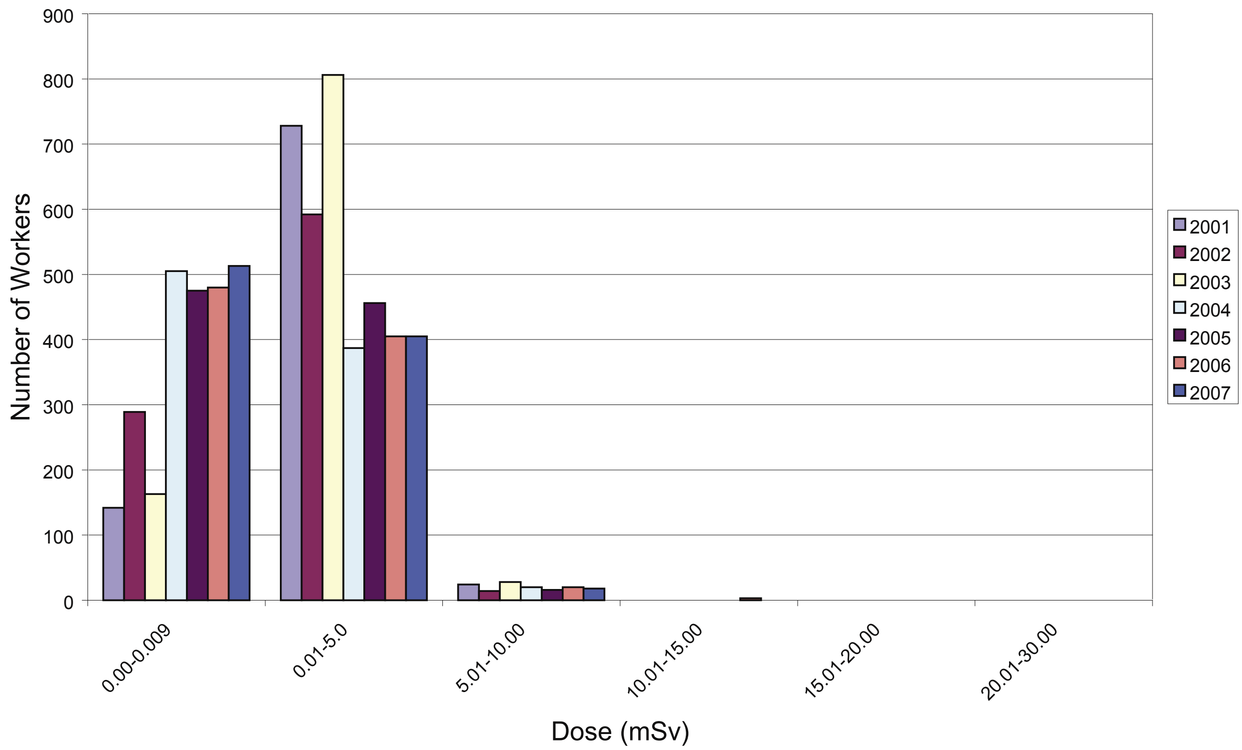


Figure 2.72. Distribution of Effective Doses Among All Workers at TRIUMF



2.6 Tritium Light Source Production Facilities

This section presents dose information for two tritium light source production facilities:

- Shield Source Incorporated (Section 2.6.1)
- SRB Technologies (Canada) Inc. (Section 2.6.2)

Graphs indicate the following data for each facility:

1. average doses based on non-zero (positive) results
2. average doses based on all monitoring results
3. collective doses
4. distribution of average effective doses

Notes on data for tritium light source production facilities:

1. Total effective doses are equivalent to doses from tritium, which is the sole radiological hazard at these facilities.

2.6.1 Shield Source Incorporated

Shield Source Incorporated operates a facility in Peterborough, Ontario, where it uses tritium gas to manufacture self-luminescent light sources. These are distributed throughout Canada, the United States and the rest of the world. Operations began in 1986.

Figures 2.73–2.76 present dose information for Shield Source Incorporated, from 2001 to 2007.

Figure 2.73. Average Dose Trends for Shield Source Incorporated (Based on Non-Zero Results)

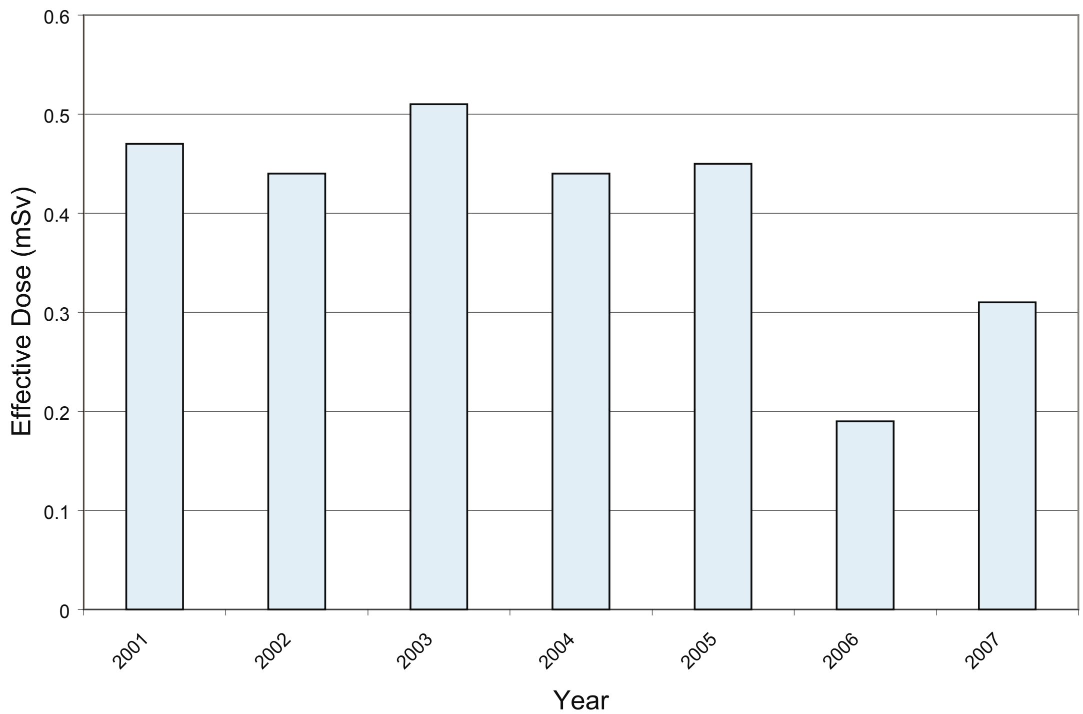


Figure 2.74. Average Dose Trends for Shield Source Incorporated (Based on All Monitoring Results)

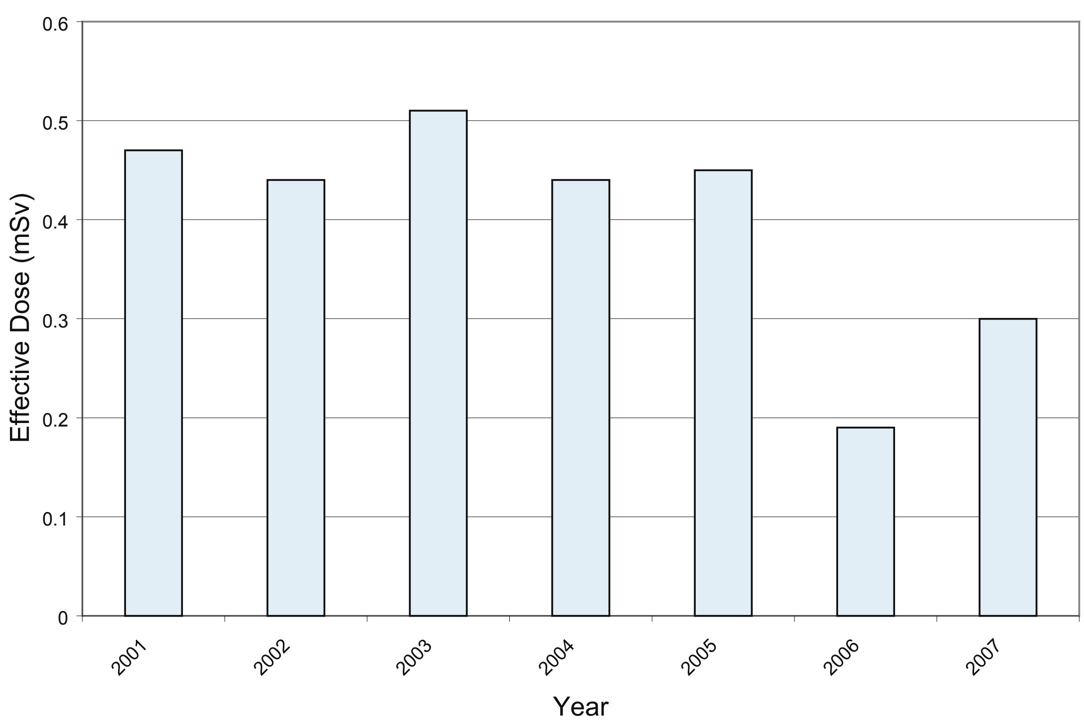


Figure 2.75. Collective Dose Trends for Shield Source Incorporated

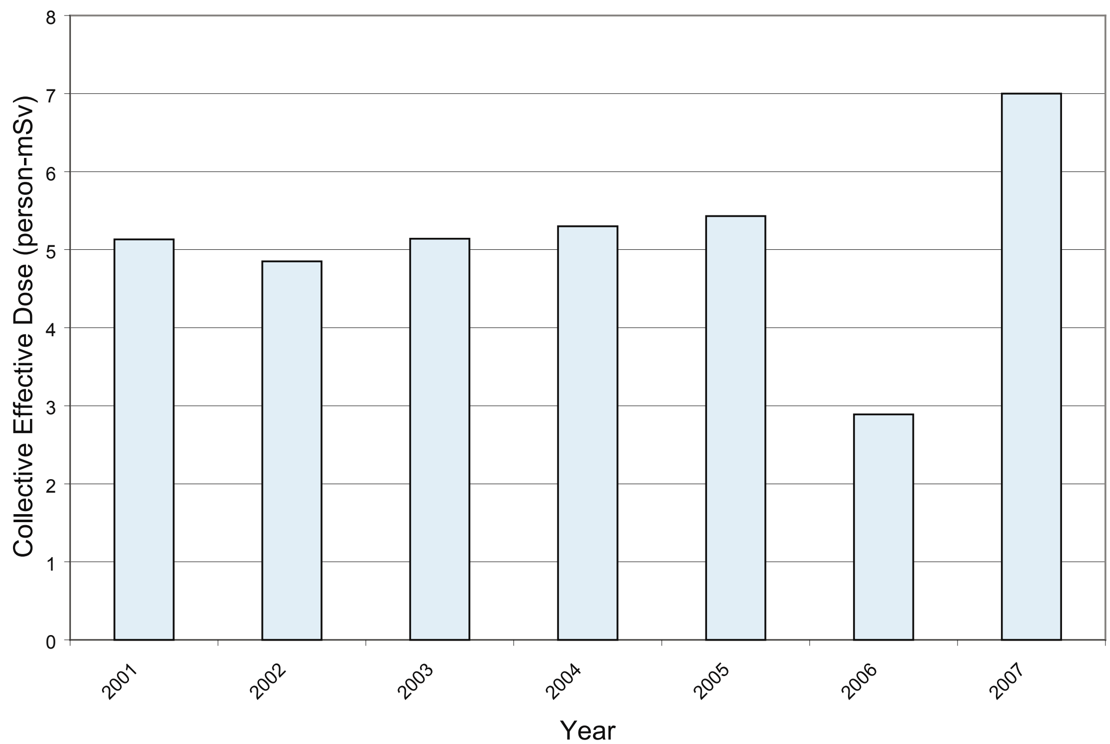
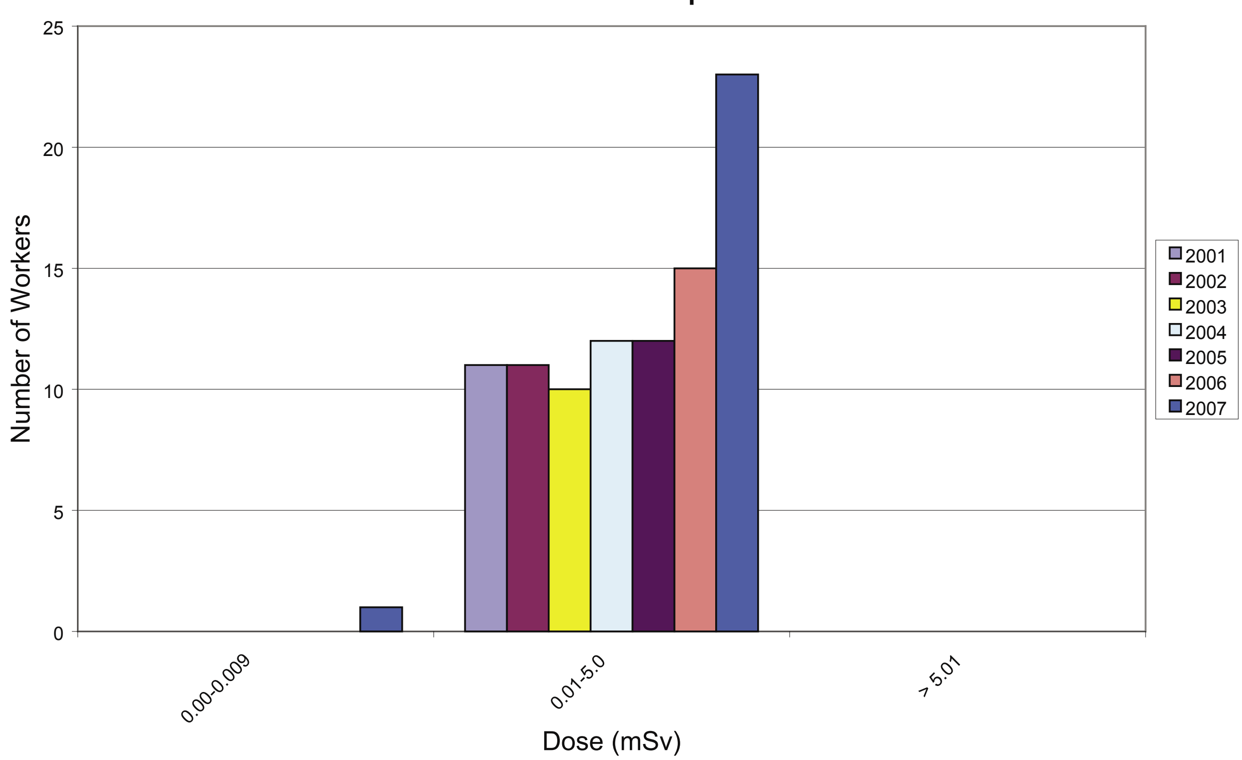


Figure 2.76. Distribution of Effective Doses Among All Workers at Shield Source Incorporated



2.6.2 SRB Technologies (Canada) Inc.

During the reporting period, SRB Technologies (Canada) Inc. operated a facility in Pembroke, Ontario, using tritium in sealed tubes to manufacture self-luminescent light sources. SRB Technologies did not process tritium for the majority of 2007. In mid-2008, SRB Technologies resumed processing tritium at its facility.

Figures 2.77–2.80 present dose information for SRB Technologies (Canada) Inc., from 2001 to 2007.

Figure 2.77. Average Dose Trends for SRB Technologies (Canada) Inc. (Based on Non-Zero Results)

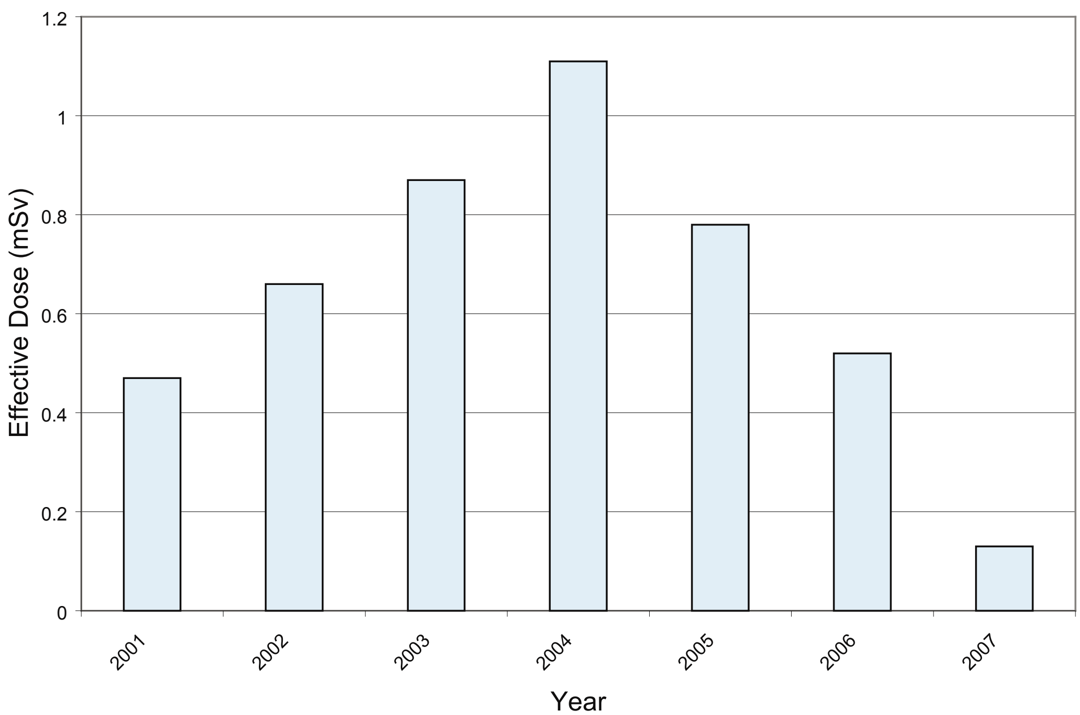


**Figure 2.78. Average Dose Trends for SRB Technologies (Canada) Inc.
(Based on All Monitoring Results)**

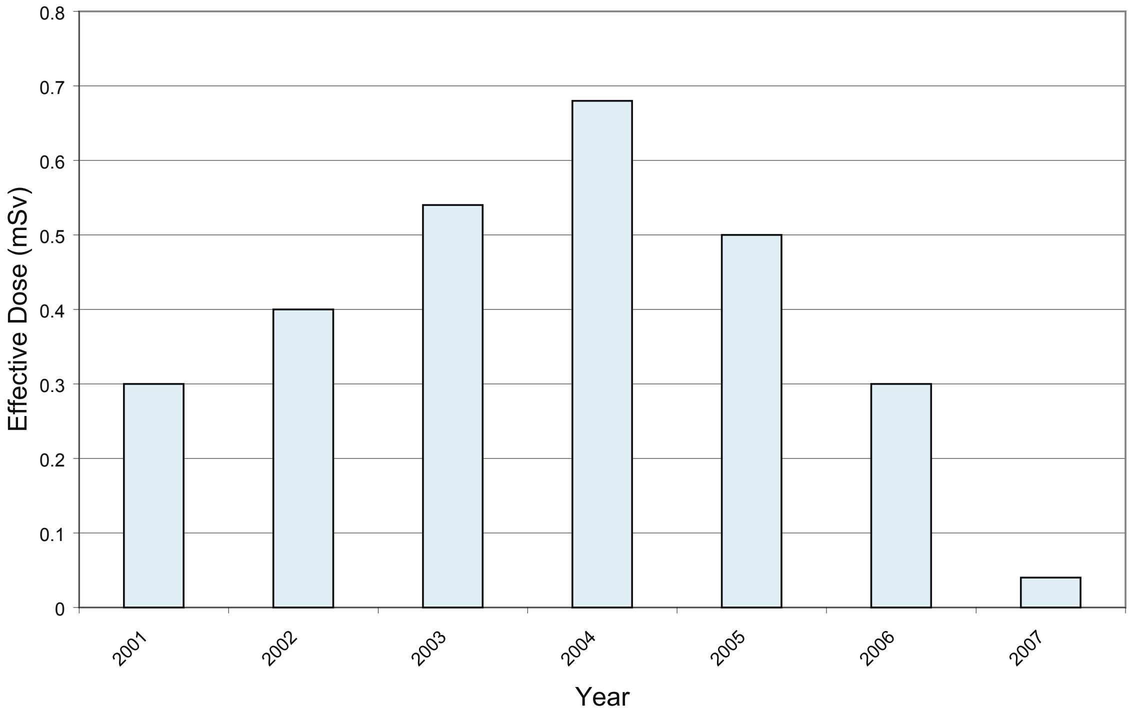


Figure 2.79. Collective Dose Trends for SRB Technologies (Canada) Inc.

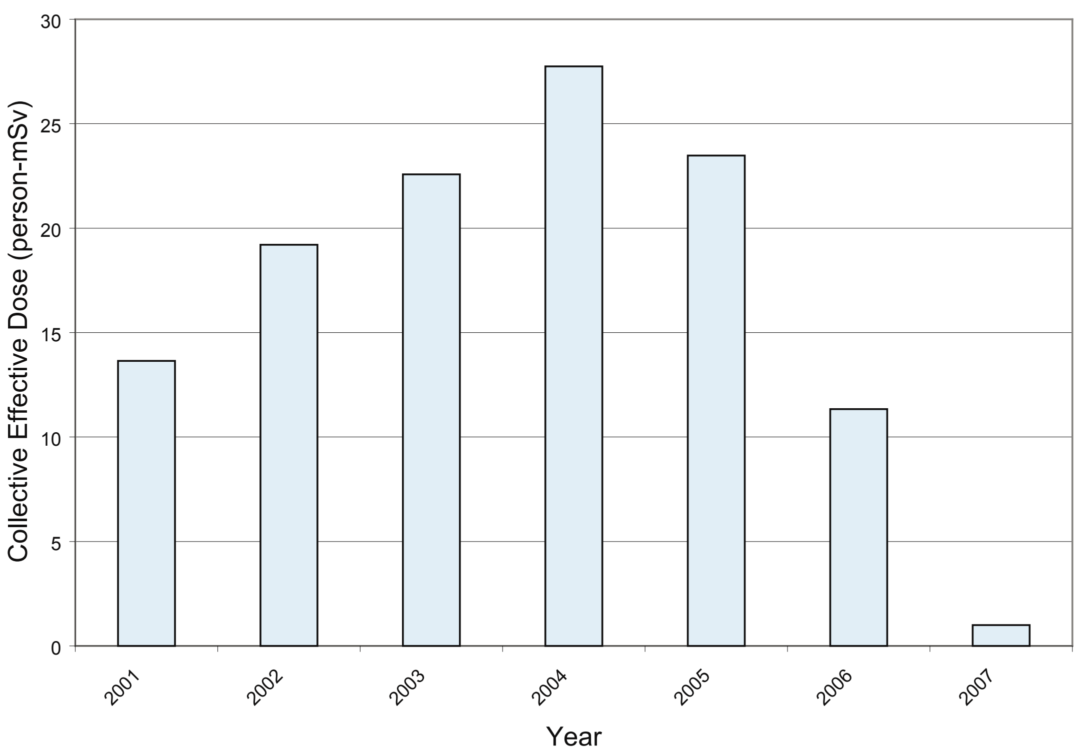
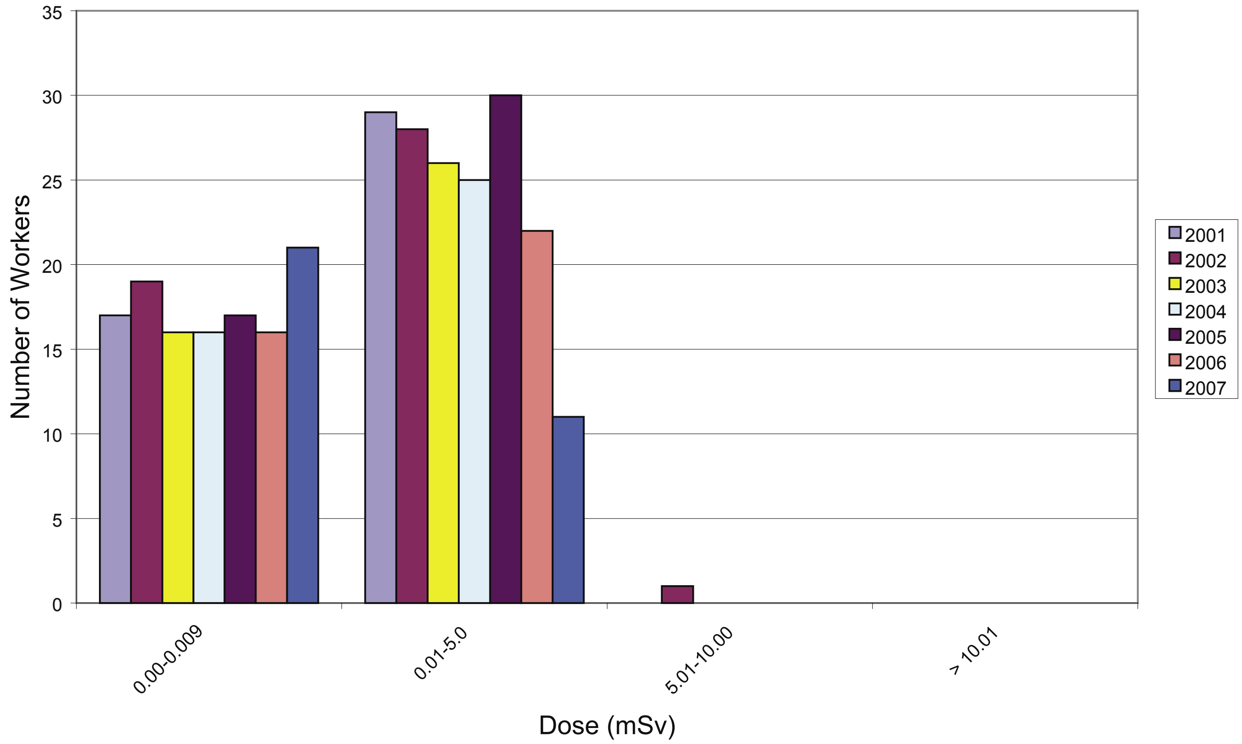


Figure 2.80. Distribution of Effective Doses Among All Workers at SRB Technologies (Canada) Inc.



Glossary

all monitoring average dose: average dose determined using the entire data set of dose readings. As the zero readings are included in the data set, the all monitoring average dose values will be less than or equal to the non-zero (positive) average dose values for the same facility. For example, if a data set of five effective doses was 0, 0, 1.3, 1.6 and 2.2 (all measured in mSv) then the all monitoring average dose would be (0+0+1.3+1.6+2.2)/5 = 1.0 mSv and the non-zero average dose would be (1.3+1.6+2.2)/3 = 1.7 mSv.

collective dose: A total radiation dose incurred by a population.

cyclotron: a particle accelerator that causes a beam of charged particles to travel in a roughly circular path. The particles are accelerated using a high frequency, alternating voltage.

dose limit: a limit on radiation dose, specified in the *Radiation Protection Regulations*

effective dose: a measure of dose designed to reflect the amount of radiation detriment likely to result from the dose. Measured in Sieverts (Sv), it is obtained by multiplying the equivalent dose to each tissue or organ by an appropriate tissue weighting factor and summing the products.

licensee: a person who is licensed to carry on an activity described in any of paragraphs 26(a) to (f) of the *Nuclear Safety and Control Act*.

long-lived radioactive dust: dust composed of Uranium-238 and its long-lived progeny, such as U-234, Th-230 and Ra-226.

milliSievert (mSv): one one-thousandth of a Sievert.

National Dose Registry (NDR): Canada's central repository for occupational radiation doses. Managed by Health Canada, it publishes annual reports on occupational dose information and trends, according to job type.

net radiological detriment: The total harm that would eventually be experienced by an exposed person or group and their descendants, as a result of their exposure to radiation.

non-zero (positive) average dose: average dose determined using the subset of data containing only the non-zero (positive) values. The zero dose readings, which include both zero and below measurable threshold readings, are not included in this subset.

nuclear energy worker: a person who is required, in the course of the person's business or occupation in connection with a nuclear substance or nuclear facility, to perform duties in such circumstances that there is a reasonable probability that the person may receive a dose of radiation that is greater than the prescribed limit for the general public.

radiation: energy, in the form of waves or particles, propagating through space.

radon progeny: the following radioactive decay products of radon 222: bismuth 214, lead 214, polonium 214 and polonium 218.

Sievert: the SI unit of dose, which corresponds to the rem (1 Sv = 100 rem). It is the product of absorbed dose in units of Grays and the radiation weighting factor.

tritium: a radioactive form of hydrogen, having an atomic mass number of three. Tritium is produced during the normal operation of CANDU reactors.

uranium ore concentrate: U_3O_8 (also known as yellowcake); the product of an intermediate step in the processing of uranium ore.

working level month: the exposure that results from the inhalation of air containing one working level for 170 hours.

working level: means the concentration of radon progeny in 1 m^3 of air that has a potential alpha energy of 2.08×10^{-5} Joules.

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