Canadian Nuclear Safety Commission
Commission canadienne de sûreté nucléaire

Radioactive Release Data from Canadian Nuclear Generating Stations 1993 to 2002

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RADIOACTIVE RELEASE DATA FROM CANADIAN NUCLEAR GENERATING STATIONS 1993 to 2002

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Document Availability

The document can be viewed on the CNSC internet web site *www.nuclearsafety.gc.ca*.

Copies may be ordered in English or in French using the contact information below:

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NOTICE

On May 31, 2000, the Atomic Energy Control Board (AECB), Canada’s nuclear regulatory authority, became the Canadian Nuclear Safety Commission (CNSC).

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INTRODUCTION

All nuclear generating stations release small quantities of radioactive materials in a controlled manner into both the atmosphere (as gaseous effluents) and adjoining water bodies (as liquid effluents). The purpose of this document is to report the magnitude of these releases for each operating nuclear generating station in Canada. The report also indicates how these releases compare with the limitations imposed by the Canadian Nuclear Safety Commission (CNSC) as part of its regulatory and licensing program. The data shows that the levels of gaseous and liquid effluents from all currently operating nuclear generating stations are well below the values authorized by the CNSC. In all but a few cases, the releases have been below 1% of the regulatory release limit. The few exceptions have been releases slightly above 1% but less than 2%.

This 11th revision of INFO 0210 presents data for the ten year period from 1993 to 2002. The first edition of the report was published in September 1986 and covered the period from 1972 to 1985.

The present report incorporates histograms for each nuclear generating station displaying annual gaseous releases containing tritium in the form of tritium oxide, noble gases, iodine 131, and radioactive particulate, as well as the annual liquid releases containing tritium in the form of tritium oxide and gross beta gamma activity. In addition, when monitored, annual releases of carbon 14 are depicted, and for Darlington nuclear generating station, airborne releases of elemental tritium are given. Darlington is required to monitor and report airborne releases of elemental tritium as a result of the operation of a tritium removal facility at Darlington nuclear generating station.

In each case, the release data are compared to the derived release limits (see below for an explanation of this term) in order that the data may be placed in perspective.

Derived release limits

Radioactive material released into the environment through gaseous and liquid effluents from nuclear generating stations can result in radiation doses to members of the public through direct irradiation. Such doses are subject to statutory dose limits for members of the public, which are set out in paragraphs 13 and 14 of the Radiation Protection Regulations and are provided in Table 1 below. On May 31st 2000, the Nuclear Safety and Control Act (NSCA) and its associated Regulations came into force to replace the Atomic Energy Control Act and its Regulations. The Radiation Protection Regulations introduced new dose limits which reflect the recommendations of the International Commission on Radiation Protection (ICRP 60). The annual public dose limit was reduced from 5 mSv to 1mSv.

Table 1
Annual dose limits for members of the public

Application	Dose
Effective dose, whole body	1 mSv
Equivalent dose, lens of an eye	15 mSv
Equivalent dose, skin	50 mSv
Equivalent dose, hands and feet	50 mSv

The doses received by members of the public from routine releases from nuclear generating stations are too low to measure directly. Therefore, to ensure that the public dose limit is not exceeded CNSC licences restrict the amount of radioactive materials that may be released in effluents from nuclear generating stations. These effluent limits are derived from the public dose limit and are referred to as “derived release limits” or DRLs. In addition, the industry sets operating targets that are typically a small percentage of the derived release limits. These targets are based on the ALARA principle that doses be kept “as low as reasonably achievable.” These targets are unique to each facility depending on the factors that exist at each one.

Table 2
Derived release limits for gaseous effluents

Nuclear generating station	Tritium* (TBq)	Iodine-131 (TBq)	Noble gases (TBq-MeV**)	Particulates (TBq)	Carbon-14 (TBq)
Point Lepreau	4.3×10^5	9.9	7.3×10^4	5.2	3.3×10^3
Bruce-A	8.8×10^4	1.2	5.0×10^4	2.1	5.7×10^2
Bruce-B	9.3×10^4	1.3	1.2×10^5	2.5	6.0×10^2
Darlington	4.6×10^4 (HTO) 4.6×10^5 (HT)***	0.33	3.1×10^4	0.94	1.5×10^2
Pickering-A	7.0×10^4	2.2	1.7×10^4	1.2	1.8×10^3
Pickering-B	7.0×10^4	2.2	1.7×10^4	1.2	1.8×10^3
Gentilly-2	4.4×10^5	1.3	1.7×10^5	1.9	9.1×10^2

* Tritium oxide (HTO)
** TBq MeV (terabecquerel million electron volts)
*** Derived release limit for elemental tritium (HT) resulting from the tritium removal facility at Darlington nuclear generating station

Methodology for establishing derived release limits

When it approved the DRLs for each nuclear generating station, the CNSC considered the environmental pathways through which radioactive material could reach the most exposed members of the public after being released from the facility. The most exposed members of the public are called the "critical group." They are defined as those individuals who are expected to receive the highest dose of radiation because of such considerations as their age, diet, lifestyle and location.

Since 1987, DRL calculations have been based on a method recommended by the Canadian Standards Association in document CAN/CSA N288.1 M87. This approach takes into account many more environmental pathways than did previous methods of calculating DRLs, and it allows for the use of more site specific data. More realistic assumptions were incorporated into the method, for example, the use of shielding factors and occupancy times. Environmental transfer parameters for individual radionuclides were also updated. In addition to the use of this standard, the CNSC may place additional requirements on the calculation of DRLs such as the use of certain site specific information to enable better estimates of environmental transfer processes.

As methods of calculating DRLs become more sophisticated, the improvements make it necessary for licensees to revise their DRLs. At the same time, licensees review the assumptions affecting the exposure of critical groups and adjust them where necessary to make them more representative, including, for example, such factors as location and lifestyle habits of critical groups and the location of dairy farms. In addition, licensees may use more site specific data obtained from their routine environmental monitoring programs, such as liquid dispersion factors or surveys of the local population.

The net effect of these changes on the methodology for calculating DRLs has been that over time, some limits increased while others decreased, depending on the relative importance of the various pathways. As new information on dose calculation methods or parameters becomes available, the DRLs may require subsequent revisions. The current DRLs for all Canadian nuclear generating stations are listed in Tables 2 and 3.

The heavy horizontal lines at the top of the histograms in this report show the DRL for the elements in question.

Table 3
Derived release limits for liquid effluents

Nuclear generating station	Tritium* (TBq)	Gross beta-gamma activity (TBq)	Carbon-14 (TBq)
Point Lepreau**	1.6×10^7	16.0	3.0×10^2
Bruce-A***	4.5×10^4	0.58	1.1×10^1
Bruce-B	6.0×10^5	4.9	9.1×10^1
Darlington	8.8×10^5	2.6×10^1	6.0×10^2
Pickering-A	1.7×10^5	2.0	2.6×10^1
Pickering-B	1.7×10^5	2.0	2.6×10^1
Gentilly-2	1.2×10^6	5.3	1.0×10^2

* Tritium oxide (HTO)
** The derived release limit for tritium in liquid releases at Point Lepreau is higher than for the other nuclear generating stations because the effluent is discharged to sea water, thus eliminating the drinking water pathway to humans.
*** The liquid DRLs for Bruce A provided here are based on one condenser cooling water pump operating. Other liquid DRLs are available for 2, 3 or 12 pumps operating.

Internal operating targets

Nuclear generating stations maintain their own internal operating targets of approximately 1% of the specified DRLs. Although DRLs are expressed as an annual release limit, weekly and monthly rates of release are further controlled. For gaseous releases, a limit of the annual DRL divided by 52 weeks is maintained. For liquid releases, a limit of the annual DRL divided by 12 months is maintained. Weekly airborne releases and monthly liquid releases at each nuclear generating station are compared to the respective weekly and monthly limits and are reported to the CNSC on a quarterly basis.

Release data

Licensees measure and report their releases in different ways. Some analyse releases for all radionuclides that are present in station effluent, while most report the radionuclides that are major contributing factors to public dose such as airborne releases of tritium, iodine 131, noble gases, particulate and carbon 14, and liquid releases of tritium, gross beta gamma and carbon-14. As particulate and gross beta-gamma consist of a mixture of radionuclides, the most dose-restrictive radionuclide is chosen to represent the mixture as the basis for comparison with the DRL.

The use of "ND" in the following histograms and tables is to indicate that radioactive releases were not detected in that particular year.

Interim DRLs

The DRLs used at Pickering, Bruce and Darlington nuclear generating stations were last revised and implemented in 2001 to reflect the annual statutory public dose limit of 1 mSv, and to incorporate more recently accepted values for factors such as breathing and ingestion rates which are used in the calculations. These most recent DRLs are referred to as "interim" as they are expected to be replaced by a more comprehensive revision in the future. The DRLs for Point Lepreau nuclear generating station were last revised in 1996. and the DRLs are based on a public dose limit of 1 mSv, as recommended by the ICRP in 1990. The DRLs for Gentilly-2 nuclear generating station were last revised in 1992 and the DRLs take into account the previous annual statutory public dose limit of 5 mSv. However, as mentioned above the internal administrative targets are set at 1% of the DRL, which is well below the current 1 mSv public dose limit. Updated DRLs for Gentilly-2 are expected in the near future.

Terminology

A brief glossary is provided at the end of this report so that all readers may understand the words and expressions that relate to radioactive release data.

Scientific notation

Due to the magnitude of the numbers it is often more convenient to express them in scientific rather than decimal notation. In most cases the numbers in this report are rounded to two significant figures. Examples follow:

100 000	10^{5}
1 260 000	1.26 H 10^{6} or
	1.3 H 10^{6} (to two significant figures)
0.003473	3.5 H 10^{3} (to two significant figures)

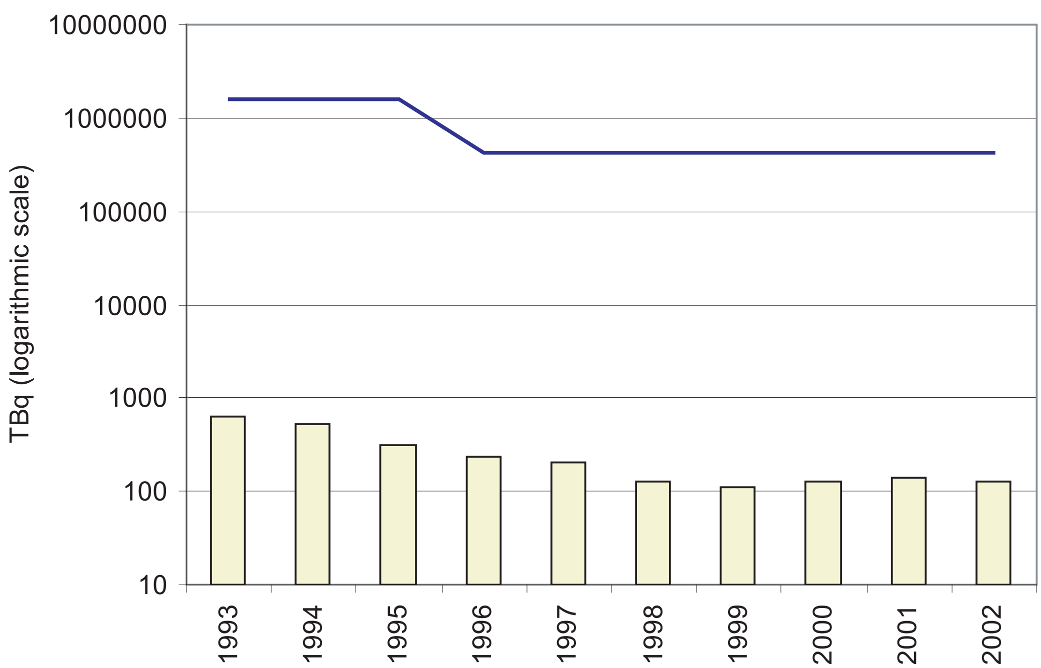
The Point Lepreau nuclear generating station consists of one nuclear reactor which began operation in 1982. It is located in New Brunswick on Point Lepreau, which extends into the Bay of Fundy.

Data for radioactive gaseous and liquid effluents released between 1993 and 2002 from the Point Lepreau nuclear generating station are presented in the following histograms. The major radionuclides in gaseous effluents are tritium in the form of tritium oxide (Figure 1.1), iodine 131 (Figure 1.2), noble gases (Figure 1.3), radioactive particulate (Figure 1.4) and carbon-14 (Figure 1.5). Those in liquid effluents are tritium in the form of tritium oxide (Figure 1.6), gross beta-gamma activity (Figure 1.7) and carbon-14 (Figure 1.8).

Point Lepreau nuclear generating station began measuring carbon-14 in liquid releases in 1997.

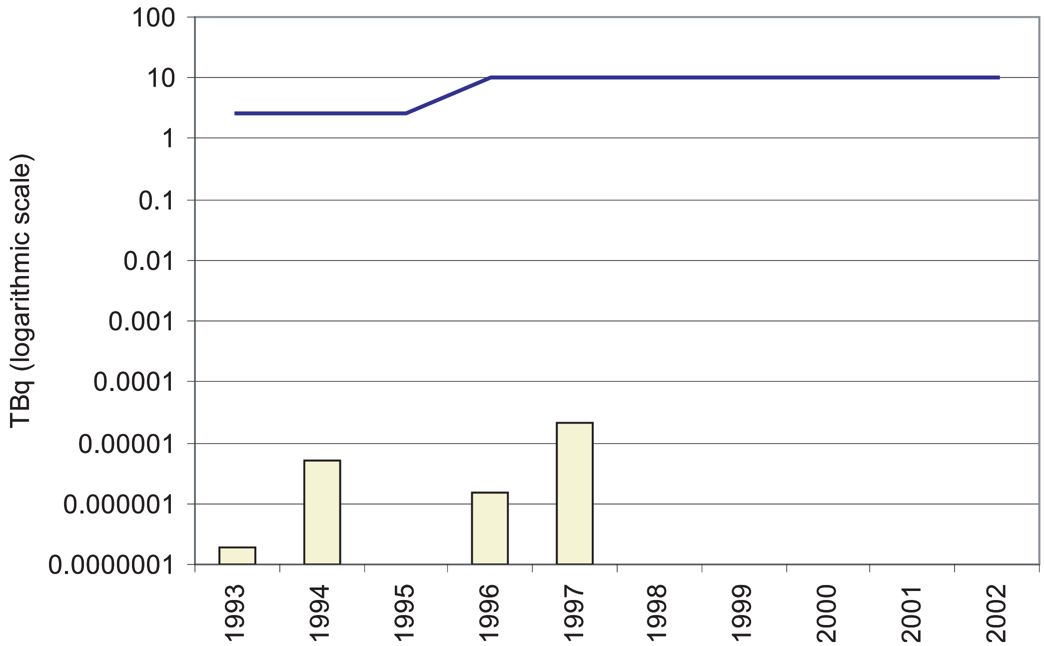
It should be noted that the DRL for tritium in liquid effluent is higher than that for the other nuclear generating stations (see Table 3). This occurs because the effluent goes directly to sea water, thus eliminating the drinking water pathway to humans.

Figure 1.1
Tritium oxide in gaseous effluent from the Point Lepreau nuclear generating station (1993-2002)
DRL since 1996: 4.3×10^5 TBq



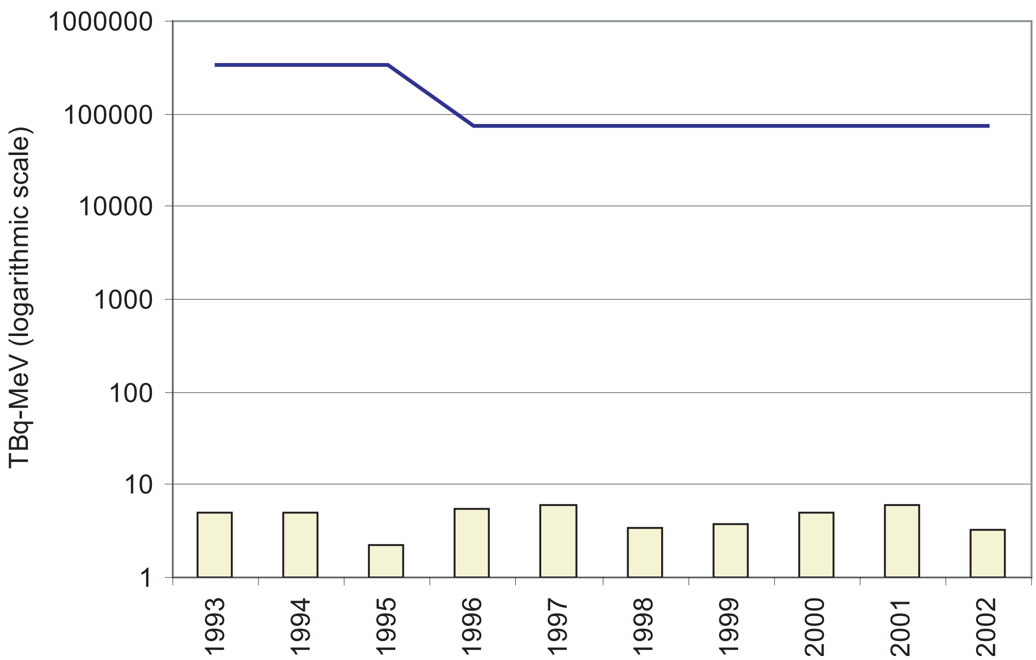
Year	TBq
1993	6.4×10^2
1994	5.2×10^2
1995	3.1×10^2
1996	2.4×10^2
1997	2.0×10^2
1998	1.3×10^2
1999	1.1×10^2
2000	1.3×10^2
2001	1.4×10^2
2002	1.3×10^2

Figure 1.2
Iodine-131 in gaseous effluent from the Point Lepreau nuclear generating station (1993-2002)
DRL since 1996: 9.9 TBq



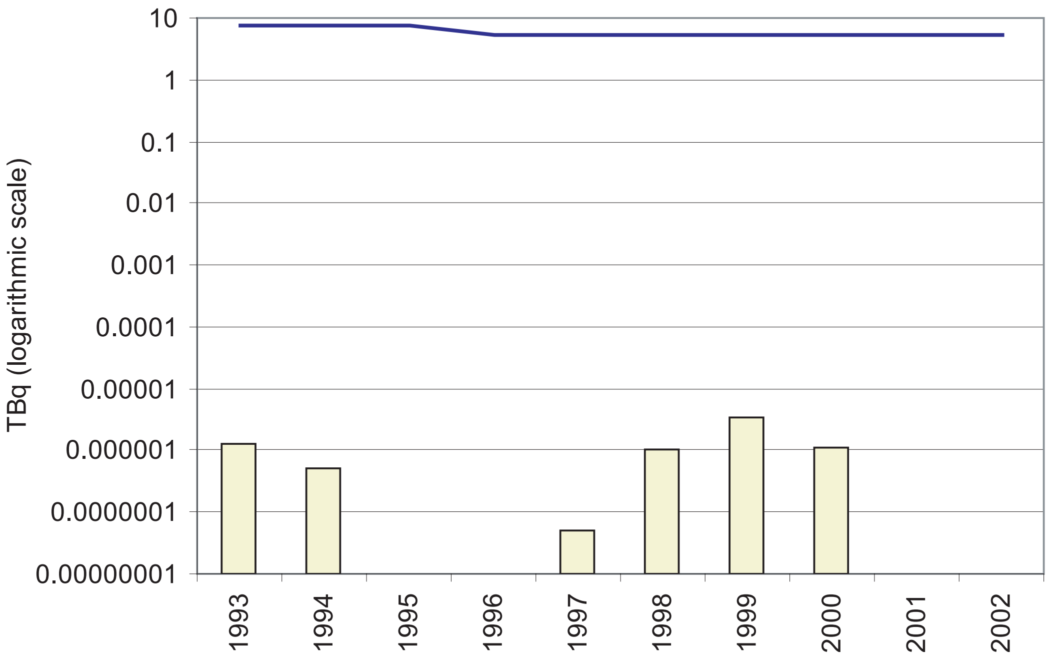
Year	TBq
1993	1.9×10^{-7}
1994	5.1×10^{-6}
1995	ND
1996	1.5×10^{-6}
1997	2.1×10^{-5}
1998	ND
1999	ND
2000	ND
2001	ND
2002	ND

Figure 1.3
Noble Gas in effluent from the Point Lepreau nuclear generating station (1993-2002)
DRL since 1996: 7.3×10^4 TBq-MeV



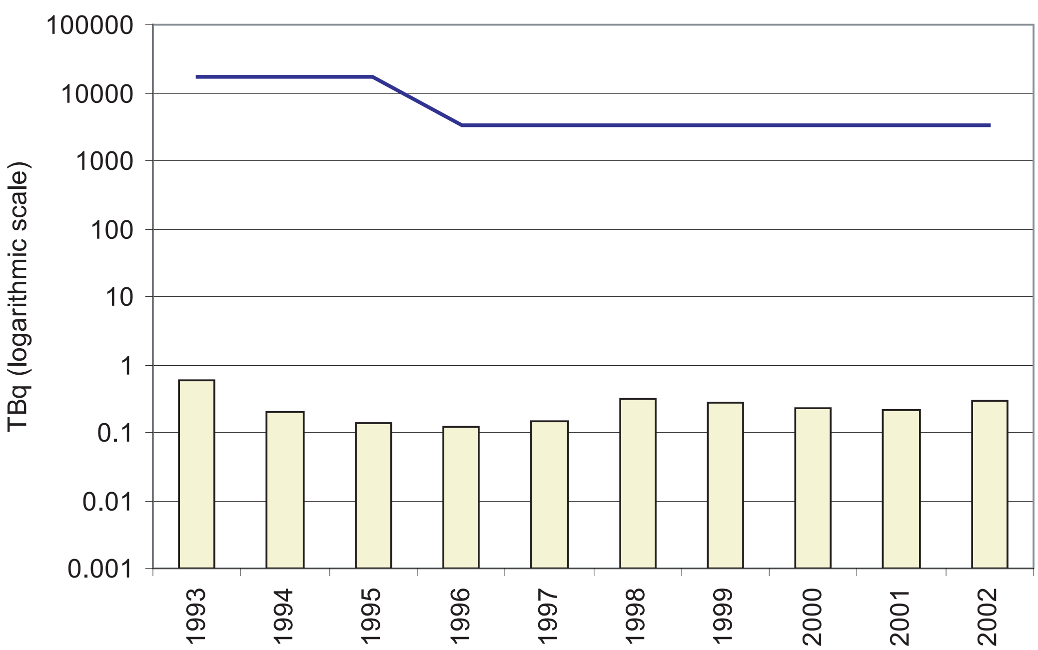
Year	TBq
1993	4.9
1994	5.1
1995	2.2
1996	5.6
1997	5.9
1998	3.4
1999	3.8
2000	5.0
2001	5.9
2002	3.2

Figure 1.4
Radioactive particulate in gaseous effluent from the Point Lepreau nuclear generating station (1993-2002)
DRL since 1996: 5.2 TBq



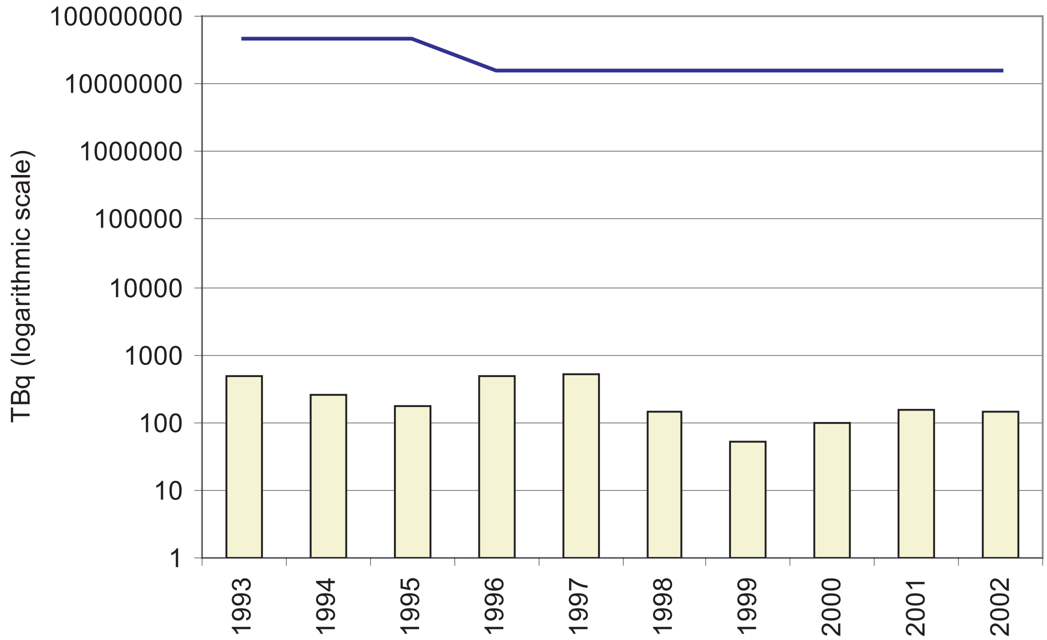
Year	TBq
1993	1.3×10^{-6}
1994	5.2×10^{-7}
1995	ND
1996	ND
1997	5.0×10^{-8}
1998	1.0×10^{-6}
1999	3.5×10^{-6}
2000	1.1×10^{-6}
2001	ND
2002	ND

Figure 1.5
Carbon-14 in gaseous effluent from the Point Lepreau nuclear generating station (1993-2002)
DRL since 1996: 3.3×10^{3} TBq



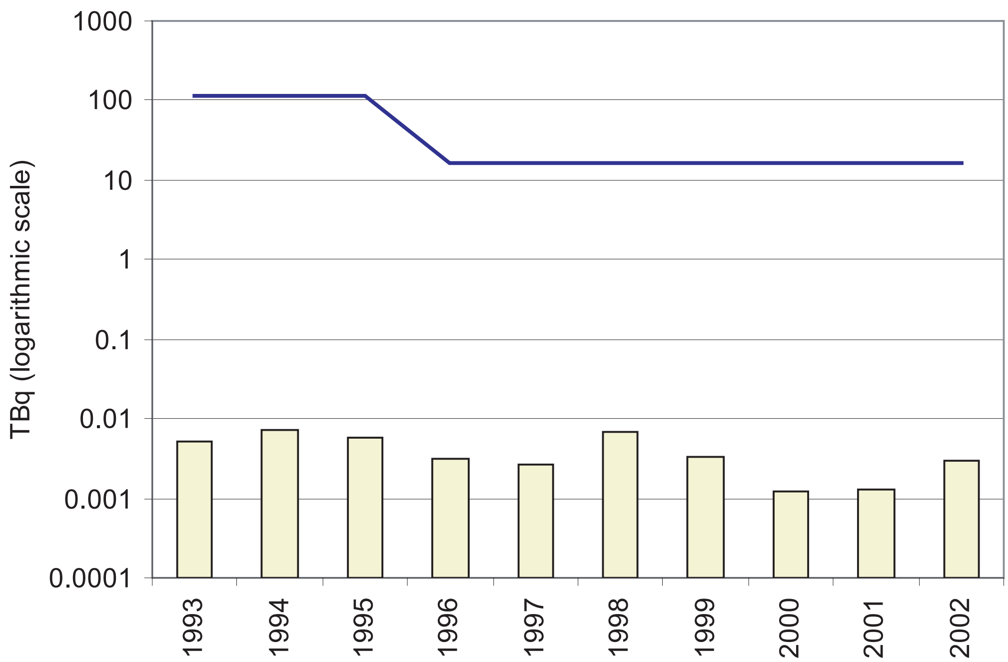
Year	TBq
1993	0.58
1994	0.20
1995	0.14
1996	0.12
1997	0.15
1998	0.32
1999	0.28
2000	0.23
2001	0.22
2002	0.29

Figure 1.6
Tritium oxide in liquid effluent from the Point Lepreau nuclear generating station (1993-2002)
DRL since 1996: 1.6×10^7 TBq



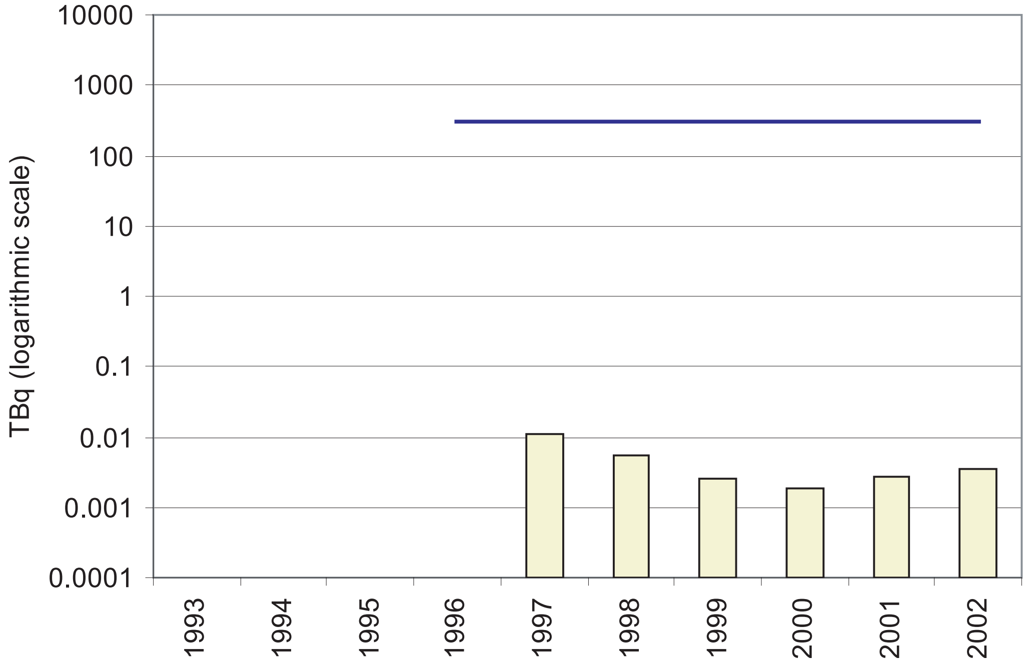
Year	TBq
1993	4.7×10^2
1994	2.6×10^2
1995	1.7×10^2
1996	4.8×10^2
1997	5.0×10^2
1998	1.4×10^2
1999	5.3×10^1
2000	9.6×10^1
2001	1.5×10^2
2002	1.4×10^2

Figure 1.7
Gross beta-gamma activity in liquid effluent from the Point Lepreau nuclear generating station (1993-2002)
DRL since 1996: 16 TBq



Year	TBq
1993	5.2×10^{-3}
1994	7.3×10^{-3}
1995	5.9×10^{-3}
1996	3.2×10^{-3}
1997	2.7×10^{-3}
1998	6.9×10^{-3}
1999	3.3×10^{-3}
2000	1.2×10^{-3}
2001	1.3×10^{-3}
2002	3.0×10^{-3}

Figure 1.8
Carbon-14 in liquid effluent from the Point Lepreau nuclear generating station (1997-2002)
DRL since 1996: 300 TBq



Year	TBq
1997	1.1×10^{-2}
1998	5.5×10^{-3}
1999	2.6×10^{-3}
2000	1.8×10^{-3}
2001	2.8×10^{-3}
2002	3.4×10^{-3}

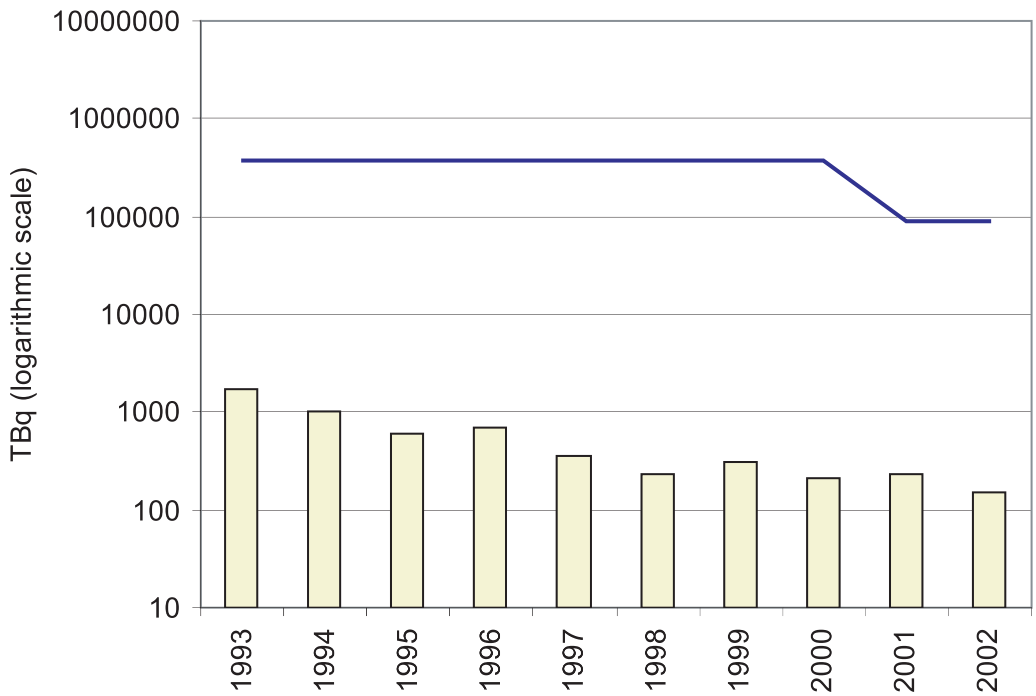
The Bruce-A nuclear generating station consists of four nuclear reactors (units 1-4) which began operation in 1976. It is located in Ontario on the shore of Lake Huron near the town of Kincardine.

In 1997 as part of its extensive recovery program, Ontario Hydro (now Ontario Power Generation) temporarily shut down all Bruce-A reactors. Since then all units have been maintained in a guaranteed shut down state. When this report was compiled, Units 3 and 4 were in the process of returning to service. The Bruce nuclear generating station is currently operated by Bruce Power.

Data for radioactive gaseous and liquid effluents released between 1993 and 2002 from the Bruce-A nuclear generating station are presented in the following histograms. The pertinent items in the gaseous effluents are tritium, in the form of tritium oxide (Figure 2.1), iodine 131 (Figure 2.2), noble gases (Figure 2.3), radioactive particulates (Figure 2.4) and carbon-14 (Figure 2.5); while those in the liquid effluents are tritium, in the form of tritium oxide (Figure 2.6), gross beta gamma activity (Figure 2.7) and carbon-14 (Figure 2.8).

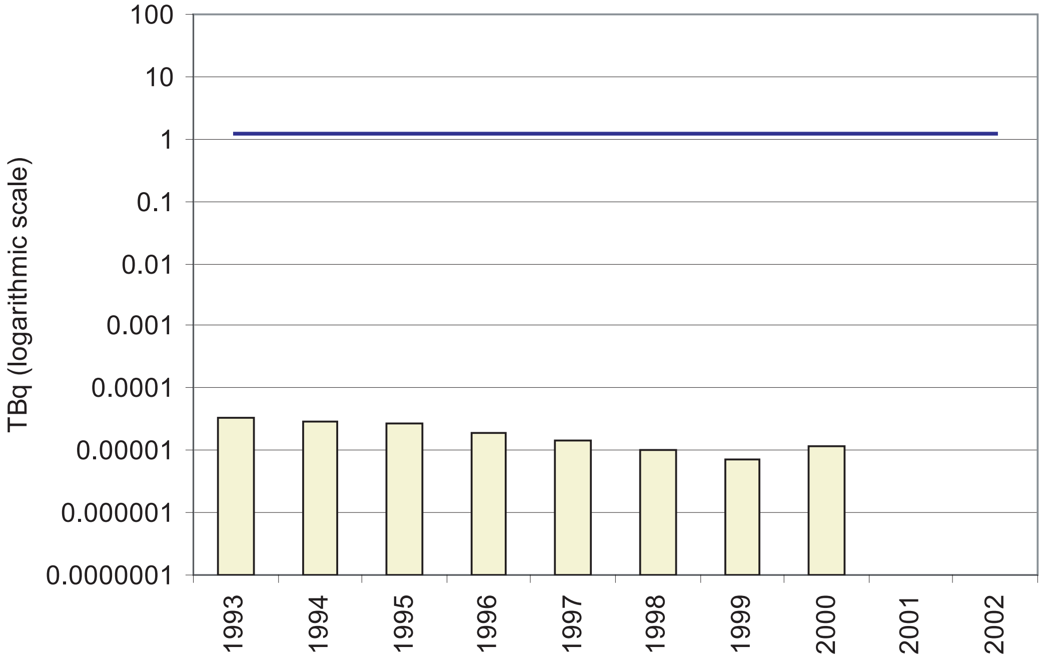
Bruce-A began reporting carbon-14 releases in gaseous and liquid effluents in 1999.

Figure 2.1
Tritium oxide in gaseous effluent from the Bruce-A nuclear generating station (1993-2002)
DRL from 1990 to 2001: 3.8×10^5 TBq; DRL since 2001: 8.8×10^4 TBq



Year	TBq
1993	1.7×10^3
1994	1.0×10^3
1995	6.1×10^2
1996	7.0×10^2
1997	3.5×10^2
1998	2.3×10^2
1999	3.1×10^2
2000	2.1×10^2
2001	2.3×10^2
2002	1.5×10^2

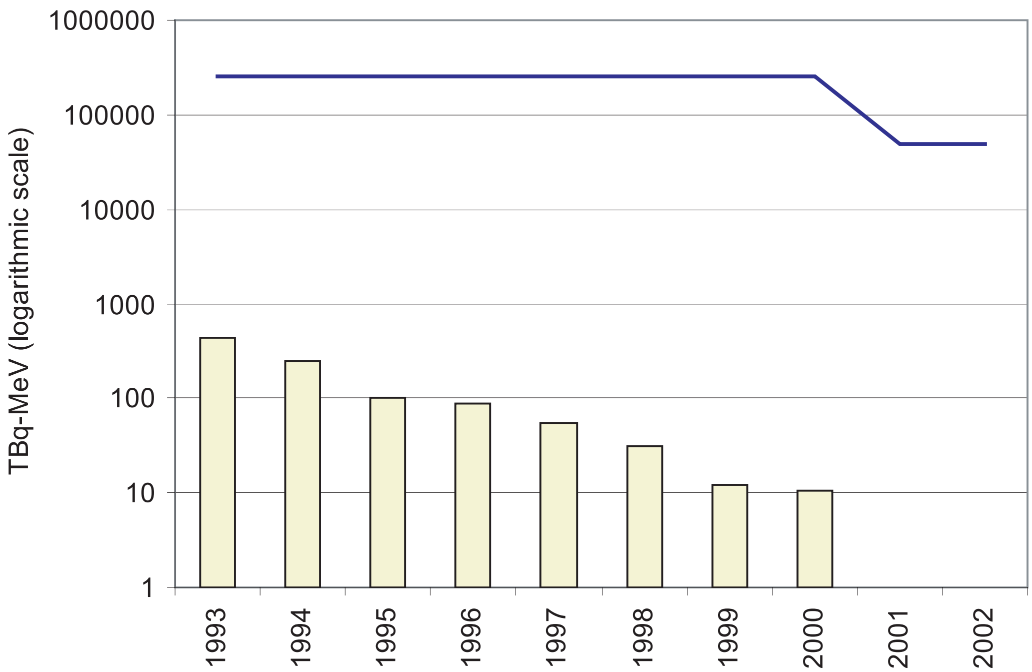
Figure 2.2
Iodine-131 in gaseous effluent from the Bruce-A nuclear generating station (1993-2002)
DRL since 1990: 1.2 TBq



Year	TBq
1993	3.3×10^{-5}
1994	3.0×10^{-5}
1995	2.7×10^{-5}
1996	1.9×10^{-5}
1997	1.4×10^{-5}
1998	9.9×10^{-6}
1999	7.2×10^{-6}
2000	1.2×10^{-5}
2001	NA
2002	NA

*NA= Not Applicable

Figure 2.3
Noble gas in effluent from the Bruce-A nuclear generating station (1993-2002)
DRL from 1990 to 2001: 2.5×10^{5} TBq-MeV; DRL since 2001: 5.0×10^{4} TBq-MeV

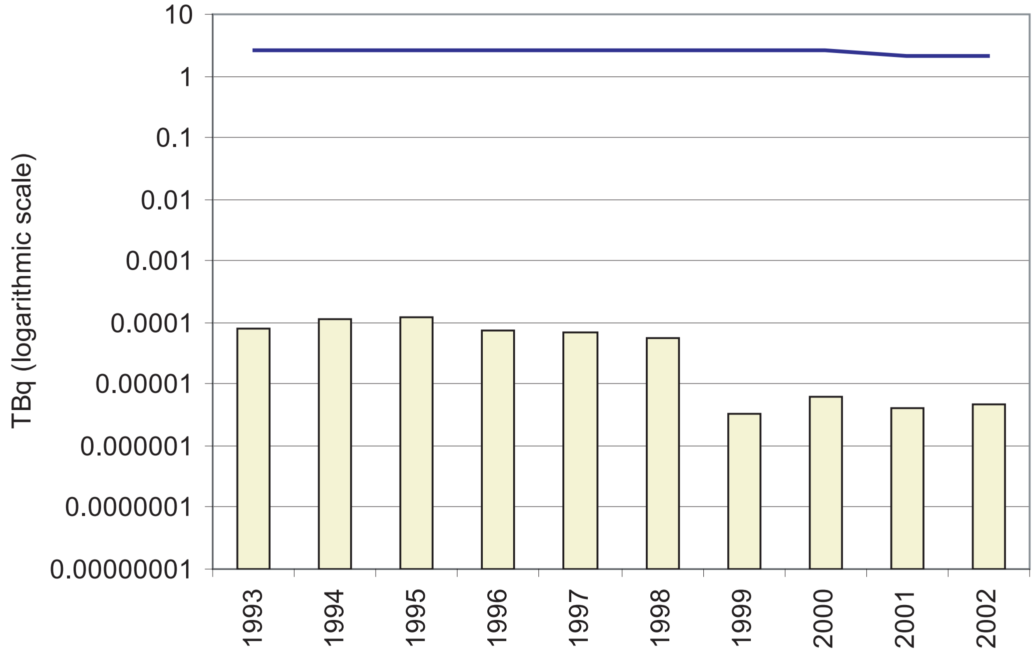


Year	TBq
1993	4.3×10^{2}
1994	2.5×10^{2}
1995	1.0×10^{2}
1996	8.8×10^{1}
1997	5.4×10^{1}
1998	3.1×10^{1}
1999	1.2×10^{1}
2000	1.1×10^{1}
2001	NA
2002	NA

*NA= Not Applicable

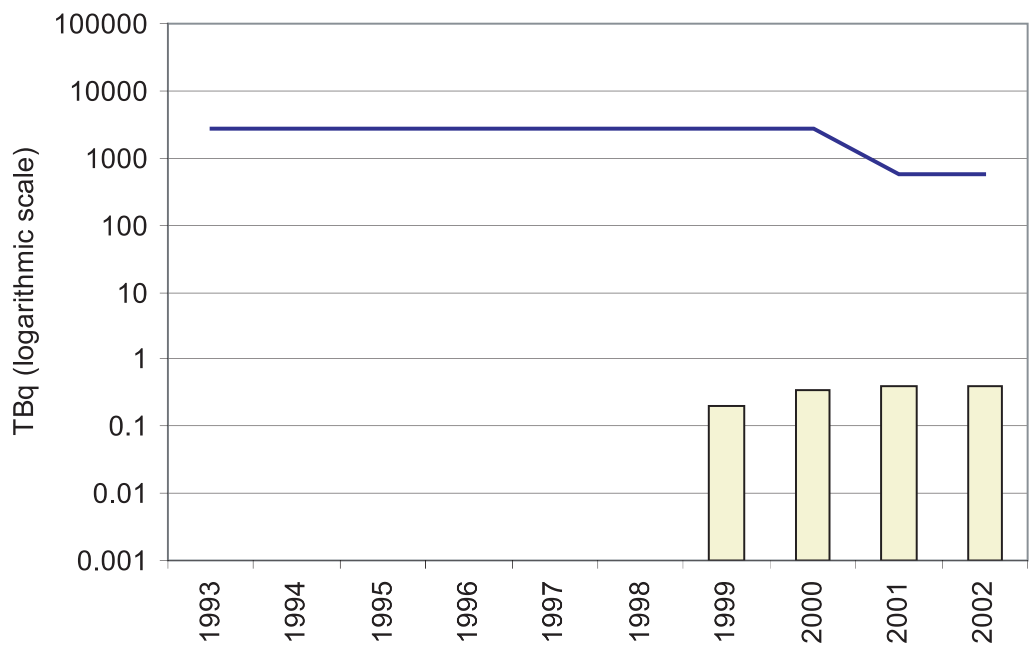
*In 2000, OPG shut down all non- contaminated stack monitors and all contaminated stack noble gas and iodine monitors at Bruce A

Figure 2.4
Radioactive particulate in gaseous effluent from the Bruce-A nuclear generating station (1993-2002)
DRL from 1990 to 2001: 2.7 TBq; DRL since 2001: 2.1 TBq



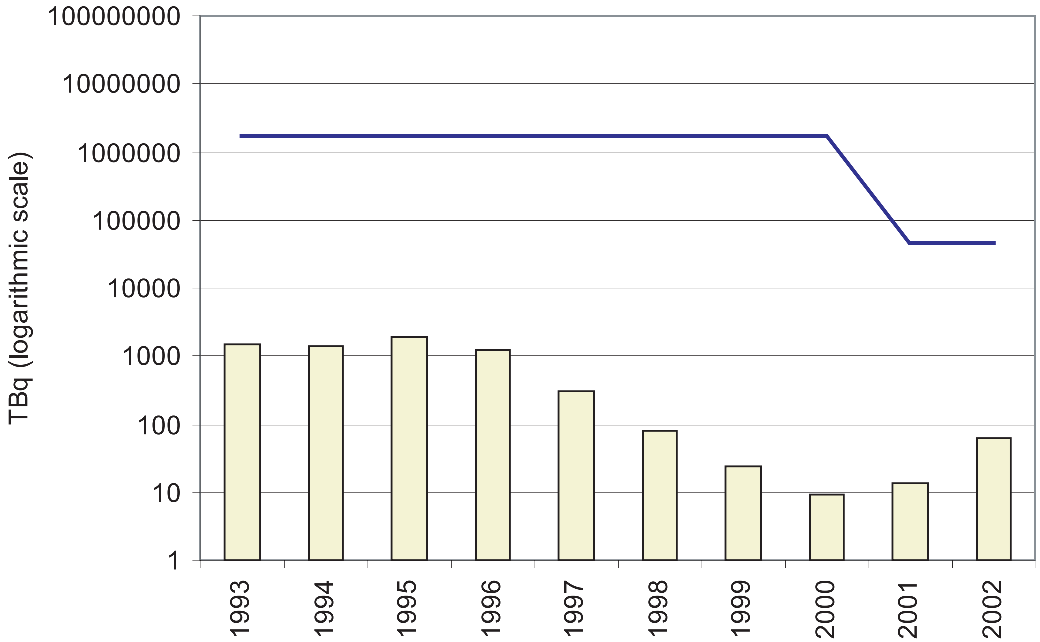
Year	TBq
1993	7.9×10^{-5}
1994	1.1×10^{-4}
1995	1.2×10^{-4}
1996	7.2×10^{-5}
1997	7.0×10^{-5}
1998	5.6×10^{-5}
1999	3.4×10^{-6}
2000	6.1×10^{-6}
2001	4.1×10^{-6}
2002	4.7×10^{-6}

Figure 2.5
Carbon-14 in gaseous effluent from the Bruce-A nuclear generating station (1999-2002)
DRL from 1990 to 2001: 2.8×10^3 TBq; DRL since 2001: 5.7×10^2 TBq



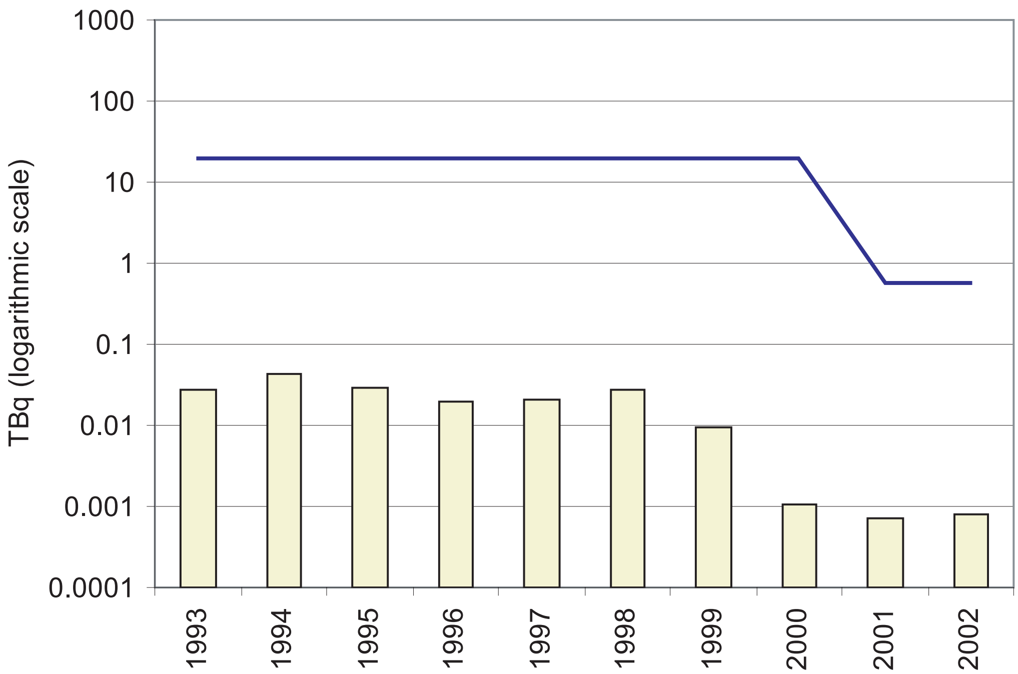
Year	TBq
1999	0.20
2000	0.35
2001	0.39
2002	0.39

Figure 2.6
Tritium oxide in liquid effluent from the Bruce-A nuclear generating station (1993-2002)
DRL from 1990 to 2001: 1.7×10^6 TBq; DRL since 2001: 4.5×10^4 TBq



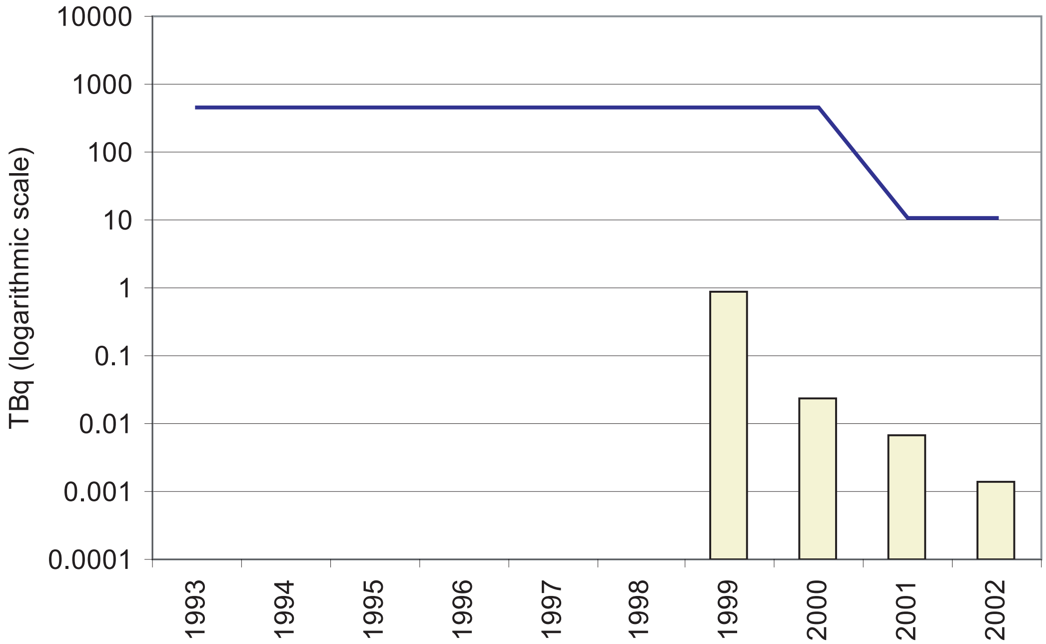
Year	TBq
1993	1.5×10^3
1994	1.4×10^3
1995	1.9×10^3
1996	1.2×10^3
1997	3.1×10^2
1998	7.8×10^1
1999	2.4×10^1
2000	9.0×10^0
2001	1.3×10^1
2002	6.4×10^1

Figure 2.7
Gross beta-gamma activity in liquid effluent from the Bruce-A nuclear generating station (1993-2002)
DRL from 1990 to 2001: 20 TBq; DRL since 2001: 0.58 TBq



Year	TBq
1993	2.7×10^{-2}
1994	4.4×10^{-2}
1995	2.9×10^{-2}
1996	2.0×10^{-2}
1997	2.1×10^{-2}
1998	2.8×10^{-2}
1999	9.7×10^{-3}
2000	1.0×10^{-3}
2001	7.0×10^{-4}
2002	8.1×10^{-4}

Figure 2.8
Carbon-14 in liquid effluent from the Bruce-A nuclear generating station (1999-2002)
DRL from 1990 to 2001: 4.5×10^{2} TBq; DRL since 2001: 1.1×10^{1} TBq



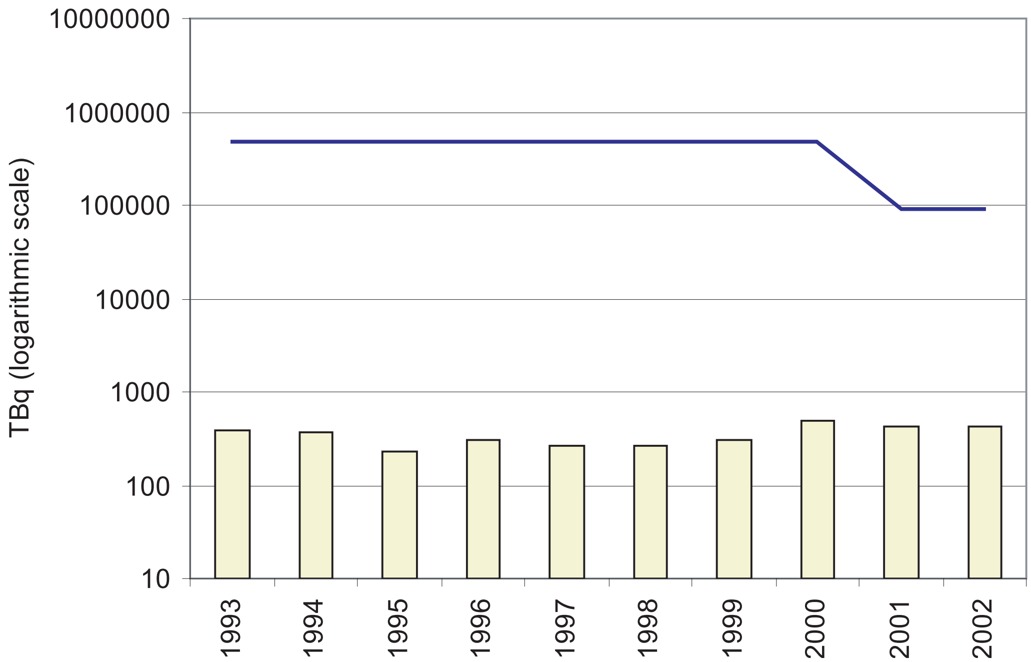
Year	TBq
1999	8.6×10^{-1}
2000	2.4×10^{-2}
2001	6.4×10^{-3}
2002	1.4×10^{-3}

The Bruce-B nuclear generating station consists of four nuclear reactors (units 5-8) which began operation in 1984. It is located in Ontario on the shore of Lake Huron near the town of Kincardine. The Bruce nuclear generating station is currently operated by Bruce Power.

Data for radioactive gaseous and liquid effluents released between 1993 and 2002 from the Bruce-B nuclear generating station are presented in the following histograms. The pertinent items in the gaseous effluents are tritium, in the form of tritium oxide (Figure 3.1), iodine 131 (Figure 3.2), noble gases (Figure 3.3) and radioactive particulates (Figure 3.4) and carbon-14 (Figure 3.5), while those in the liquid effluents are tritium, in the form of tritium oxide (Figure 3.6), gross beta gamma activity (Figure 3.7) and carbon-14 (Figure 3.7).

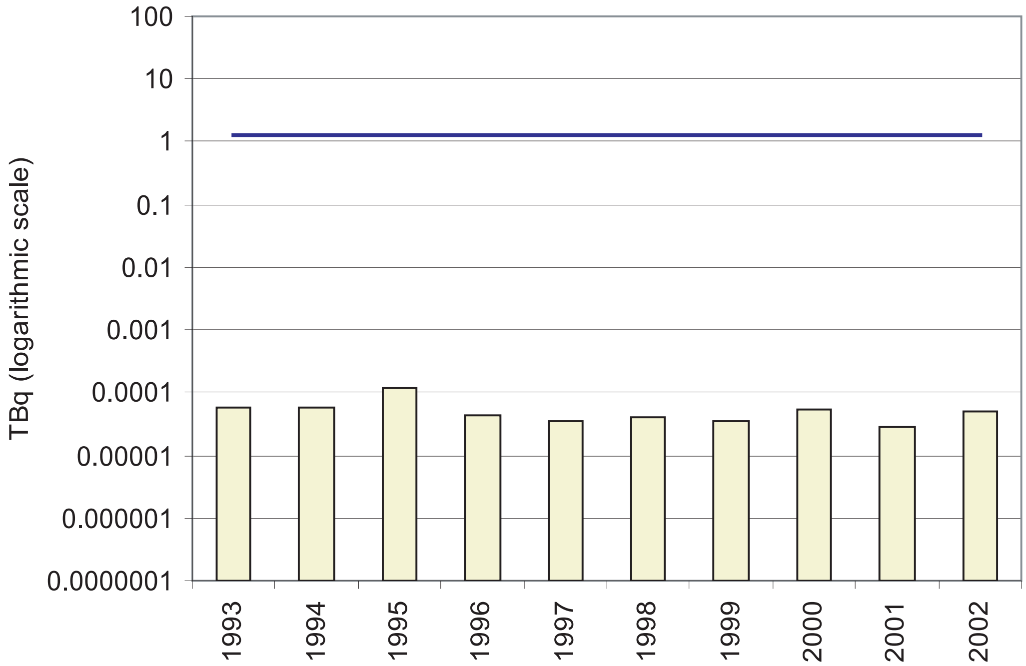
Bruce-B began reporting carbon-14 releases in liquid effluents in 1999, and began reporting carbon-14 releases in gaseous effluents starting in 2000.

Figure 3.1
Tritium oxide in gaseous effluent from the Bruce-B nuclear generating station (1993-2002)
DRL from1990 to 2001: 4.7×10^5 TBq; DRL since 2001: 9.3×10^4 TBq



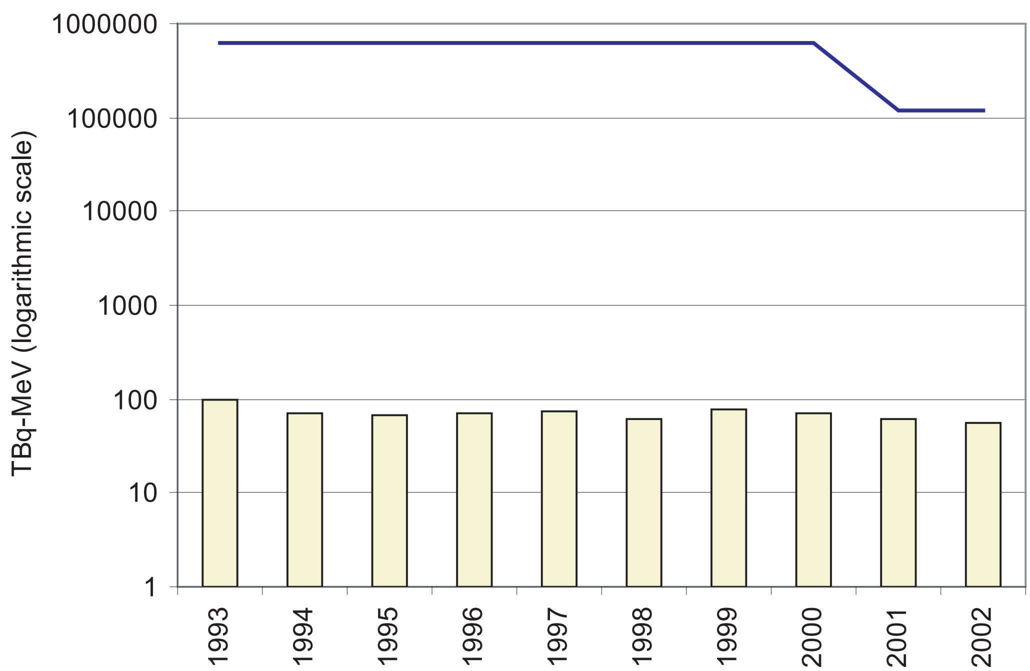
Year	TBq
1993	3.9×10^2
1994	3.7×10^2
1995	2.3×10^2
1996	3.1×10^2
1997	2.7×10^2
1998	2.6×10^2
1999	3.1×10^2
2000	4.9×10^2
2001	4.2×10^2
2002	4.3×10^2

Figure 3.2
Iodine-131 in gaseous effluent from the Bruce-B nuclear generating station (1993-2002)
DRL since 1990: 1.3 TBq



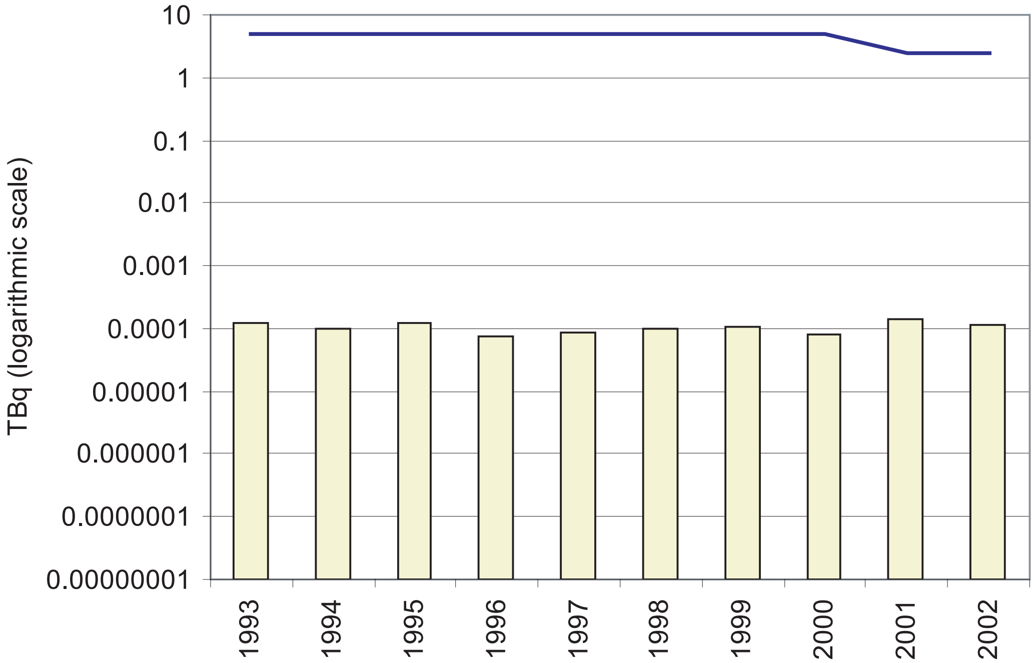
Year	TBq
1993	5.7×10^{-5}
1994	5.9×10^{-5}
1995	1.2×10^{-4}
1996	4.4×10^{-5}
1997	3.5×10^{-5}
1998	4.0×10^{-5}
1999	3.5×10^{-5}
2000	5.5×10^{-5}
2001	2.8×10^{-5}
2002	4.9×10^{-5}

Figure 3.3
Noble gas in effluent from the Bruce-B nuclear generating station (1993-2002)
DRL from 1990 to 2001: 6.1×10^5 TBq-MeV; DRL since 2001: 1.2×10^5 TBq-MeV



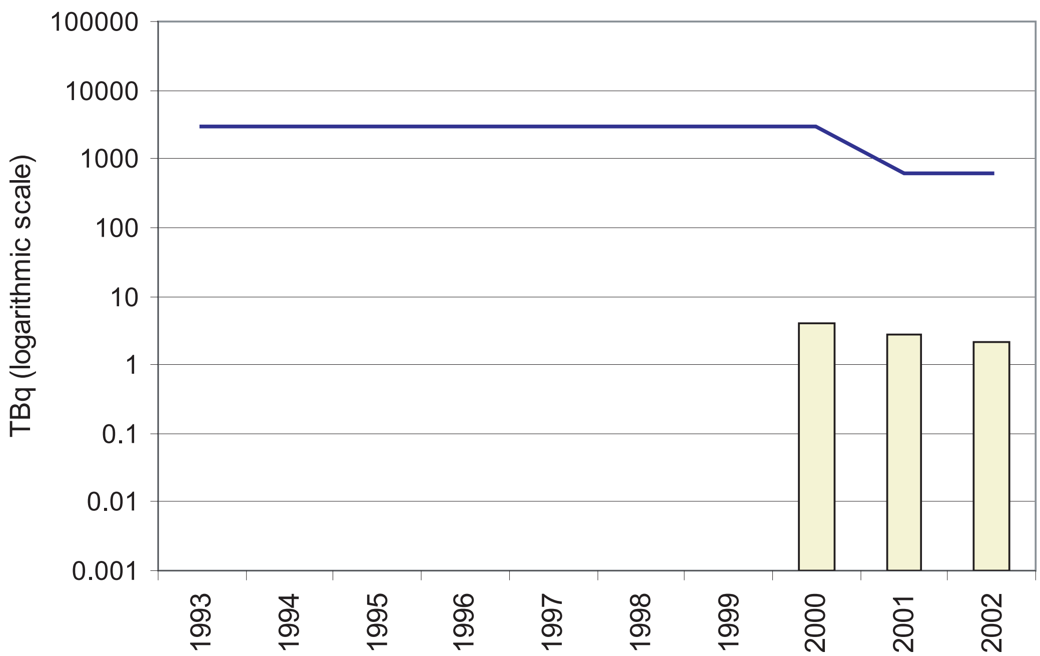
Year	TBq
1993	100
1994	70
1995	67
1996	70
1997	74
1998	62
1999	79
2000	72
2001	61
2002	56

Figure 3.4
Radioactive particulate in gaseous effluent from the Bruce-B nuclear generating station (1993-2002)
DRL from 1990 to 2001: 4.8 TBq; DRL since 2001: 2.5 TBq



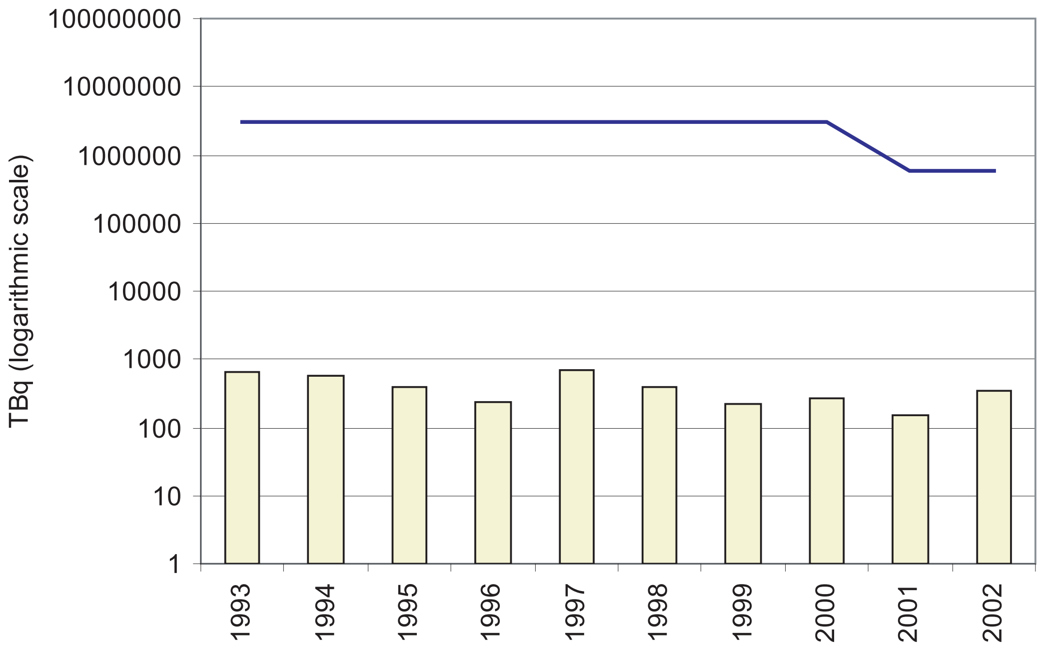
Year	TBq
1993	1.2×10^{-4}
1994	1.0×10^{-4}
1995	1.2×10^{-4}
1996	7.5×10^{-5}
1997	8.8×10^{-5}
1998	9.6×10^{-5}
1999	1.1×10^{-4}
2000	7.9×10^{-5}
2001	1.4×10^{-4}
2002	1.1×10^{-4}

Figure 3.5
C-14 in gaseous effluent from the Bruce-B nuclear generating station (2000-2002)
DRL from 1990 to 2001: 3.0×10^{3} TBq; DRL since 2001: 6.0×10^{2} TBq



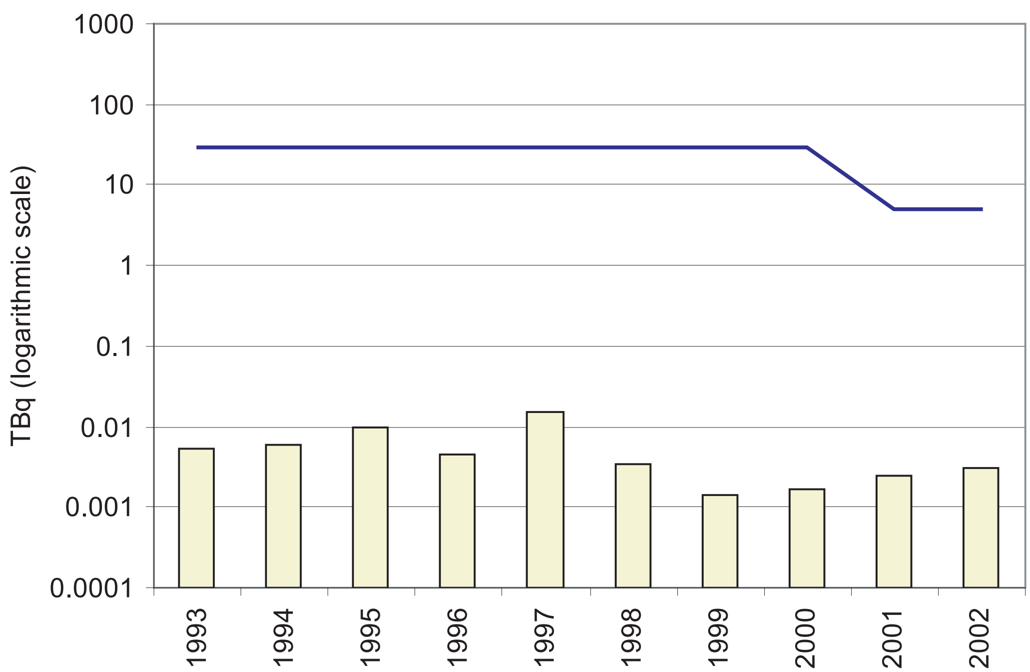
Year	TBq
2000	4.1
2001	2.7
2002	2.1

Figure 3.6
Tritium oxide in liquid effluent from the Bruce-B nuclear generating station (1993-2002)
DRL from 1990 to 2001: 3.0×10^6 DRL since 2001: 6.0×10^5 TBq



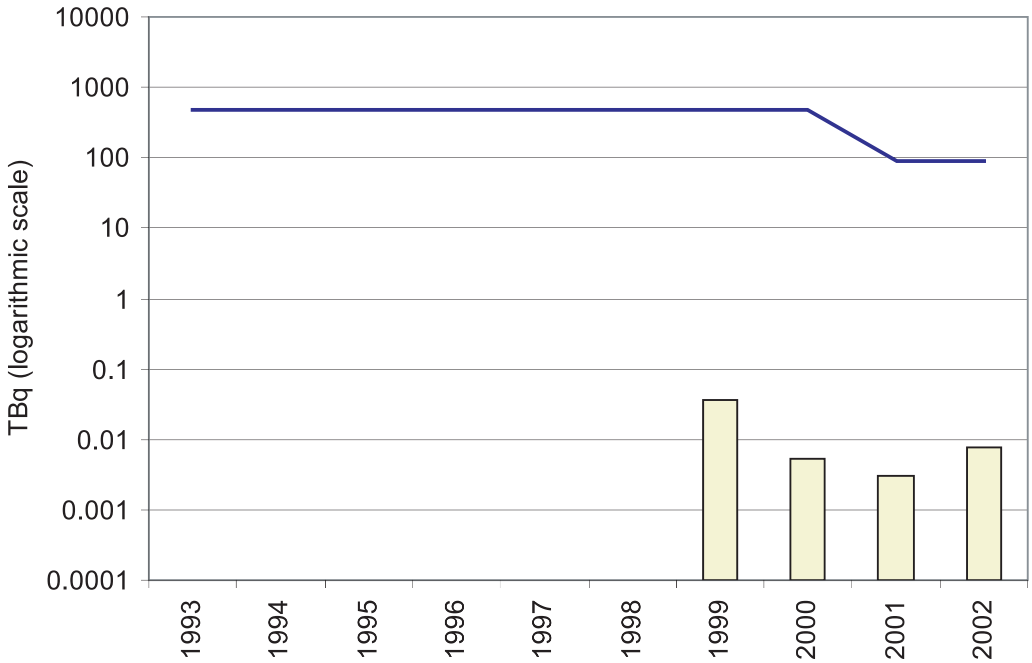
Year	TBq
1993	6.6×10^2
1994	5.6×10^2
1995	3.8×10^2
1996	2.3×10^2
1997	6.8×10^2
1998	3.8×10^2
1999	2.2×10^2
2000	2.7×10^2
2001	1.5×10^2
2002	3.5×10^2

Figure 3.7
Gross beta- gamma activity in liquid effluent from the Bruce-B nuclear generating station (1993-2002)
DRL from 1990 to 2001: 23 TBq; DRL since 2001: 4.9 TBq



Year	TBq
1993	5.2×10^{-3}
1994	5.9×10^{-3}
1995	9.6×10^{-3}
1996	4.5×10^{-3}
1997	1.5×10^{-2}
1998	3.4×10^{-3}
1999	1.4×10^{-3}
2000	1.7×10^{-3}
2001	2.4×10^{-3}
2002	3.0×10^{-3}

Figure 3.8
C-14 in liquid effluent from the Bruce-B nuclear generating station (1999-2002)
DRL from 1990 to 2001: 4.8 × 10^{2} TBq; DRL since 2001: 9.1 × 10^{1} TBq



Year	TBq
1999	3.6 x 10^{-2}
2000	5.2 x 10^{-3}
2001	3.1 x 10^{-3}
2002	7.1 x 10^{-3}

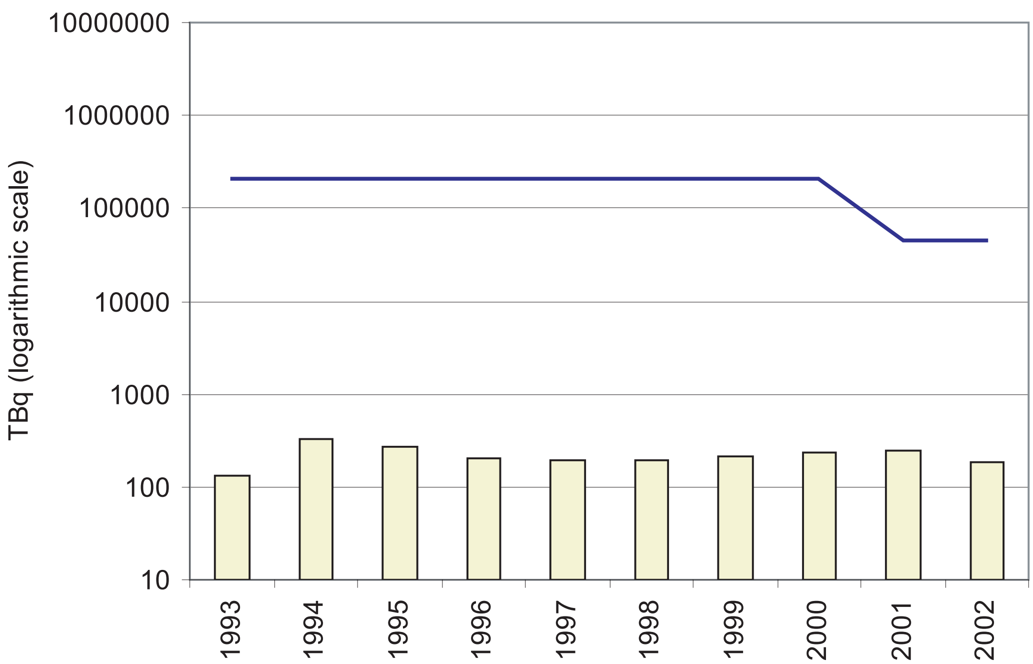
The Darlington Nuclear Generating Station consists of four nuclear reactors, the first of which started up in 1989, and a tritium removal facility which started operations in 1988. Both facilities are located in Ontario on the shore of Lake Ontario near the town of Bowmanville.

Data for radioactive gaseous and liquid effluents released between 1993 and 2002 from the Darlington nuclear generating station are presented in the following histograms. The pertinent items in the gaseous effluents are tritium, in the form of tritium oxide (Figure 4.1) and elemental tritium (Figure 4.2), iodine 131 (Figure 4.3), noble gases (Figure 4.4), radioactive particulates (Figure 4.5) and carbon-14 (Figure 4.6); while those in the liquid effluents are tritium, in the form of tritium oxide (Figure 4.7), gross beta gamma activity (Figure 4.8) and carbon-14 (Figure 4.9).

Gaseous effluent releases of tritium in elemental form occur due to the operation of the tritium removal facility.

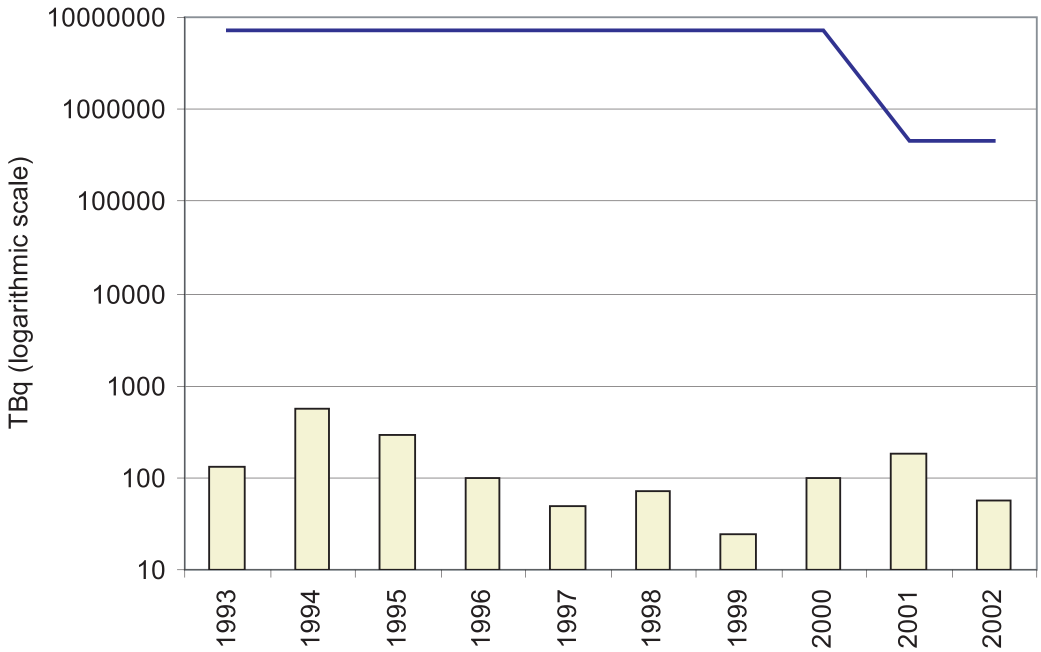
Darlington began reporting carbon-14 releases in gaseous and liquid effluents in 1999.

Figure 4.1
Tritium oxide in gaseous effluent from the Darlington nuclear generating station (1993-2002)
DRL from 1989 to 2001: 2.1×10^5 TBq; DRL since 2001: 4.6×10^4 TBq



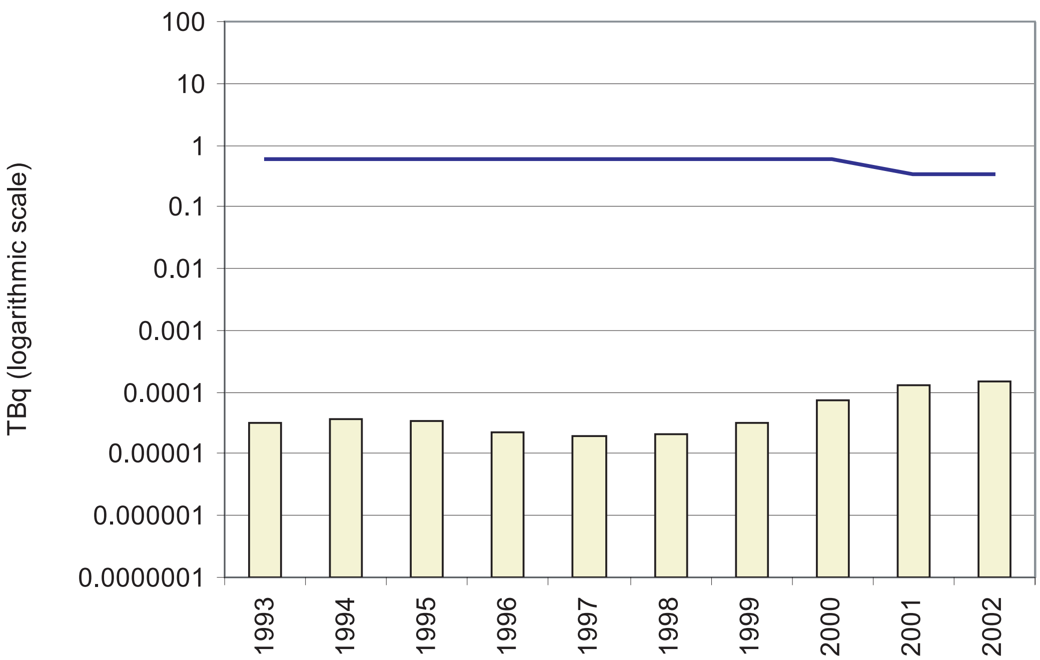
Year	TBq
1993	1.3×10^2
1994	3.3×10^2
1995	2.7×10^2
1996	2.0×10^2
1997	1.9×10^2
1998	1.9×10^2
1999	2.2×10^2
2000	2.3×10^2
2001	2.4×10^2
2002	1.9×10^2

Figure 4.2
Elemental tritium in gaseous effluent from the Darlington nuclear generating station (1993-2002)
DRL from 1993 to 2001: 7.3×10^6 TBq; DRL since 2001: 4.6×10^5 TBq



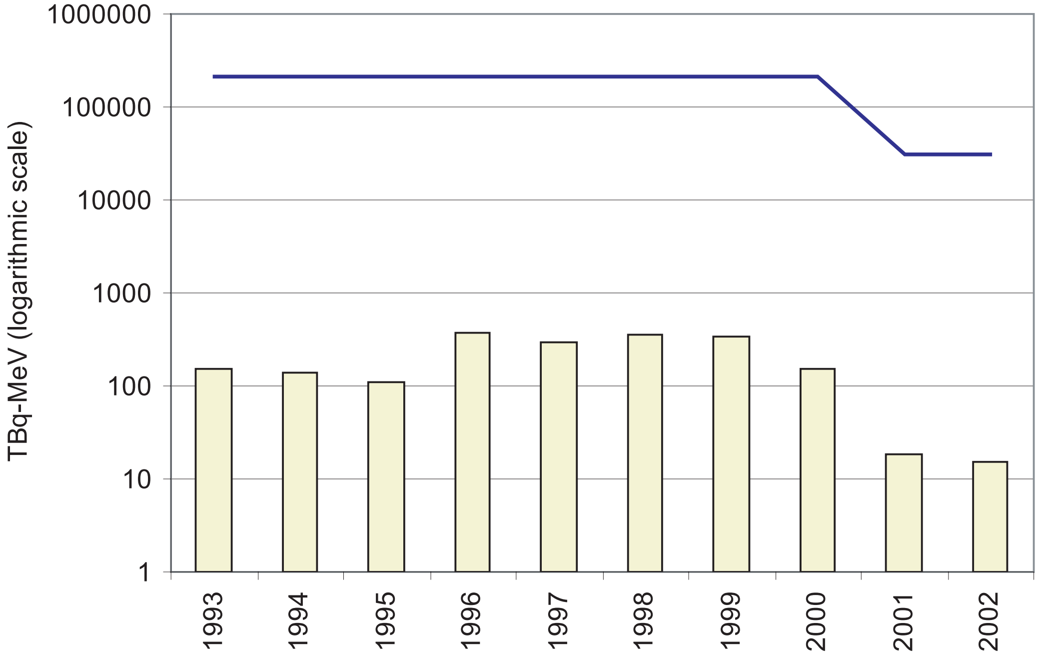
Year	TBq
1993	1.3×10^2
1994	5.6×10^2
1995	2.9×10^2
1996	1.0×10^2
1997	5.0×10^1
1998	7.0×10^1
1999	2.4×10^1
2000	1.0×10^2
2001	1.8×10^2
2002	5.6×10^1

Figure 4.3
Iodine-131 in gaseous effluent from the Darlington nuclear generating station (1993-2002)
DRL from 1989 to 2001: 0.60 TBq; DRL since 2001: 0.33 TBq



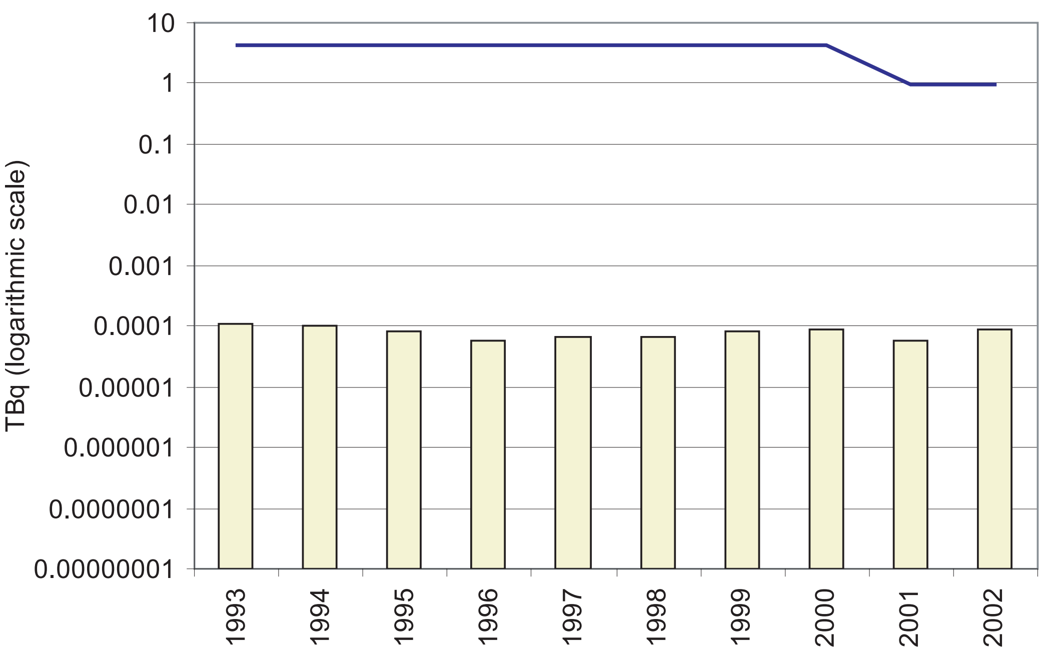
Year	TBq
1993	3.1×10^{-5}
1994	3.6×10^{-5}
1995	3.4×10^{-5}
1996	2.2×10^{-5}
1997	2.0×10^{-5}
1998	2.1×10^{-5}
1999	3.2×10^{-5}
2000	7.5×10^{-5}
2001	1.3×10^{-4}
2002	1.5×10^{-4}

Figure 4.4
Noble gas in effluent from the Darlington nuclear generating station (1993-2002)
DRL from 1989 to 2001: 2.1×10^5 TBq-MeV; DRL since 2001: 3.1×10^4 TBq-MeV



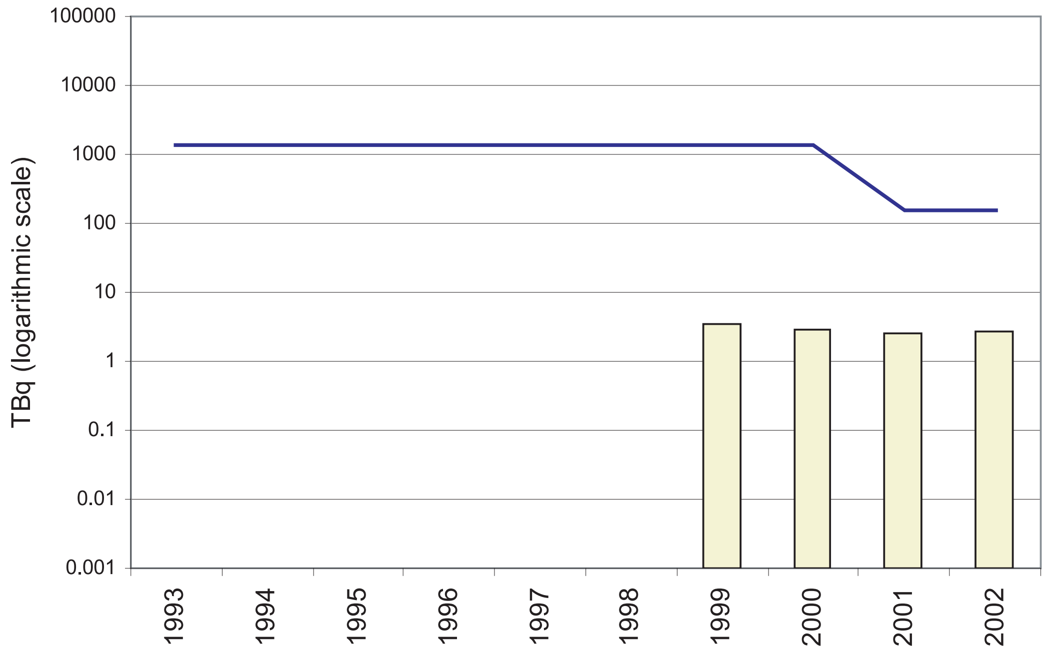
Year	TBq
1993	1.5×10^2
1994	1.4×10^2
1995	1.1×10^2
1996	3.8×10^2
1997	3.0×10^2
1998	3.5×10^2
1999	3.4×10^2
2000	1.5×10^2
2001	1.8×10^1
2002	1.5×10^1

Figure 4.5
Radioactive particulate in gaseous effluent from the Darlington nuclear generating station (1993-2002)
DRL from 1989 to 2001: 4.4 TBq; DRL since 2001: 0.94 TBq



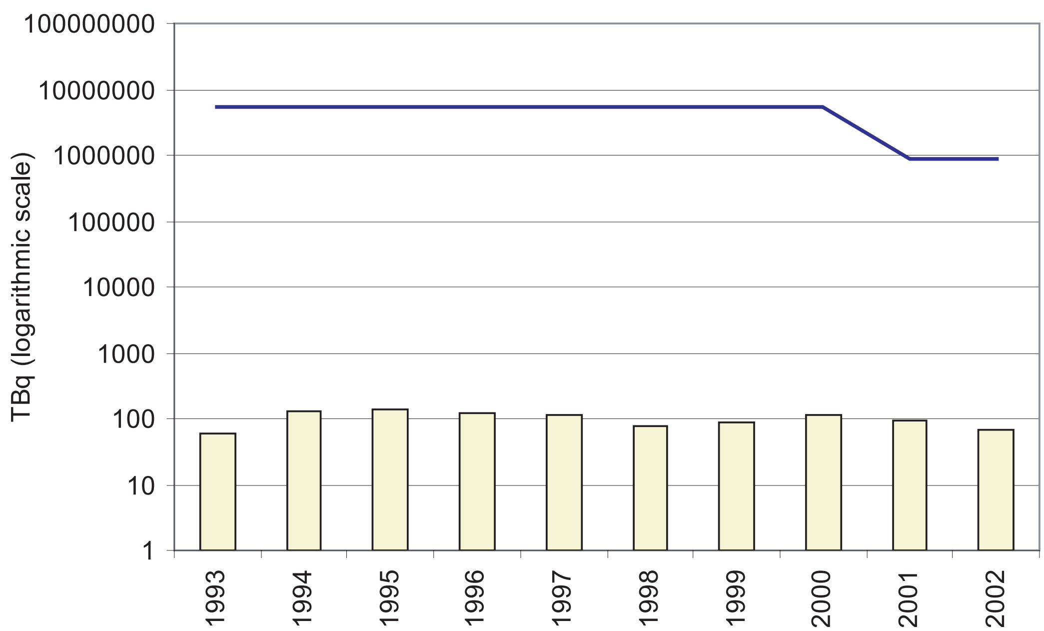
Year	TBq
1993	1.1×10^{-4}
1994	1.0×10^{-4}
1995	8.5×10^{-5}
1996	5.8×10^{-5}
1997	6.5×10^{-5}
1998	6.5×10^{-5}
1999	8.2×10^{-5}
2000	8.6×10^{-5}
2001	5.6×10^{-5}
2002	8.7×10^{-5}

Figure 4.6
Carbon-14 in gaseous effluent from the Darlington nuclear generating station (1999-2002)
DRL from 1989 to 2001: 1.4×10^3 TBq; DRL since 2001: 1.5×10^2 TBq



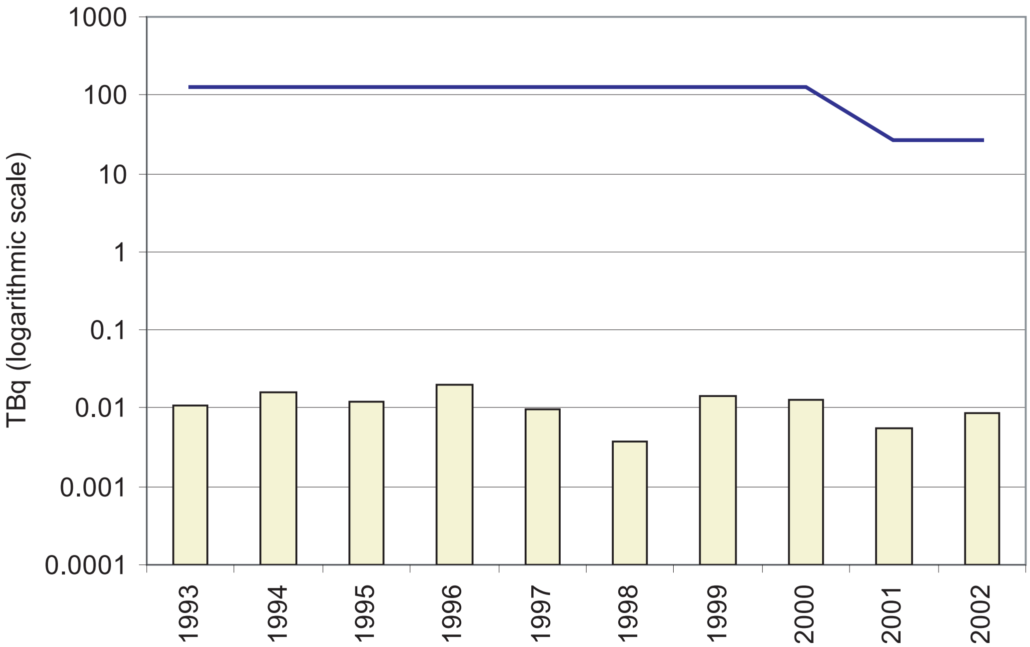
Year	TBq
1999	3.5
2000	2.8
2001	2.6
2002	2.8

Figure 4.7
Tritium oxide in liquid effluent from the Darlington nuclear generating station (1993-2002)
DRL from 1989 to 2001: 5.3×10^6 TBq; DRL since 2001: 8.8×10^5 TBq



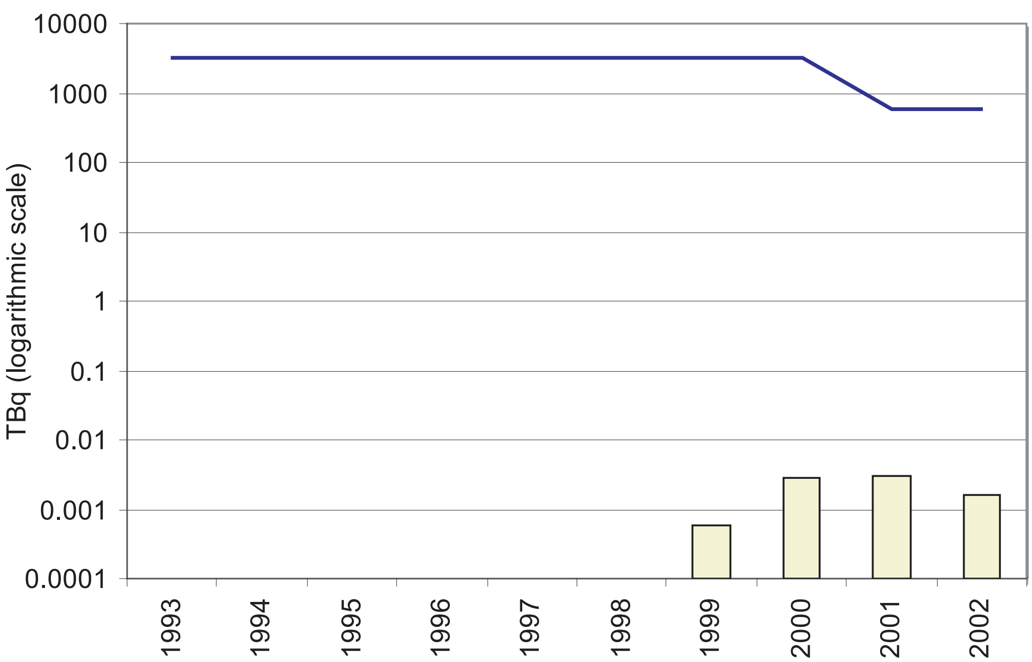
Year	TBq
1993	5.8×10^1
1994	1.3×10^2
1995	1.4×10^2
1996	1.2×10^2
1997	1.1×10^2
1998	7.5×10^1
1999	8.9×10^1
2000	1.1×10^2
2001	9.4×10^1
2002	6.9×10^1

Figure 4.8
Gross beta-gamma activity in liquid effluent from the Darlington nuclear generating station (1993-2002)
DRL from 1989 to 2001: 130 TBq; DRL since 2001: 26 TBq



Year	TBq
1993	1.1×10^{-2}
1994	1.6×10^{-2}
1995	1.2×10^{-2}
1996	2.0×10^{-2}
1997	9.8×10^{-3}
1998	3.8×10^{-3}
1999	1.4×10^{-2}
2000	1.3×10^{-2}
2001	5.6×10^{-3}
2002	8.5×10^{-3}

Figure 4.9
Carbon-14 in liquid effluent from the Darlington nuclear generating station (1999-2002)
DRL from 1989 to 2001: 3.2×10^{3} TBq; DRL since 2001: 6.0×10^{2} TBq



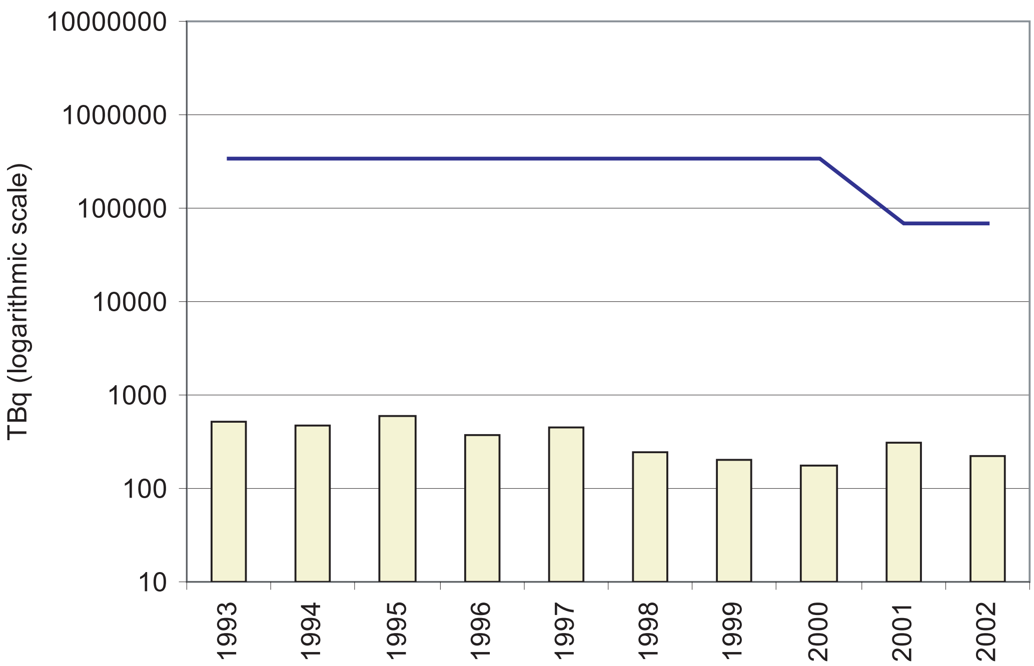
Year	TBq
1999	5.7×10^{-4}
2000	2.8×10^{-3}
2001	3.0×10^{-3}
2002	1.7×10^{-3}

The Pickering-A nuclear generating station consists of four nuclear reactors (units 1-4) which began operation in 1971. It is located in Ontario on the shore of Lake Ontario near the town of Pickering.

In 1997 as part of its extensive recovery program, Ontario Hydro (now Ontario Power Generation) temporarily shut down all Pickering-A reactors. Since then, Pickering-A reactors were maintained in a guaranteed shut-down state. While this report was being compiled, Unit 4 was in the process of being returned to service.

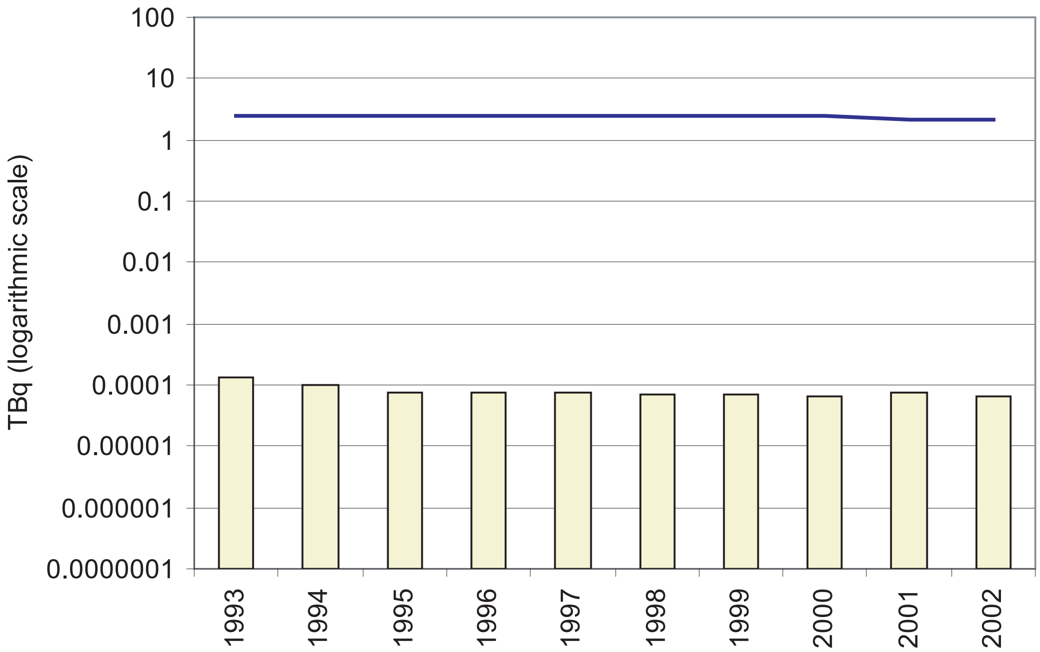
Data for radioactive gaseous and liquid effluents released between 1993 and 2002 from the Pickering-A nuclear generating station are presented in the following histograms. The pertinent items in the gaseous effluents are tritium, in the form of tritium oxide (Figure 5.1), iodine 131 (Figure 5.2), noble gases (Figure 5.3), radioactive particulates (Figure 5.4) and carbon 14 (Figure 5.5); while those the liquid effluents are tritium, in the form of tritium oxide (Figure 5.6) and gross beta gamma activity (Figure 5.7). Since 1999, carbon-14 releases in liquid effluent from Pickering A have been reported in the carbon-14 liquid release data for Pickering B.

Figure 5.1
Tritium oxide in gaseous effluent from the Pickering-A nuclear generating station (1993-2002)
DRL from 1992 to 2001: 3.4×10^5 TBq; DRL since 2001: 7.0×10^4 TBq



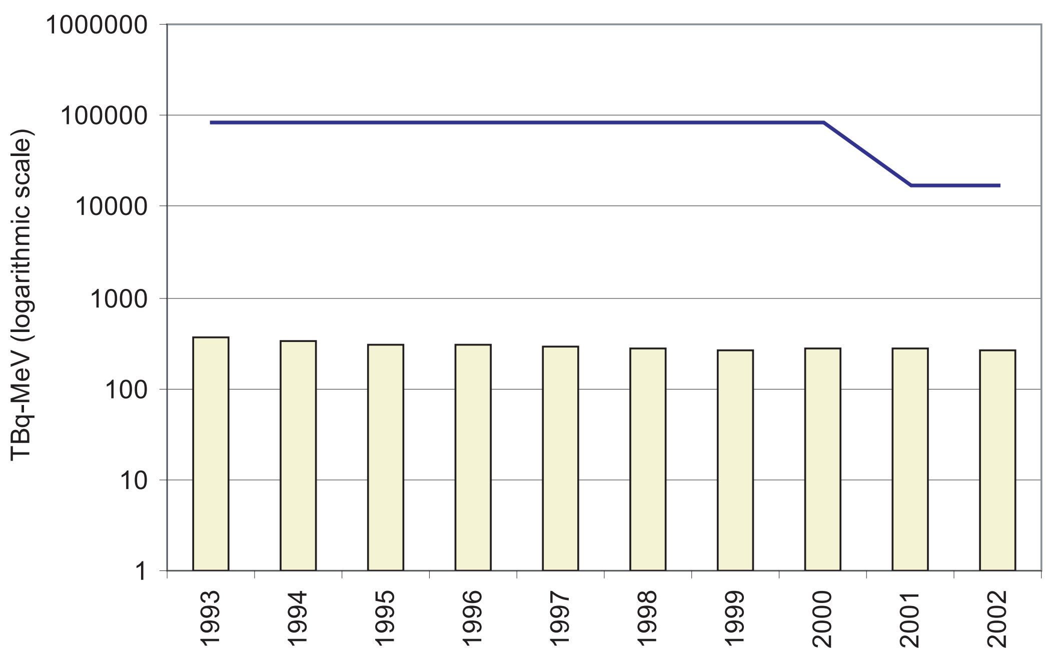
Year	TBq
1993	5.2×10^2
1994	4.8×10^2
1995	5.9×10^2
1996	3.7×10^2
1997	4.4×10^2
1998	2.5×10^2
1999	2.0×10^2
2000	1.8×10^2
2001	3.1×10^2
2002	2.3×10^2

Figure 5.2
Iodine-131 in gaseous effluent from the Pickering-A nuclear generating station (1993-2002)
DRL since 1992: 2.4 TBq; DRL since 2001: 2.2 TBq



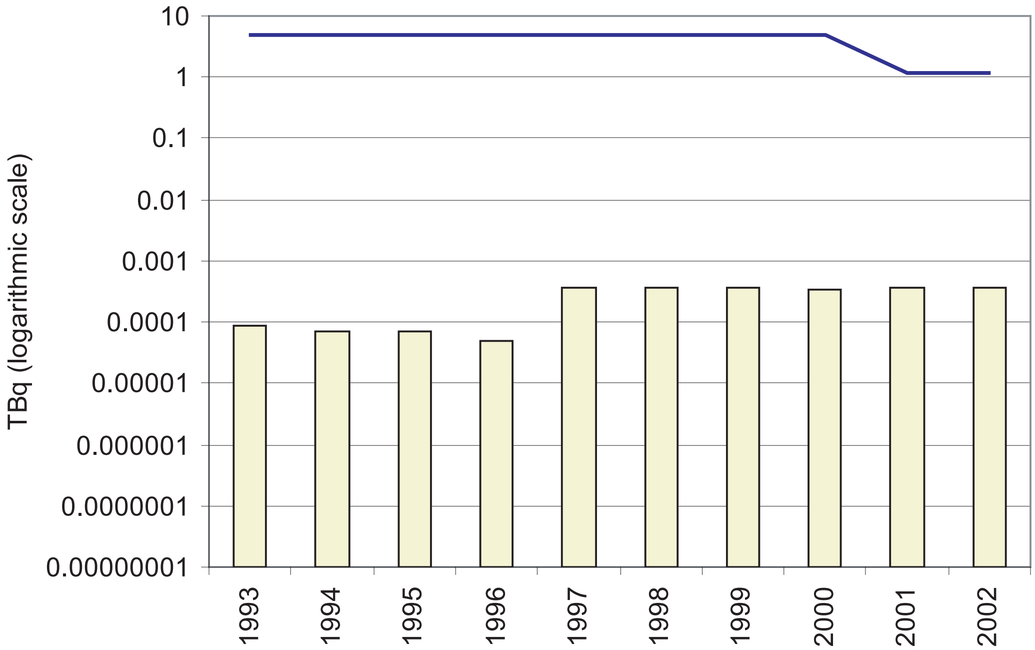
Year	TBq
1993	1.3×10^{-4}
1994	1.0×10^{-4}
1995	7.4×10^{-5}
1996	7.3×10^{-5}
1997	7.4×10^{-5}
1998	7.0×10^{-5}
1999	7.2×10^{-5}
2000	6.7×10^{-5}
2001	7.8×10^{-5}
2002	6.7×10^{-5}

Figure 5.3
Noble gas in effluent from the Pickering-A nuclear generating station (1993-2002)
DRL from 1992 to 2001: 8.3×10^{4} TBq-MeV; DRL since 2001: 1.7×10^{4} TBq-MeV



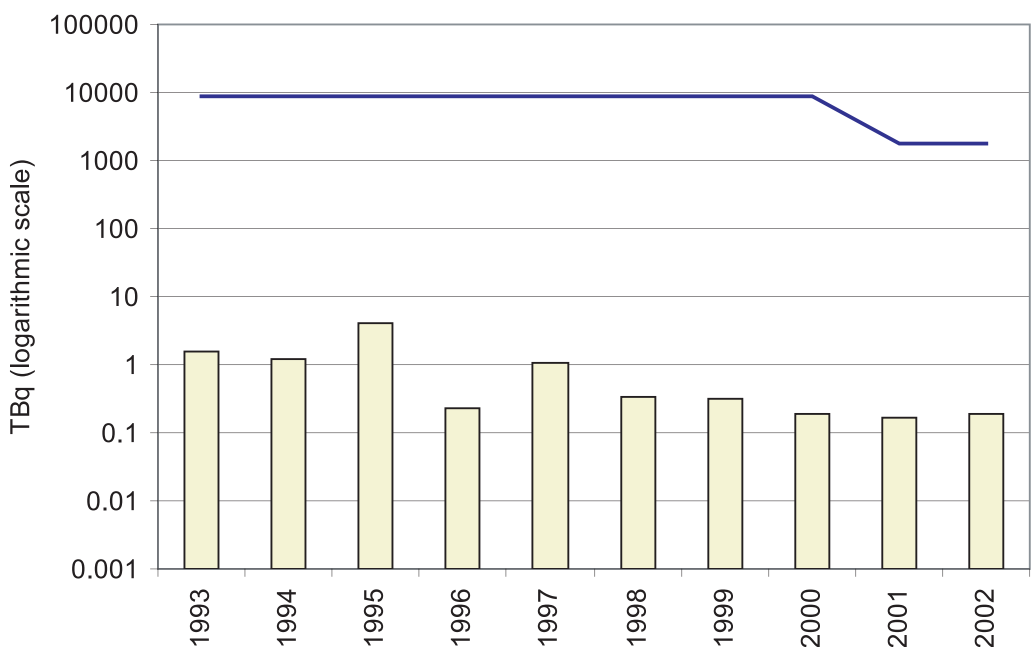
Year	TBq
1993	3.7×10^{2}
1994	3.4×10^{2}
1995	3.1×10^{2}
1996	3.1×10^{2}
1997	2.9×10^{2}
1998	2.7×10^{2}
1999	2.6×10^{2}
2000	2.7×10^{2}
2001	2.8×10^{2}
2002	2.7×10^{2}

Figure 5.4
Radioactive particulates in gaseous effluent from the Pickering-A nuclear generating station (1993-2002)
DRL from 1992 to 2001: 5.0 TBq; DRL since 2001: 1.2 TBq



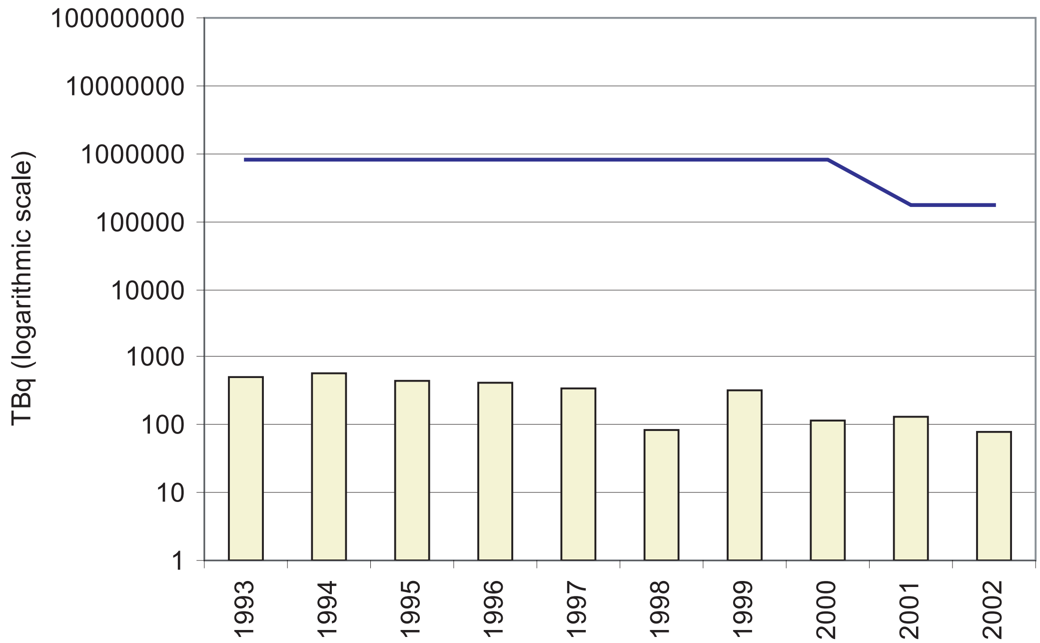
Year	TBq
1993	8.5×10^{-5}
1994	7.0×10^{-5}
1995	7.0×10^{-5}
1996	5.1×10^{-5}
1997	3.6×10^{-4}
1998	3.6×10^{-4}
1999	3.6×10^{-4}
2000	3.5×10^{-4}
2001	3.5×10^{-4}
2002	3.6×10^{-4}

Figure 5.5
C-14 in gaseous effluent from the Pickering-A nuclear generating station (1993-2002)
DRL from 1992 to 2001: 8.8×10^3 TBq; DRL since 2001: 1.8×10^3 TBq



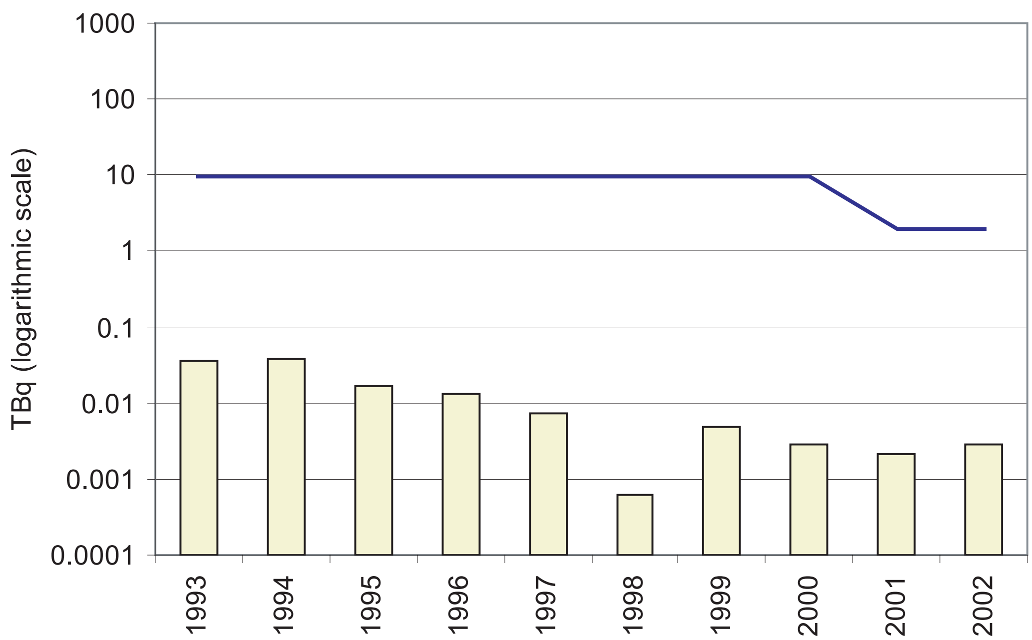
Year	TBq
1993	1.6
1994	1.2
1995	4.1
1996	0.23
1997	1.1
1998	0.33
1999	0.32
2000	0.19
2001	0.16
2002	0.19

Figure 5.6
Tritium oxide in liquid effluent from the Pickering-A nuclear generating station (1993-2002)
DRL from 1992 to 2001: 8.3×10^5 TBq; DRL since 2001: 1.7×10^5 TBq



Year	TBq
1993	5.2×10^2
1994	5.6×10^2
1995	4.4×10^2
1996	4.3×10^2
1997	3.5×10^2
1998	8.5×10^1
1999	3.2×10^2
2000	1.1×10^2
2001	1.3×10^2
2002	7.7×10^1

Figure 5.7
Gross beta-gamma activity in liquid effluent from the Pickering-A nuclear generating station (1993-2002)
DRL from 1992 to 2001: 9.7 TBq; DRL since 2001: 2.0 TBq



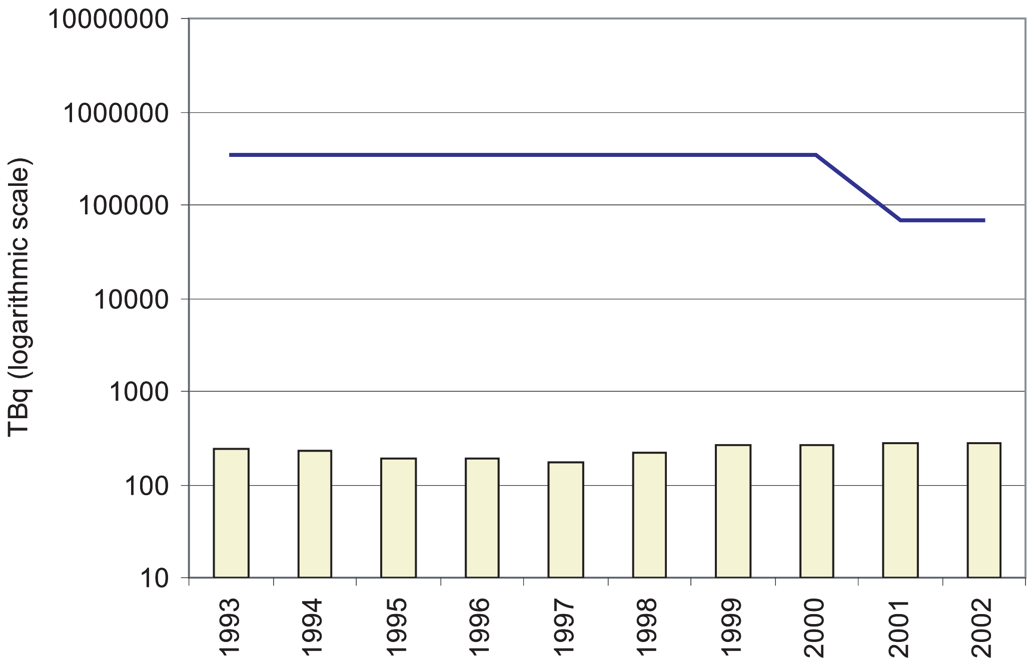
Year	TBq
1993	3.5×10^{-2}
1994	3.7×10^{-2}
1995	1.7×10^{-2}
1996	1.3×10^{-2}
1997	7.3×10^{-3}
1998	6.2×10^{-4}
1999	4.8×10^{-3}
2000	2.9×10^{-3}
2001	2.1×10^{-3}
2002	2.9×10^{-3}

The Pickering-B nuclear generating station consists of four nuclear reactors (units 5-8) which began operation in 1982. It is located in Ontario on the shore of Lake Ontario near the town of Pickering.

Data for radioactive gaseous and liquid effluents released between 1993 and 2002 from the Pickering-B nuclear generating station are presented in the following histograms. The pertinent items in the gaseous effluents are tritium, in the form of tritium oxide (Figure 6.1), iodine 131 (Figure 6.2), noble gases (Figure 6.3), radioactive particulates (Figure 6.4) and carbon-14 (Figure 6.5); while those in the liquid effluents are tritium, in the form of tritium oxide (Figure 6.6), gross beta gamma activity (Figure 6.7) and carbon-14 (Figure 6.8).

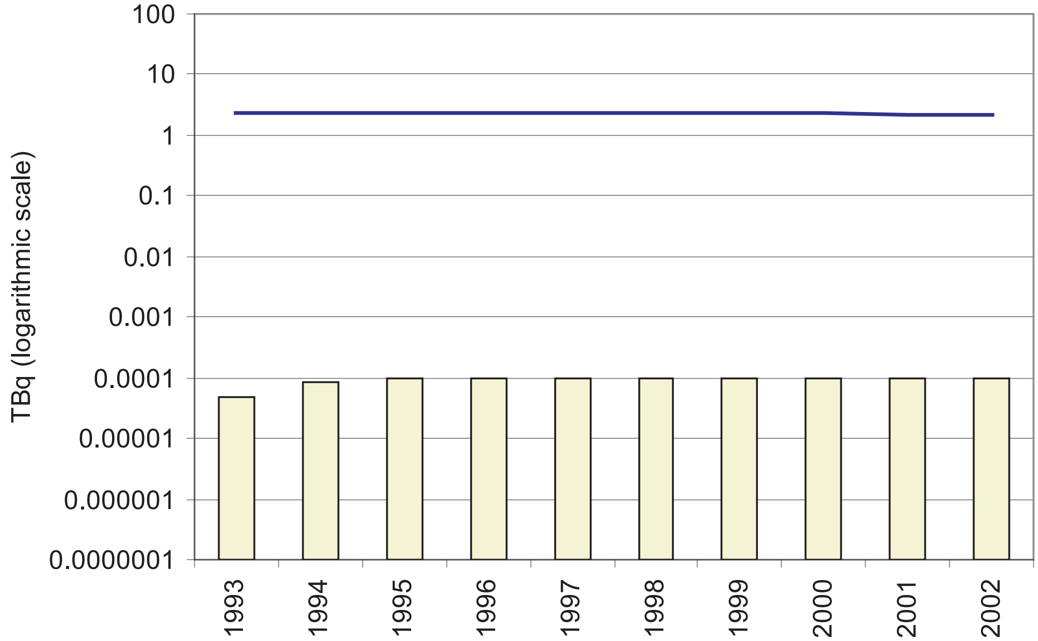
Pickering-B began reporting carbon-14 in liquid releases in 1999 and began reporting carbon-14 in gaseous releases in 2000.

Figure 6.1
Tritium oxide in gaseous effluent from the Pickering-B nuclear generating station (1993-2002)
DRL from 1992 to 2001: 3.4×10^5 TBq; DRL since 2001: 7.0×10^4 TBq



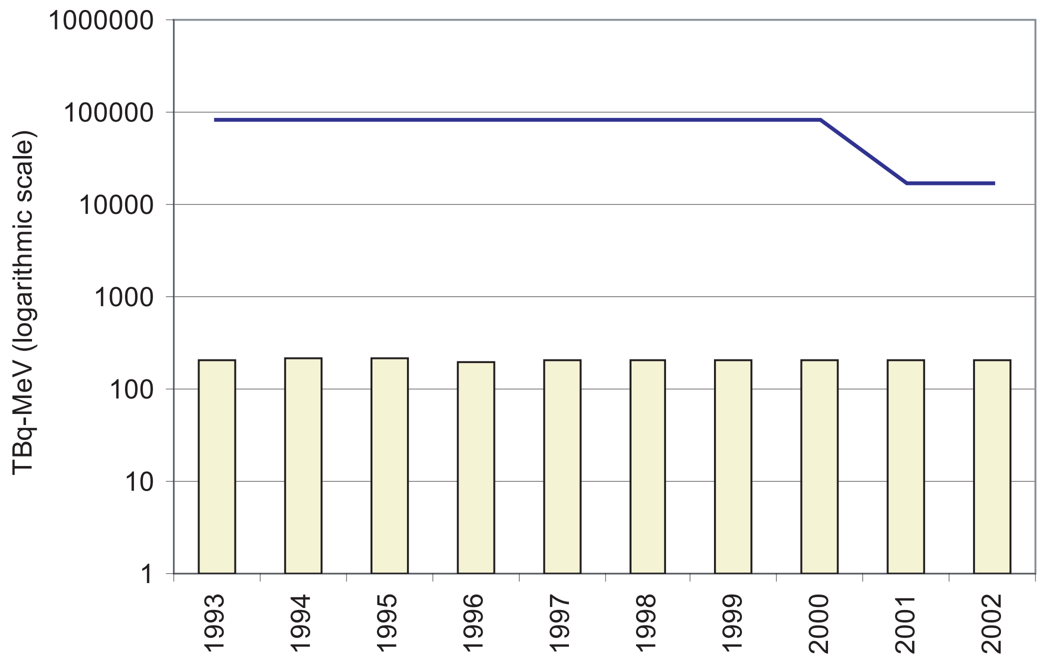
Year	TBq
1993	2.4×10^2
1994	2.3×10^2
1995	1.9×10^2
1996	1.9×10^2
1997	1.7×10^2
1998	2.2×10^2
1999	2.7×10^2
2000	2.7×10^2
2001	2.7×10^2
2002	2.8×10^2

Figure 6.2
Iodine-131 in gaseous effluent from the Pickering-B nuclear generating station (1993-2002)
DRL from 1992 to 2001: 2.4 TBq; DRL since 2001: 2.2 TBq



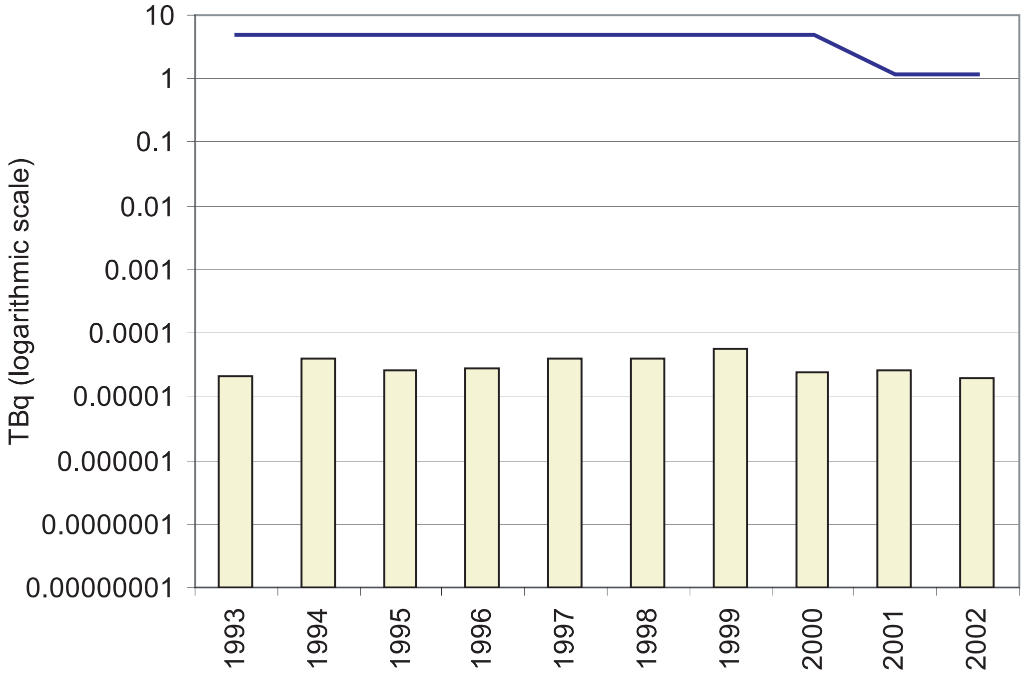
Year	TBq
1993	4.8×10^{-5}
1994	8.5×10^{-5}
1995	1.0×10^{-4}
1996	9.8×10^{-5}
1997	9.9×10^{-5}
1998	9.7×10^{-5}
1999	9.6×10^{-5}
2000	9.8×10^{-5}
2001	1.0×10^{-4}
2002	9.8×10^{-5}

Figure 6.3
Noble gas in effluent from the Pickering-B nuclear generating station (1993-2002)
DRL from 1992 to 2001: 8.3×10^4 TBq-MeV; DRL since 2001: 1.7×10^4 TBq-MeV



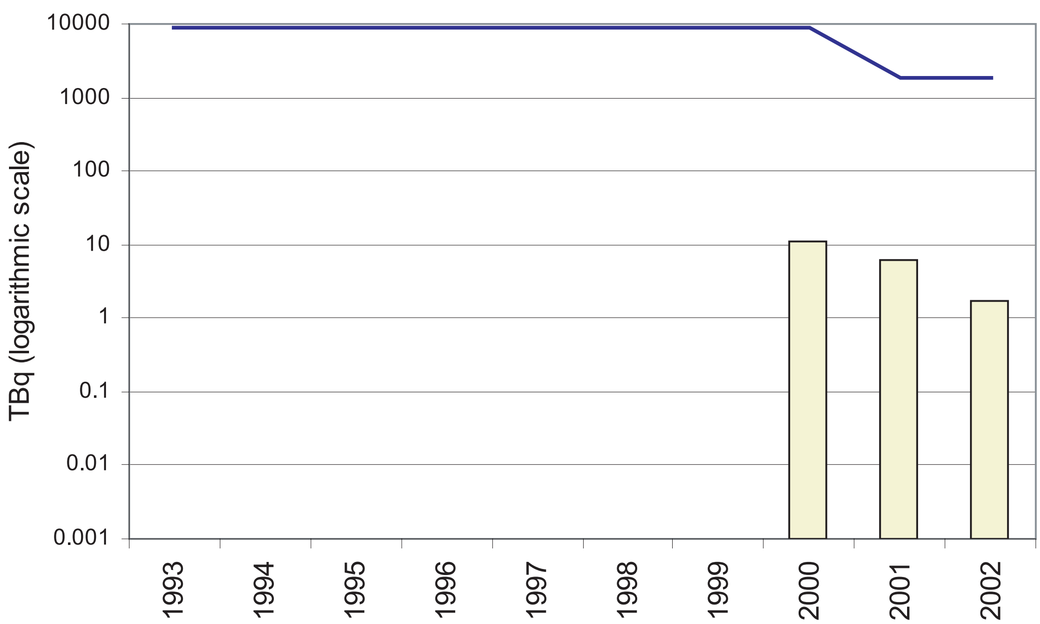
Year	TBq
1993	2.1×10^{2}
1994	2.2×10^{2}
1995	2.2×10^{2}
1996	2.0×10^{2}
1997	2.1×10^{2}
1998	2.2×10^{2}
1999	2.1×10^{2}
2000	2.1×10^{2}
2001	2.1×10^{2}
2002	2.0×10^{2}

Figure 6.4
Radioactive particulate in gaseous effluent from the Pickering-B nuclear generating station (1993-2002)
DRL from 1992 to 2001: 5.0 TBq; DRL since 2001: 1.2 TBq



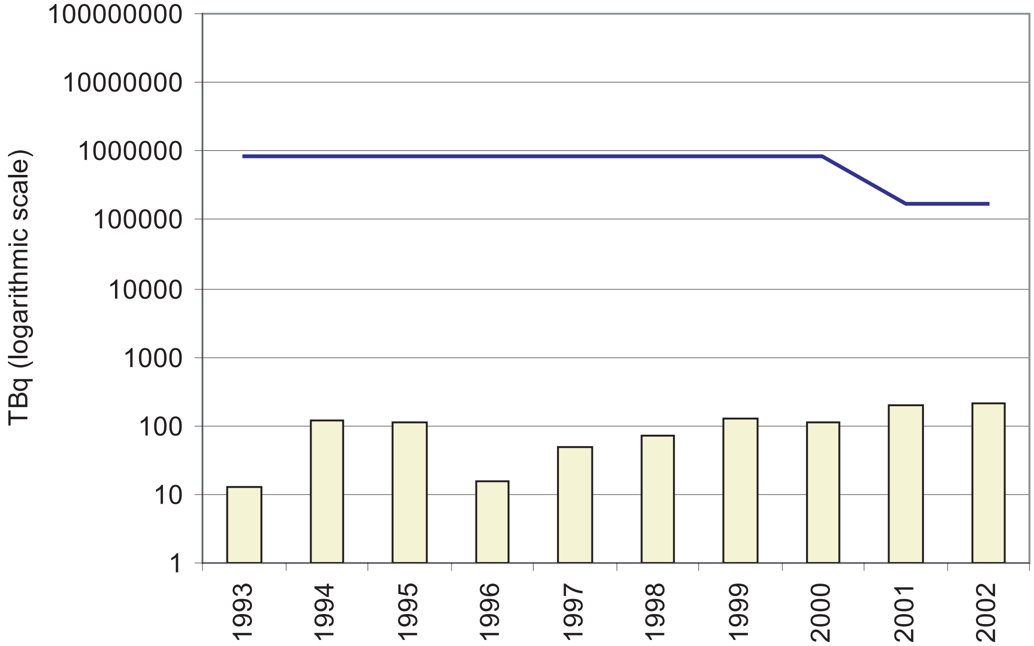
Year	TBq
1993	2.1×10^{-5}
1994	4.1×10^{-5}
1995	2.6×10^{-5}
1996	2.7×10^{-5}
1997	3.9×10^{-5}
1998	4.0×10^{-5}
1999	5.7×10^{-5}
2000	2.4×10^{-5}
2001	2.6×10^{-5}
2002	2.0×10^{-5}

Figure 6.5
C-14 in gaseous effluent from the Pickering-B nuclear generating station (2000-2002)
DRL from 1992-2001: 8.8×10^3 TBq; DRL since 2001: 1.8×10^3 TBq



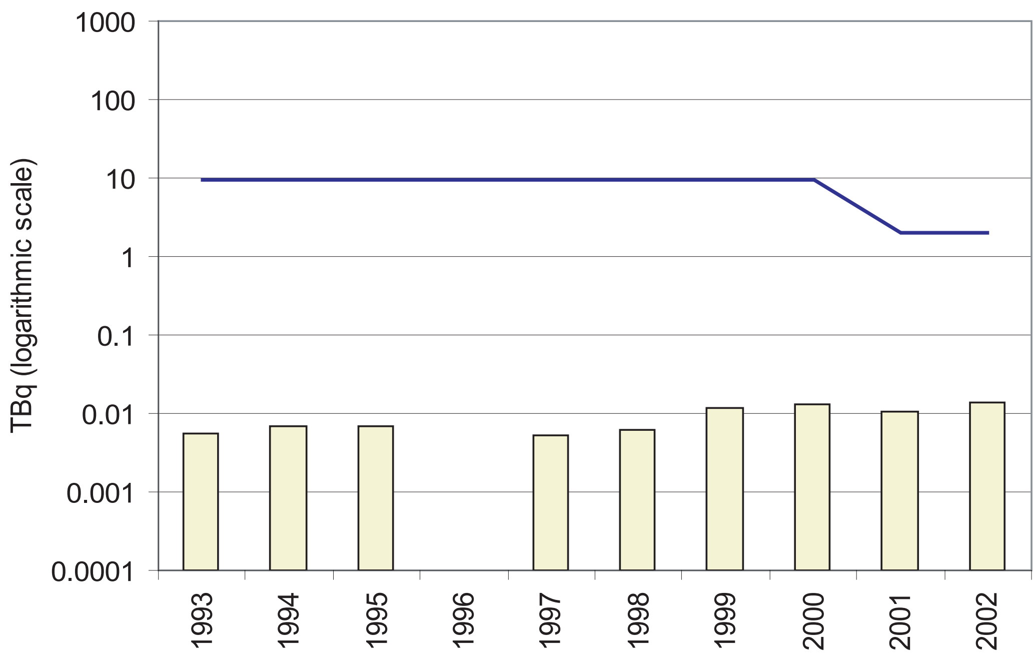
Year	TBq
2000	11
2001	6.3
2002	1.8

Figure 6.6
Tritium oxide in liquid effluent from the Pickering-B nuclear generating station (1993-2002)
DRL from 1992 to 2001: 8.3×10^5 TBq; DRL since 2001: 1.7×10^5 TBq



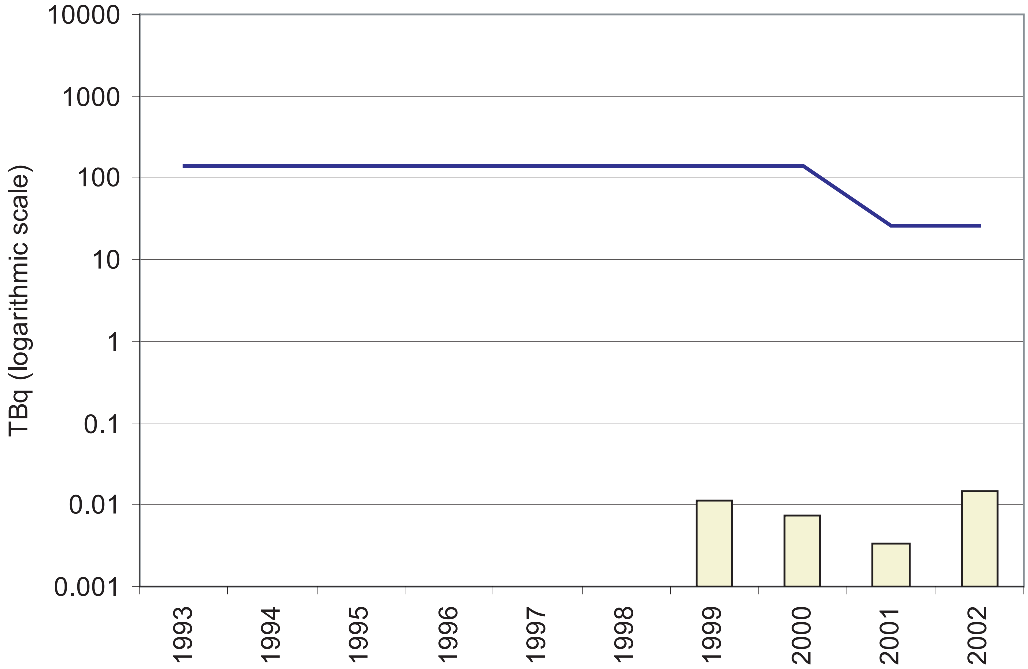
Year	TBq
1993	1.3×10^1
1994	1.2×10^2
1995	1.1×10^2
1996	1.6×10^1
1997	5.0×10^1
1998	7.1×10^1
1999	1.3×10^2
2000	1.1×10^2
2001	2.0×10^2
2002	2.1×10^2

Figure 6.7
Gross beta-gamma activity in liquid effluent from the Pickering-B nuclear generating station (1993-2002)
DRL from 1992 to 2001: 9.7 TBq; DRL since 2001: 2.0 TBq



Year	TBq
1993	5.6×10^{-3}
1994	6.7×10^{-3}
1995	6.7×10^{-3}
1996	ND
1997	5.2×10^{-3}
1998	6.3×10^{-3}
1999	1.2×10^{-2}
2000	1.3×10^{-2}
2001	1.1×10^{-2}
2002	1.4×10^{-2}

Figure 6.8
C-14 in liquid effluent from the Pickering-B nuclear generating station (1993-2002)
DRL from 1992 to 2001: 1.4×10^2 TBq; DRL since 2001: 2.6×10^1 TBq



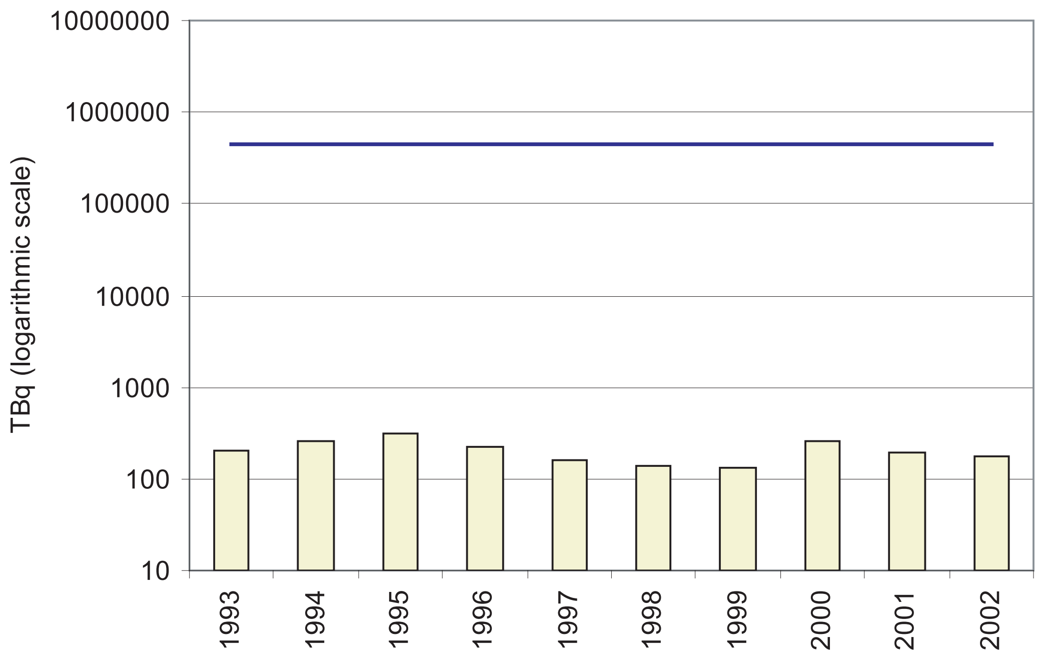
Year	TBq
1999	1.1×10^{-2}
2000	7.3×10^{-3}
2001	3.3×10^{-3}
2002	1.5×10^{-2}

The Gentilly-2 nuclear generating station consists of one nuclear reactor which began operation in 1982. It is located in Québec on the Saint Lawrence River near the city of Trois Rivières.

Data for radioactive gaseous and liquid effluents released between 1993 and 2002 from the Gentilly-2 nuclear generating station are presented in the following histograms. The pertinent items in the gaseous effluents are tritium, in the form of tritium oxide (Figure 7.1), iodine 131 (Figure 7.2), noble gases (Figure 7.3), radioactive particulates (Figure 7.4) and carbon 14 (Figure 7.5); while those in the liquid effluents are tritium, in the form of tritium oxide (Figure 7.6), gross beta gamma activity (Figure 7.7) and carbon 14 (Figure 7.8).

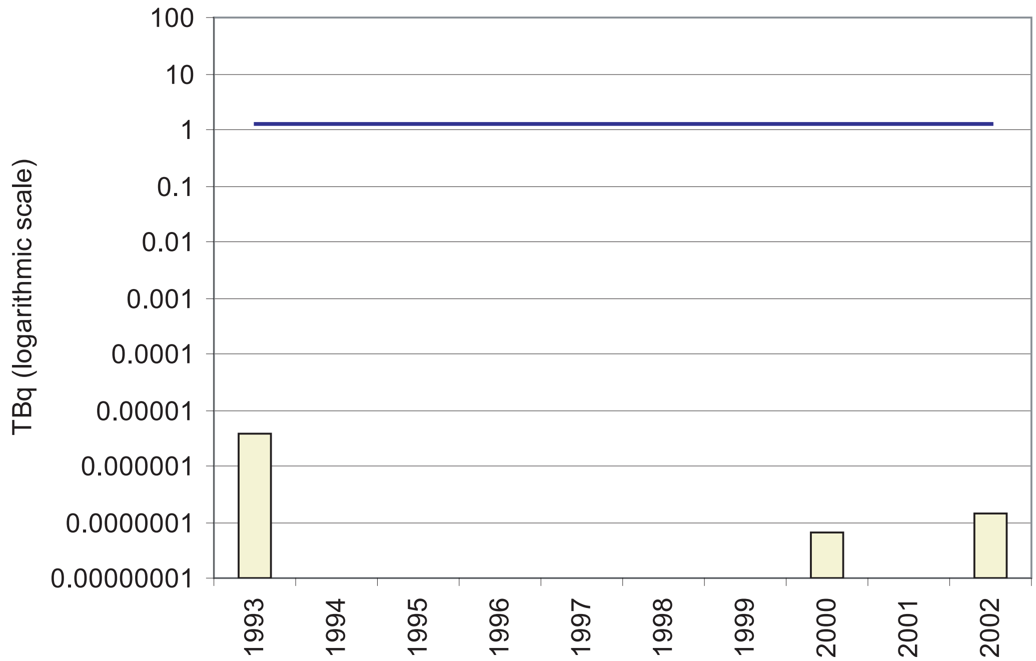
DRLs for carbon 14 in gaseous and liquid effluents were introduced in 1992.

Figure 7.1
Tritium oxide in gaseous effluent from the Gentilly-2 nuclear generating station (1993-2002)
DRL since 1992: 4.4×10^5 TBq



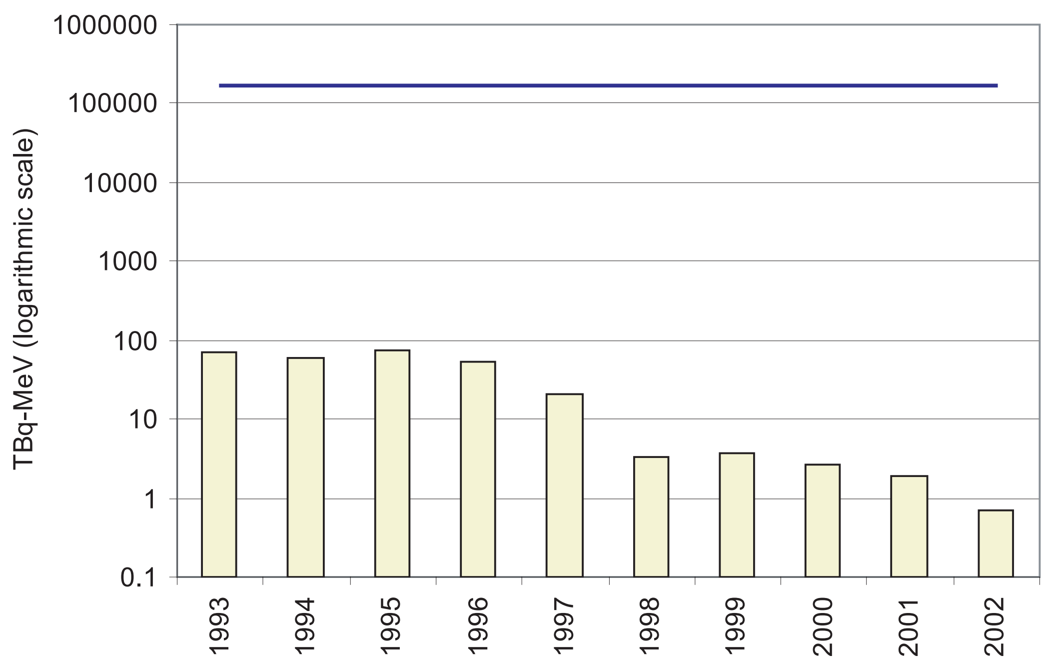
Year	TBq
1993	2.0×10^2
1994	2.6×10^2
1995	3.1×10^2
1996	2.2×10^2
1997	1.6×10^2
1998	1.4×10^2
1999	1.3×10^2
2000	2.5×10^2
2001	1.9×10^2
2002	1.8×10^2

Figure 7.2
Iodine-131 in gaseous effluent from the Gentilly-2 nuclear generating station (1993-2002)
DRL since 1992: 1.3 TBq



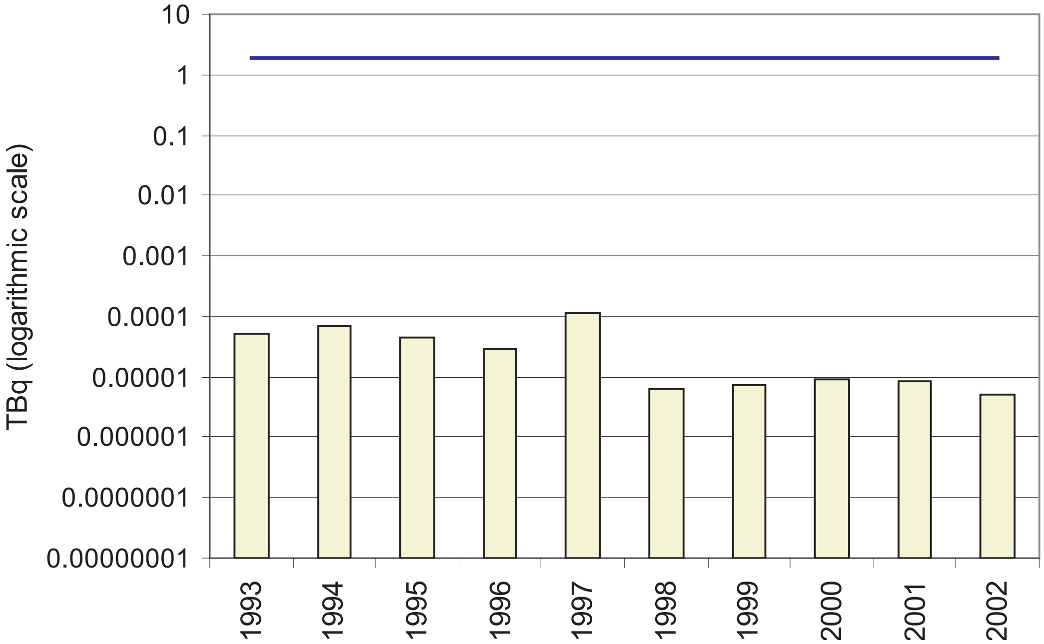
Year	TBq
1993	3.7×10^{-6}
1994	ND
1995	ND
1996	ND
1997	ND
1998	ND
1999	ND
2000	6.4×10^{-8}
2001	ND
2002	1.4×10^{-7}

Figure 7.3
Noble gas in effluent from the Gentilly-2 nuclear generating station (1993-2002)
DRL since 1992: 1.7×10^{5} TBq-MeV



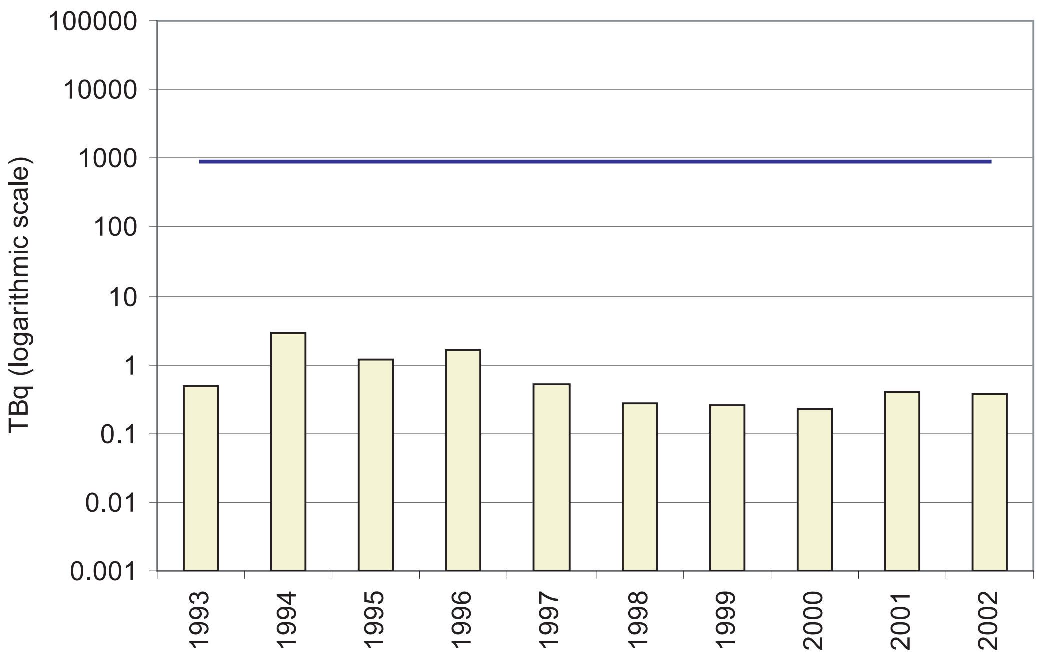
Year	TBq
1993	69
1994	59
1995	73
1996	54
1997	21
1998	3.4
1999	3.8
2000	2.6
2001	1.9
2002	0.69

Figure 7.4
Radioactive particulate in gaseous effluent from the Gentilly-2 nuclear generating station (1993-2002)
DRL since 1992: 1.9 TBq



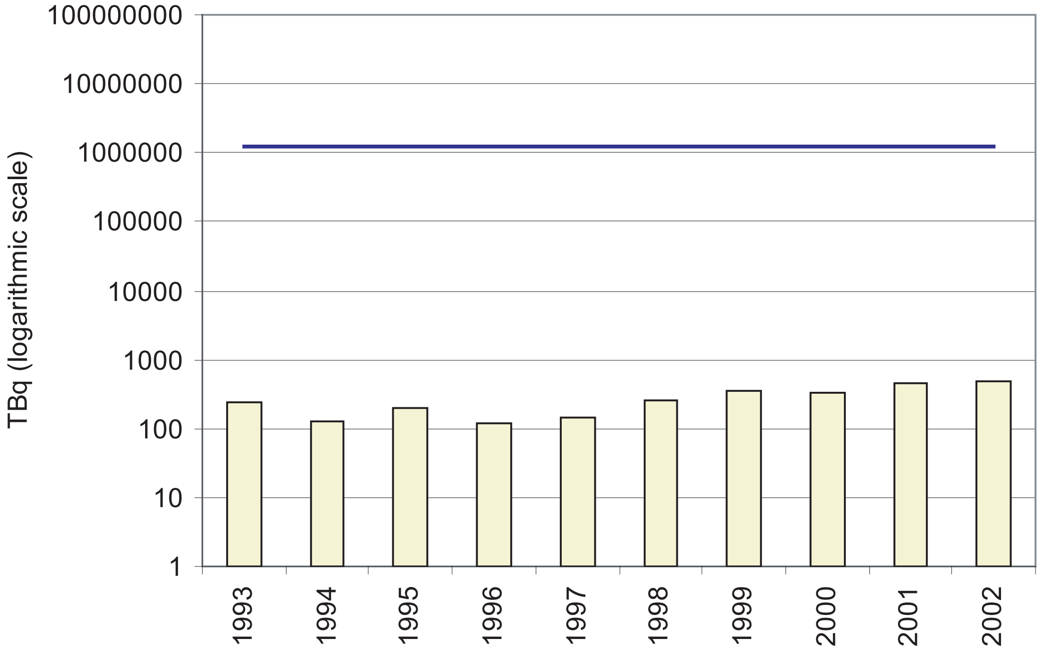
Year	TBq
1993	5.2×10^{-5}
1994	7.0×10^{-5}
1995	4.5×10^{-5}
1996	3.0×10^{-5}
1997	1.1×10^{-4}
1998	6.4×10^{-6}
1999	7.4×10^{-6}
2000	9.0×10^{-6}
2001	8.3×10^{-6}
2002	5.0×10^{-6}

Figure 7.5
Carbon-14 in gaseous effluent from the Gentilly-2 nuclear generating station (1993-2002)
DRL since 1992: 910 TBq



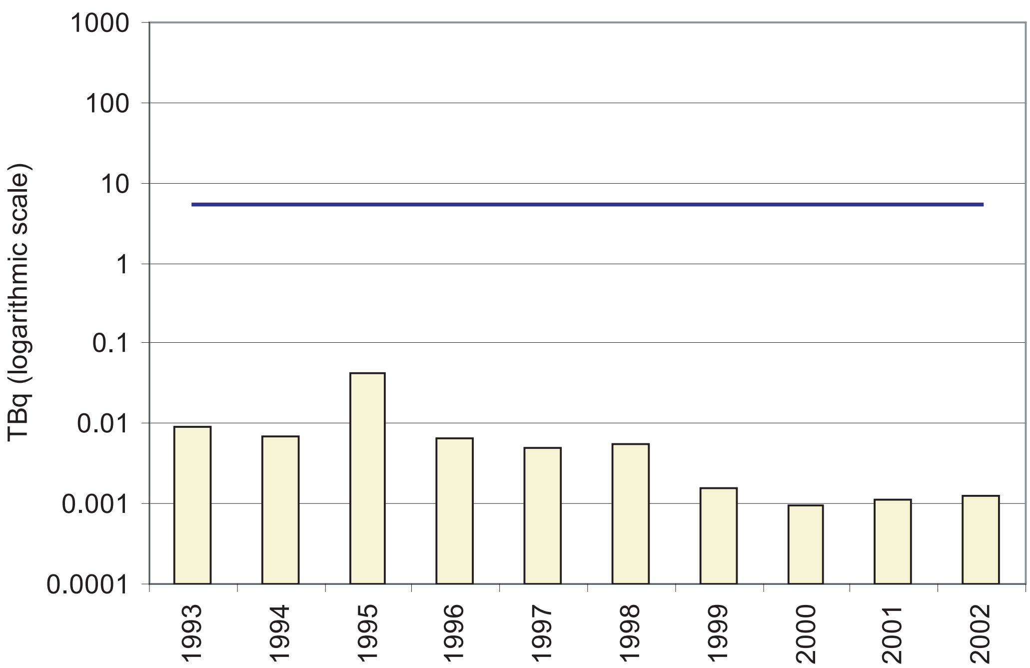
Year	TBq
1993	0.48
1994	2.9
1995	1.2
1996	1.6
1997	0.50
1998	0.27
1999	0.25
2000	0.23
2001	0.40
2002	0.37

Figure 7.6
Tritium oxide in liquid effluent from the Gentilly-2 nuclear generating station (1993-2002)
DRL since 1992: 1.2×10^6 TBq



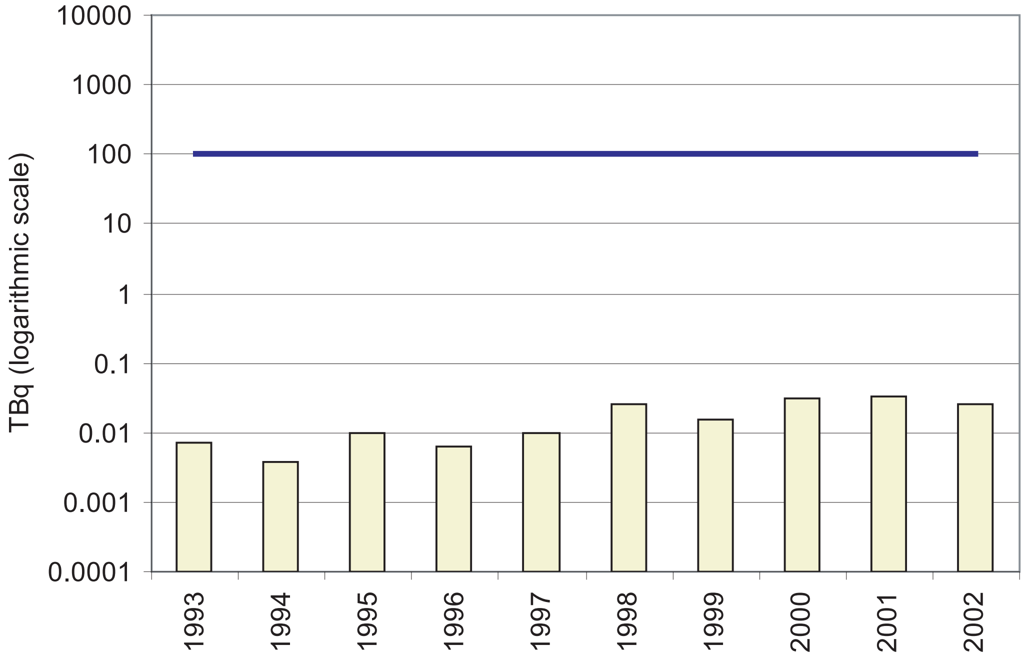
Year	TBq
1993	2.4×10^2
1994	1.3×10^2
1995	2.0×10^2
1996	1.2×10^2
1997	1.4×10^2
1998	2.5×10^2
1999	3.6×10^2
2000	3.4×10^2
2001	4.5×10^2
2002	5.0×10^2

Figure 7.7
Gross beta-gamma activity in liquid effluent from the Gentilly-2 nuclear generating station (1993-2002)
DRL since 1992: 5.3 TBq



Year	TBq
1993	9.0×10^{-3}
1994	6.9×10^{-3}
1995	4.2×10^{-2}
1996	6.5×10^{-3}
1997	5.0×10^{-3}
1998	5.6×10^{-3}
1999	1.6×10^{-3}
2000	9.4×10^{-4}
2001	1.2×10^{-3}
2002	1.3×10^{-3}

Figure 7.8
Carbon-14 in liquid effluent from the Gentilly-2 nuclear generating station (1993-2002)
DRL since 1992: 100 TBq



Year	TBq
1993	7.0×10^{-3}
1994	3.7×10^{-3}
1995	9.7×10^{-3}
1996	6.4×10^{-3}
1997	9.7×10^{-3}
1998	2.5×10^{-2}
1999	1.5×10^{-2}
2000	3.2×10^{-2}
2001	3.4×10^{-2}
2002	2.6×10^{-2}

GLOSSARY

becquerel (Bq): The unit of activity under the SI system. It is the rate of radioactive disintegration of a substance. One becquerel of radioactive substance disintegrates by radioactive decay at the rate of one disintegration per second. In this report we use a multiple of this unit (terabecquerel, or 10^{12} Bq).

critical group: A homogeneous group of members of the public identified as being those individuals which are most likely to receive the highest doses from exposure to radioactive materials released by CNSC licensees. While the concept of critical group is the same for all nuclear generating stations in Canada, the description of the critical group for each station is unique. It is based on analysis of site specific radionuclide releases and exposure pathways.

curie (Ci): The unit for measuring the rate of radioactive decay; it is defined as 3.7×10^{10} disintegrations per second. 1 Ci = 3.7×10^{10} Bq.

decommissioning: The final closing down and putting into a state of safety of a nuclear generating station or other nuclear facility when it has come to the end of its service life.

derived release limit (DRL): A limit imposed by the CNSC on the release of a radioactive substance from a licensed nuclear facility such that compliance with the DRL gives reasonable assurance that the regulatory dose limit is not exceeded.

dose limit: A limit on radiation dose specified in the CNSC *Radiation Protection Regulations.*

iodine 131: Radioactive isotope of iodine. There are several radioisotopes of iodine produced during normal operation of a nuclear reactor.

ionizing radiation: Any atomic or subatomic particle or electromagnetic wave having sufficient energy to produce ions (atoms which have become charged due to the loss or gain of electrons) in the material in which it is absorbed. Ionizing radiation includes alpha and beta particles and gamma radiation, as well as neutrons and some other particles.

irradiation: Exposure to radiation.

logarithmic scale: An exponential scale in which the distances that numbers are at from a reference point are proportional their exponents rather than their linear relationship to each other.

noble gases: Xenon, argon, krypton, neon, helium. They are chemically inert gases. Radioisotopes of the noble gases are created during the operation of a nuclear reactor.

radioactivity: The spontaneous disintegration of the nucleus of an atom by expulsion of particles. It can be accompanied by electromagnetic radiation. Solids, liquids or gases can be radioactive.

rem (Roentgen equivalent man): The unit used to describe the relative effect of radiation absorbed doses of different ionizing radiations on different body tissues. Under the SI system, the rem is replaced by the sievert (1 rem = 0.01 Sv = 10 mSv).

sievert (Sv): The SI unit corresponding to the rem (1 Sv = 100 rem). The millisievert (mSv) is more appropriate for radiation protection work. The legal dose limit has been established at 1 mSv for a member of the public with respect to any licensed nuclear activity. The limit for a Nuclear Energy Worker (NEW) is 100 mSv in a five year dosimetry period, and 50 mSv in a one year dosimetry period.

tritium: A radioactive form of hydrogen which is produced both naturally and by human activities. Tritium is produced during normal operation of Canadian nuclear reactors.