Canadian Nuclear Safety Commission
Commission canadienne de sûreté nucléaire

Radioactive Release Data from Canadian Nuclear Generating Stations 1990 to 1999

INFO-0210/REV. 10

October 2000

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RADIOACTIVE RELEASE DATA
FROM
CANADIAN NUCLEAR GENERATING STATIONS
1990 TO 1999

Compiled by
Radiation and Environmental Protection Division
Directorate of Human Performance and Assessment
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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:

Communications Division
Canadian Nuclear Safety Commission
P.O. Box 1046, Station B
280 Slater Street
Ottawa, Ontario K1P 5S9
CANADA

Telephone: (613) 995-5894 or 1-800-668-5284 (Canada only)
Facsimile: (613) 992-2915
E-mail: info@cnsc-ccsn.gc.ca

NOTICE

On May 31, 2000, the Atomic Energy Control Board (AECB), Canada's nuclear regulatory authority, became the Canadian Nuclear Safety Commission (CNSC). Since this document was compiled before that date, references to the "Atomic Energy Control Board" or to the "AECB" must henceforth be read as references to 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 Atomic Energy Control Board* (AECB) as part of its regulatory and licensing program. The data show that the levels of gaseous and liquid effluents from all currently operating nuclear generating stations are well below the values authorized by the AECB. In fact, since 1987 no releases have exceeded 1% of those values.

This 10th revision of INFO-0210 presents data for the ten year period from 1990 to 1999. 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, where 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, inhalation of contaminated air, or ingestion of contaminated food or water. Such doses are subject to statutory dose limits for members of the public, which were set out in Schedule II of the Atomic Energy Control Regulations and are reproduced in Table 1 below. On May 31st 2000, the Atomic Energy Control Regulations were superceded by the Nuclear Safety and Control Regulations.

Table 1
Annual dose limits for members of the public

Organ or tissue	Dose
whole body, gonads, red bone marrow	5 mSv (0.5 rem)
skin, bone, thyroid	30 mSv (3.0 rem) (50% of this value for children)
extremities	75 mSv (7.5 rem)
other single organs or tissues	15 mSv (1.5 rem)

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, the Atomic Energy Control Regulations limit 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.

Notes:

* On May 31st 2000, the Atomic Energy Control Board became the Canadian Nuclear Safety Commission (CNSC).

** In earlier revisions of this report DRLs have been called derived emission limits. The two terms have been used interchangeably over the years. *Release* is considered to be a more accurate term since *emissions* are physically *released* in a controlled manner over time.

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	3.8×10^5	1.2	2.5×10^5	2.7	2.8×10^3
Bruce-B	4.7×10^5	1.3	6.1×10^5	4.8	3.0×10^3
Darlington	2.1×10^5 (HTO) 7.3×10^6 (HT)***	0.6	2.1×10^5	4.4	1.4×10^3
Pickering-A	3.4×10^5	2.4	8.3×10^4	5.0	8.8×10^3
Pickering-B	3.4×10^5	2.4	8.3×10^4	5.0	8.8×10^3
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 emission limits

When it approved the DRLs for each nuclear generating station, the AECB 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 AECB 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 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	1.7×10^6	20.0	4.5×10^2
Bruce-B	3.0×10^6	23.0	4.8×10^2
Darlington	5.3×10^6	130.0	3.2×10^3
Pickering-A	8.3×10^5	9.7	1.4×10^2
Pickering-B	8.3×10^5	9.7	1.4×10^2
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.

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 AECB 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.

Annual releases of the radionuclides described above are presented in histograms and tables for each nuclear generating station. The bars of the histograms depict the amount of radionuclide released each year in units of terabecquerels (TBq) or terabecquerel-million electron volts (TBq-MeV) in the case of noble gases. Logarithmic scales are used to allow comparison between annual radioactive releases and the DRL for each radionuclide.

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

Terminology

We have provided a brief glossary 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 used in nuclear energy, 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	1.26×10^6 or
	1.3×10^6 (to two significant figures)
0.003473	3.5×10^{-3} (to two significant figures)

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

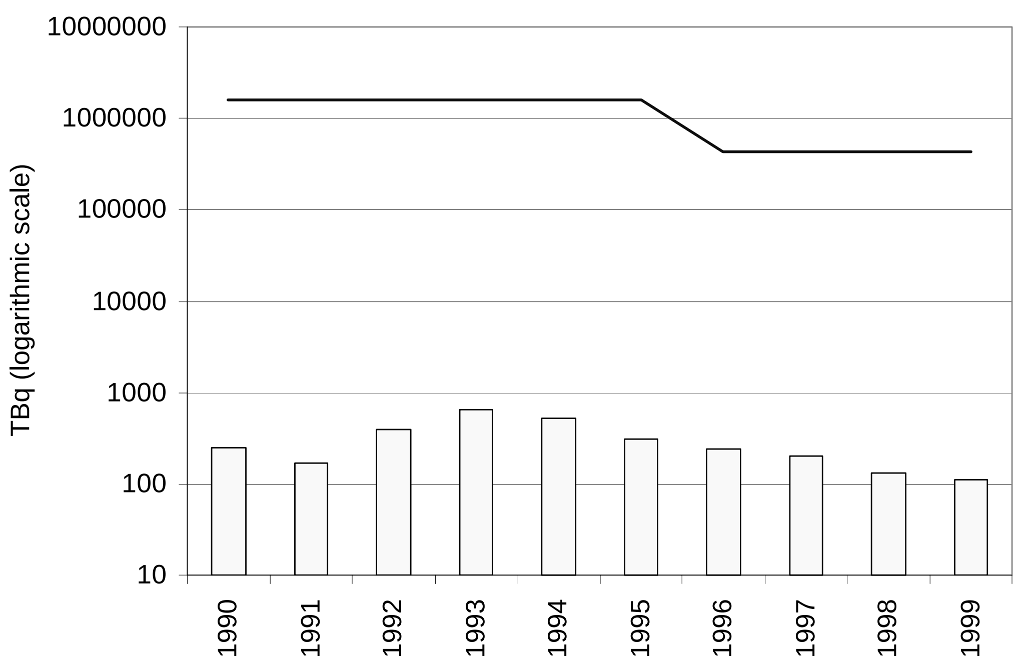
Radioactive release data for gaseous and liquid effluents released between 1990 and 1999 from the Point Lepreau nuclear generating station are presented in the following histograms. The major radionuclides in gaseous effluents are tritium in the form of tritium oxide (Figure 1.1), iodine-131 (Figure 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.

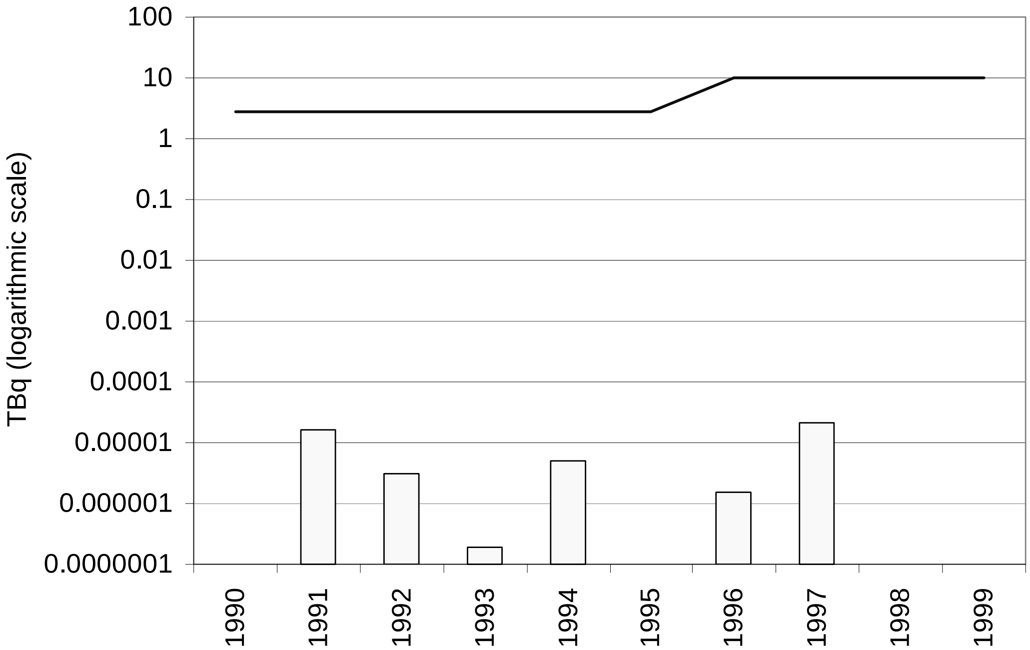
The DRLs for Point Lepreau were last revised in 1996.

Figure 1.1
Tritium oxide in gaseous effluent from the Point Lepreau nuclear generating station (1990-1999)
DRL since 1996: 4.3×10^5 TBq



Year	TBq
1990	2.5×10^2
1991	1.7×10^2
1992	4.0×10^2
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

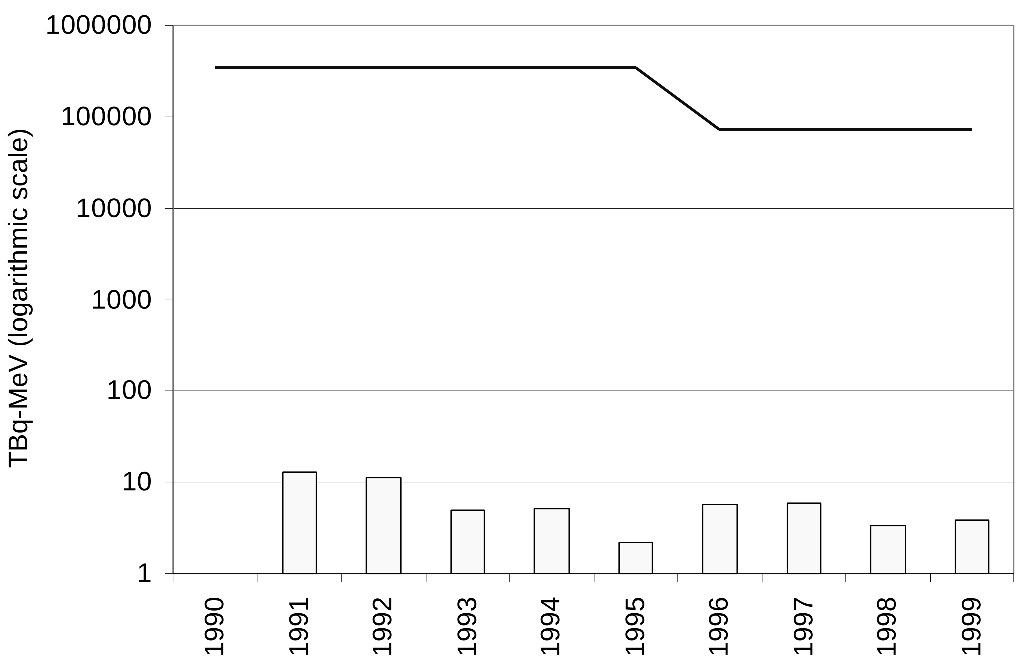
Figure 1.2
Iodine-131 in gaseous effluent from the Point Lepreau nuclear generating station (1990-1999)
DRL since 1996: 9.9 TBq



Year	TBq
1990	ND*
1991	1.6×10^{-5}
1992	3.0×10^{-6}
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*

*ND: not detected.

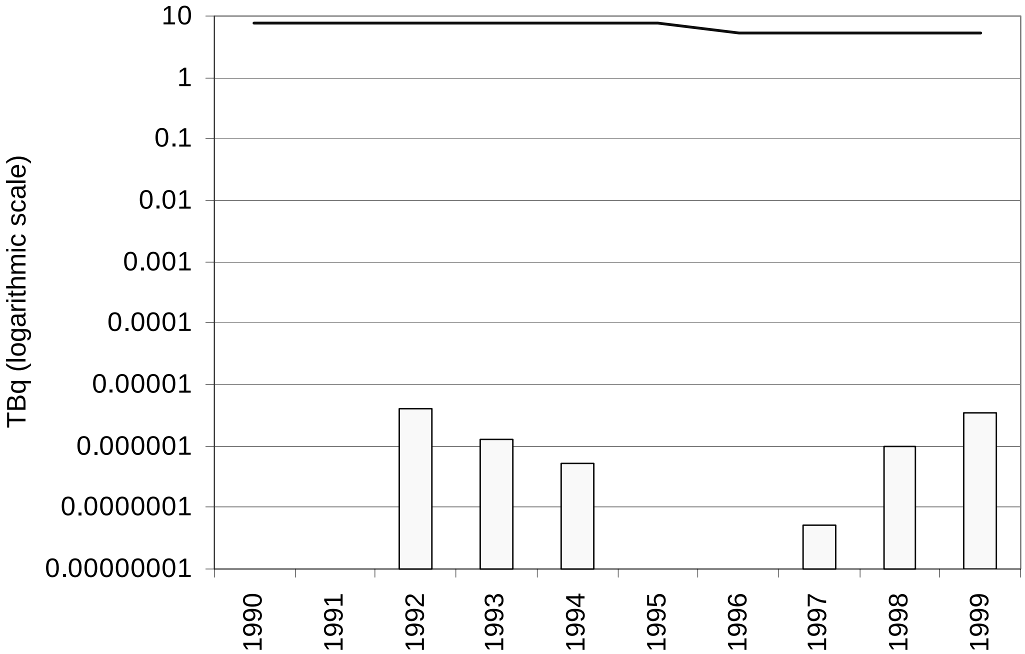
Figure 1.3
Noble Gas in effluent from the Point Lepreau nuclear generating station (1990-1999)
DRL since 1996: 7.3×10^4 TBq-MeV



Year	TBq-MeV
1990	ND*
1991	13.0
1992	11.0
1993	4.9
1994	5.1
1995	2.2
1996	5.6
1997	5.9
1998	3.4
1999	3.8

*ND: not detected.

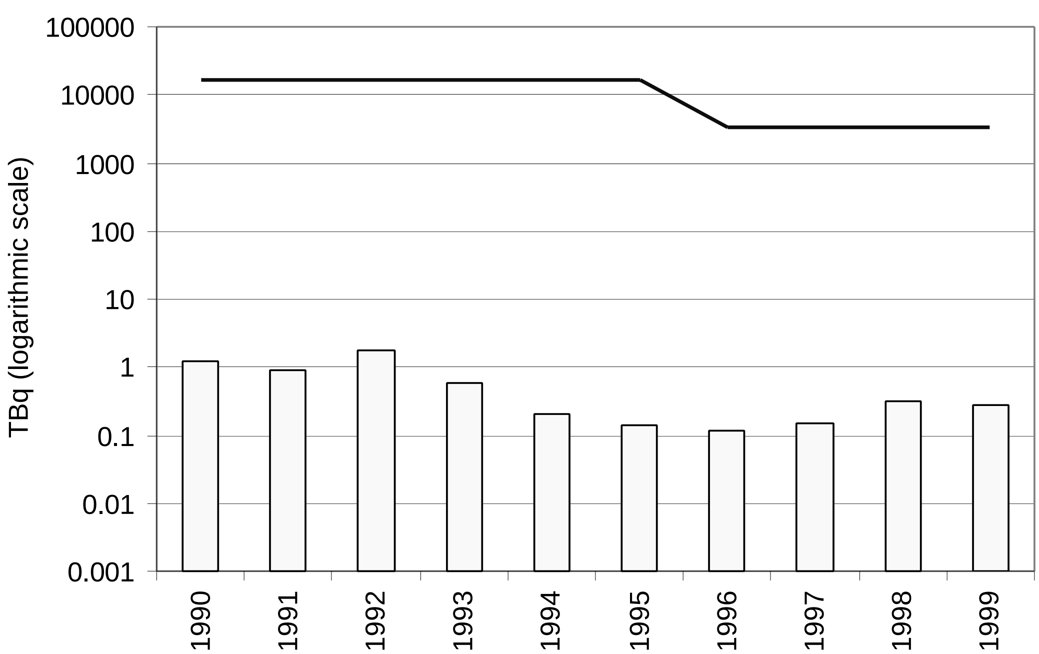
Figure 1.4
Radioactive particulate in gaseous effluent from the Point Lepreau nuclear generating station (1990-1999)
DRL since 1996: 5.2 TBq



Year	TBq
1990	ND*
1991	ND*
1992	4.0×10^{-6}
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}

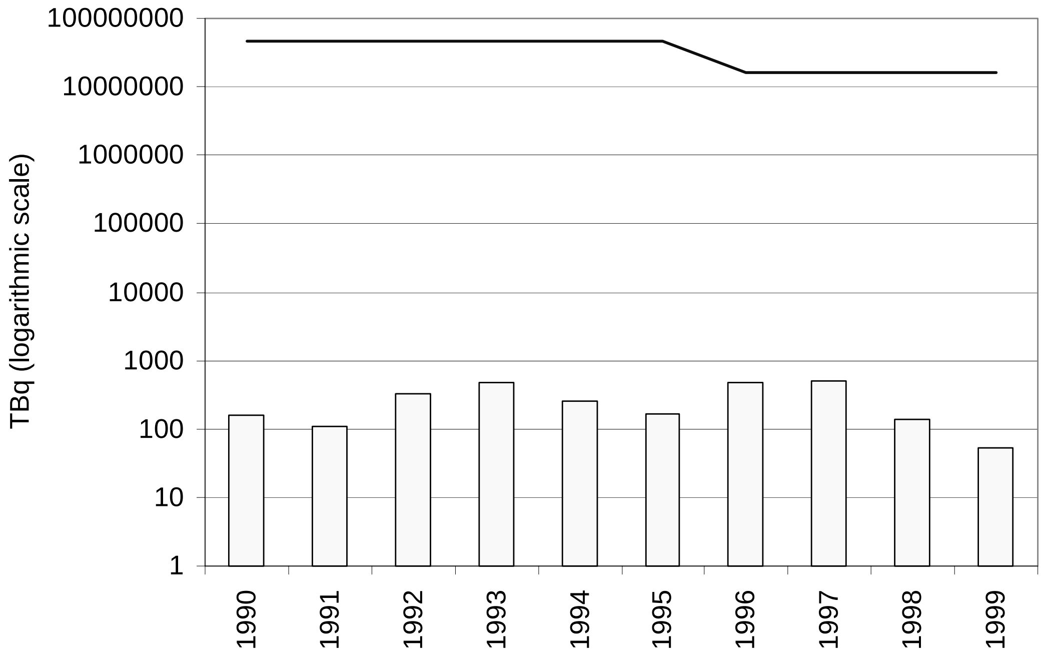
*ND: not detected.

Figure 1.5
Carbon-14 in gaseous effluent from the Point Lepreau nuclear generating station (1990-1999)
DRL since 1996: 3.3×10^3 TBq



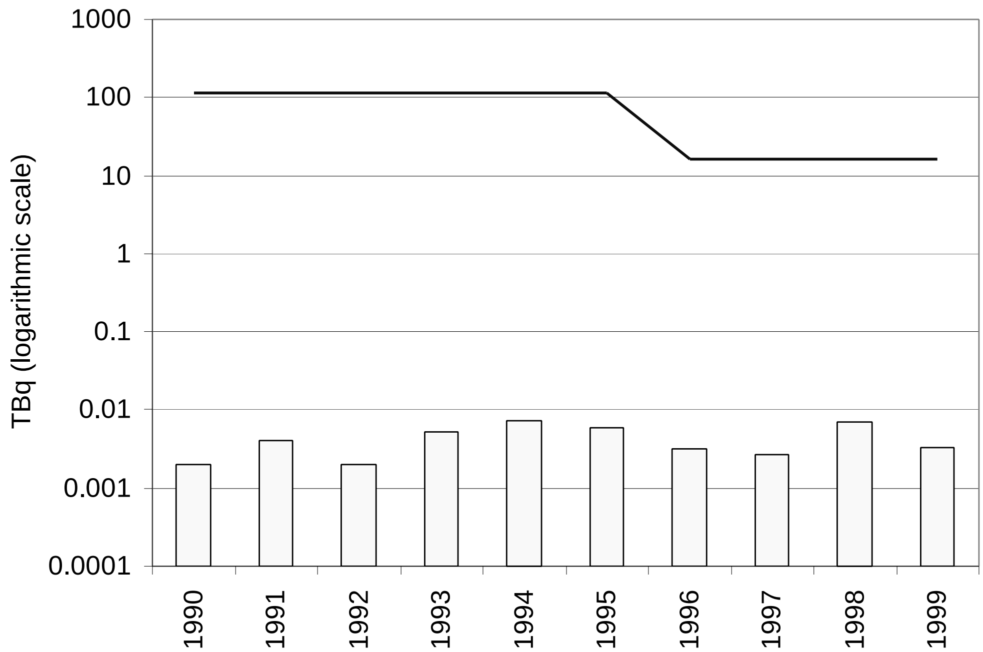
Year	TBq
1990	1.2
1991	0.88
1992	1.8
1993	0.58
1994	0.20
1995	0.14
1996	0.12
1997	0.15
1998	0.32
1999	0.28

Figure 1.6
Tritium oxide in liquid effluent from the Point Lepreau nuclear generating station (1990-1999)
DRL since 1996: 1.6×10^7 TBq



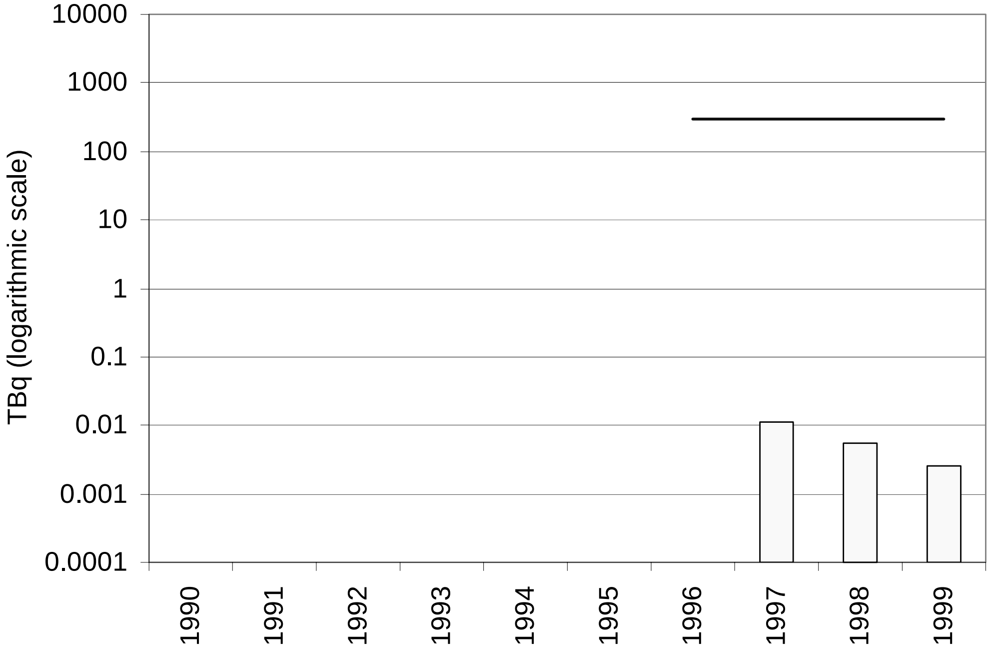
Year	TBq
1990	1.6×10^2
1991	1.1×10^2
1992	3.2×10^2
1993	4.7×10^2
1994	2.6×10^2
1995	1.7×10^2
1996	4.8×10^2
1997	5.0×10^2
1998	1.4×10^2
1999	5.3×10^1

Figure 1.7
Gross beta-gamma activity in liquid effluent from the Point Lepreau nuclear generating station (1990-1999)
DRL since 1996: 16 TBq



Year	TBq
1990	2.0×10^{-3}
1991	4.0×10^{-3}
1992	2.0×10^{-3}
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}

Figure 1.8
Carbon-14 in liquid effluent from the Point Lepreau nuclear generating station (1997-1999)
DRL since 1996: 300 TBq



Year	TBq
1997	1.1×10^{-2}
1998	5.5×10^{-3}
1999	2.6×10^{-3}

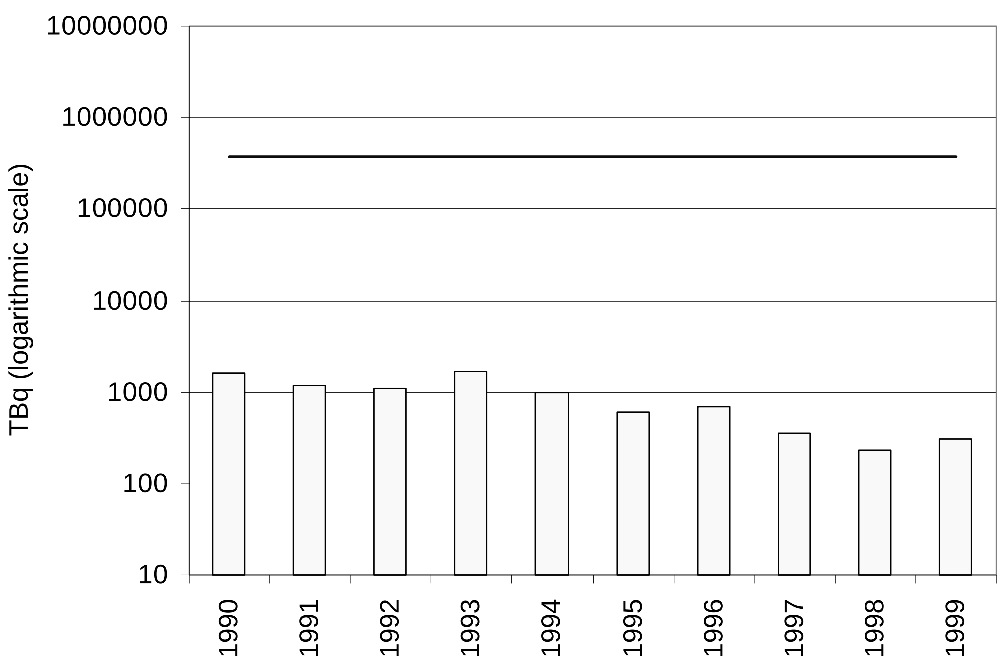
The Bruce-A nuclear generating station consists of four nuclear reactors which started operation in 1976. It is located in Ontario on the shore of Lake Huron near the town of Kincardine.

In 1997 as part of its extensive recovery program, Ontario Hydro (now Ontario Power Generation) temporarily shut down all Bruce-A reactors. During 1998 and 1999 all Bruce-A reactors were maintained in a guaranteed shut-down condition and defuelled.

Radioactive release data for gaseous and liquid effluents released between 1990 and 1999 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).

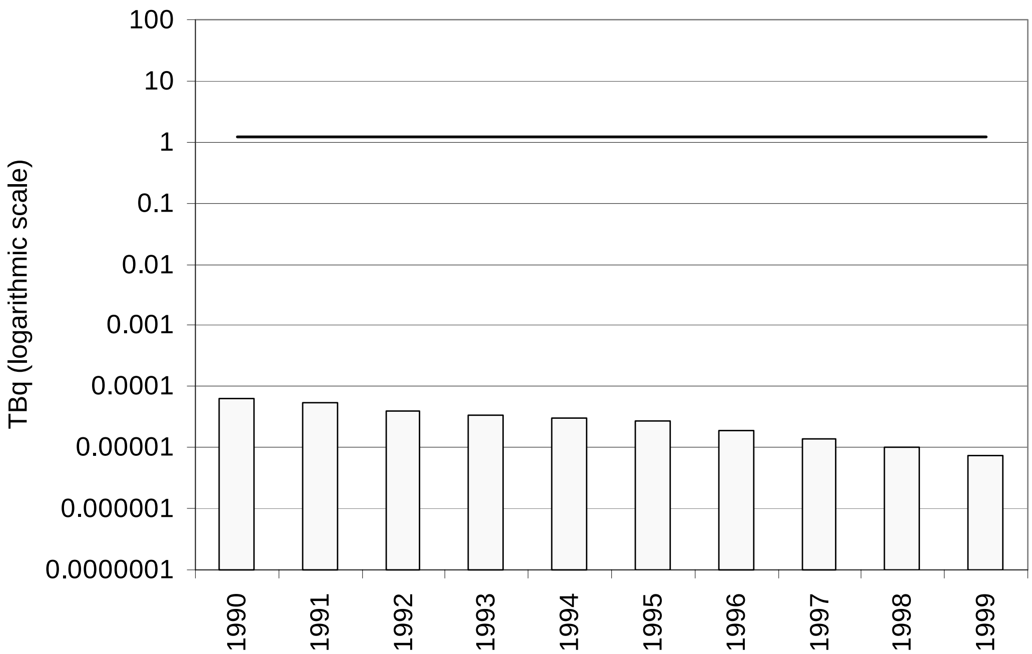
Bruce-A began reporting carbon-14 releases in gaseous and liquid effluents in 1999.

Figure 2.1
Tritium oxide in gaseous effluent from the Bruce-A nuclear generating station (1990-1999)
DRL since 1990: 3.8×10^5 TBq



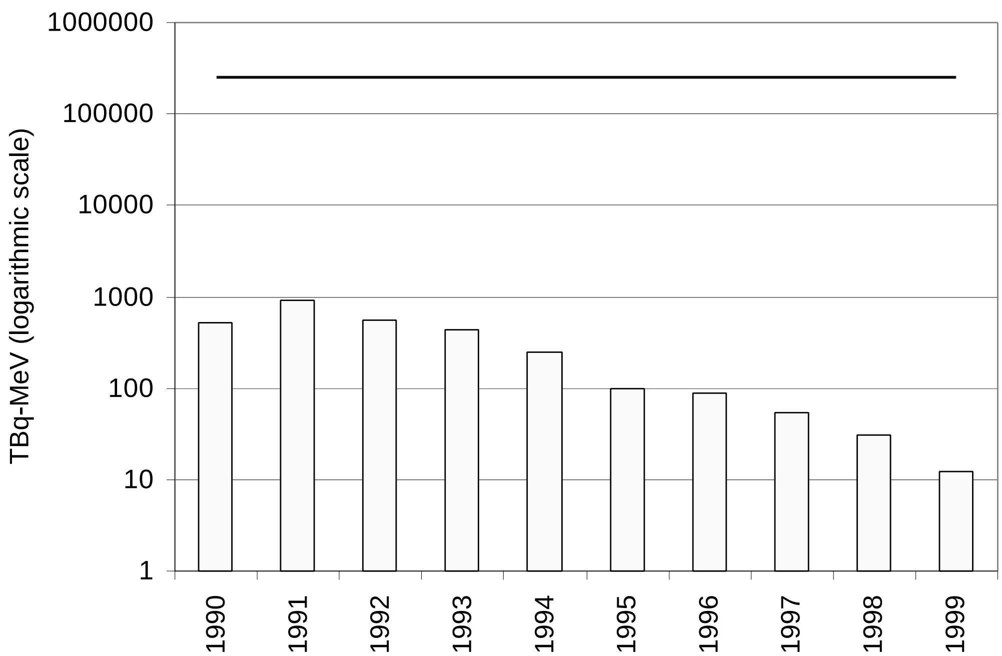
Year	TBq
1990	1.6×10^3
1991	1.2×10^3
1992	1.1×10^3
1993	1.7×10^3
1994	1.0×10^3
1995	6.1×10^2
1996	7.0×10^2
1997	3.5×10^2
1998	2.3×10^2
1999	3.1×10^2

Figure 2.2
Iodine-131 in gaseous effluent from the Bruce-A nuclear generating station (1990-1999)
DRL since 1990: 1.2 TBq



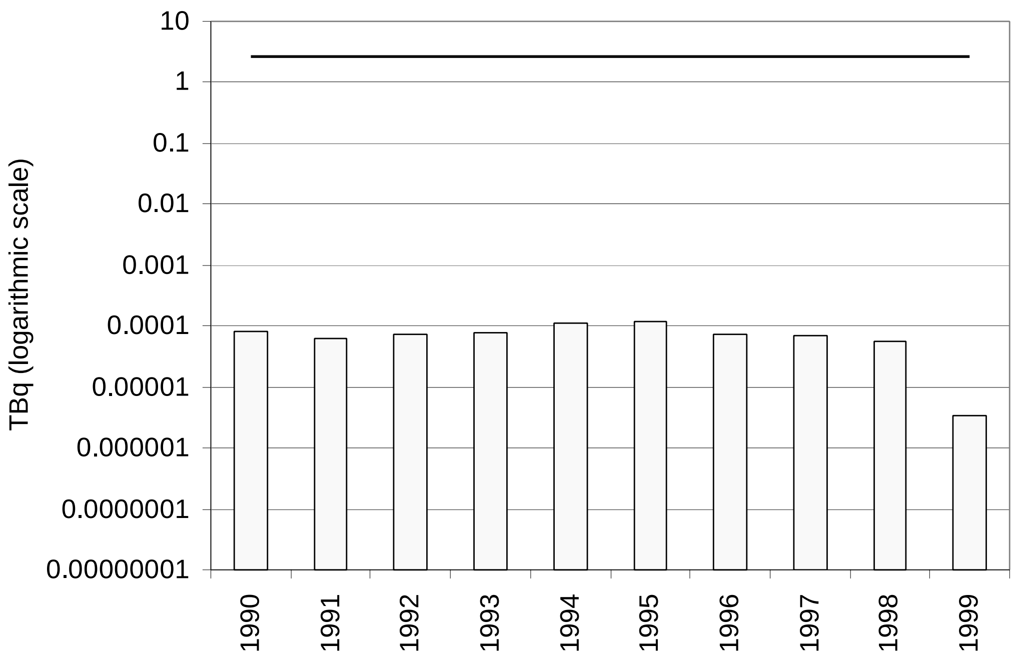
Year	TBq
1990	6.3×10^{-5}
1991	5.5×10^{-5}
1992	4.0×10^{-5}
1993	3.3×10^{-5}
1994	3.0×10^{-5}
1995	2.7×10^{-5}
1996	1.9×10^{-5}
1997	1.4×10^{-5}
1998	9.9×10^{-6}
1999	7.2×10^{-6}

Figure 2.3
Noble gas in effluent from the Bruce-A nuclear generating station (1990-1999)
DRL since 1990: 2.5×10^5 TBq-MeV



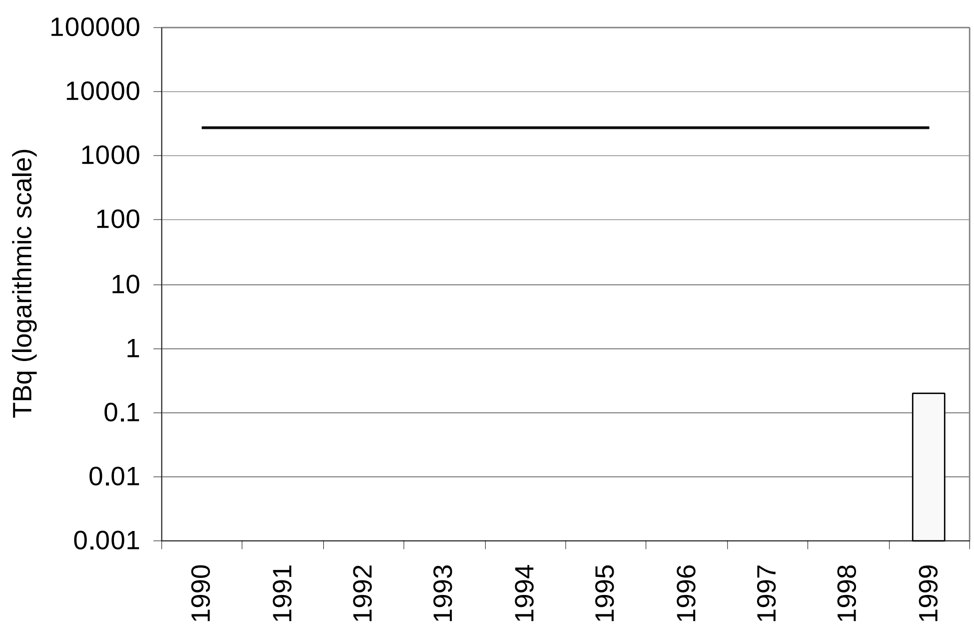
Year	TBq-MeV
1990	520
1991	900
1992	560
1993	430
1994	250
1995	100
1996	88
1997	54
1998	31
1999	12

Figure 2.4
Radioactive particulate in gaseous effluent from the Bruce-A nuclear generating station (1990-1999)
DRL since 1990: 2.7 TBq



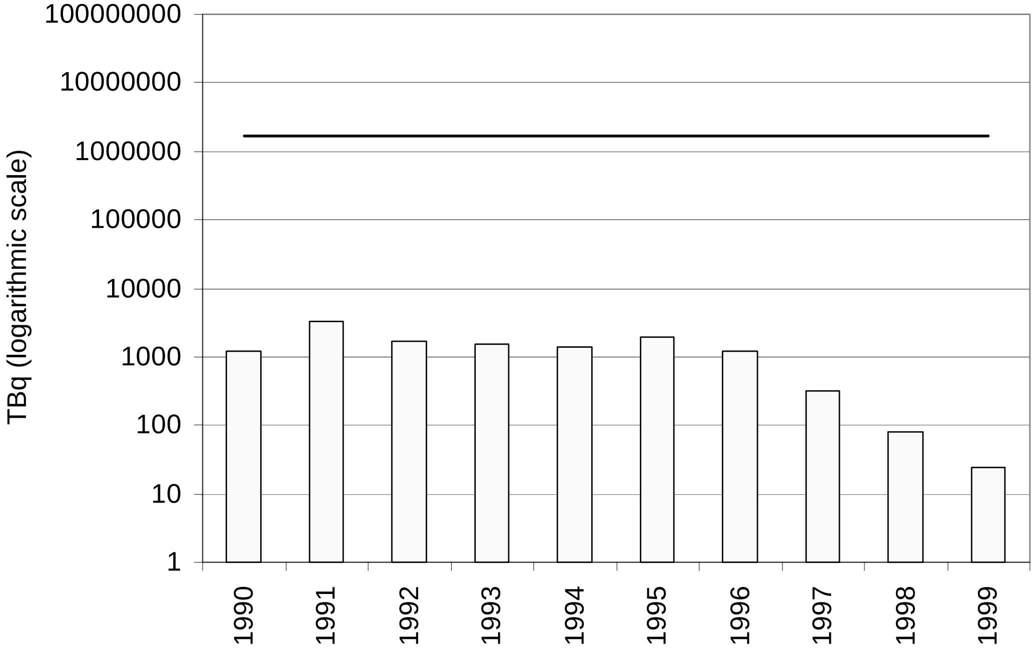
Year	TBq
1990	8.1×10^{-5}
1991	6.3×10^{-5}
1992	7.2×10^{-5}
1993	7.9×10^{-5}
1994	1.1×10^{-4}
1995	1.2×10^{-4}
1996	7.2×10^{-5}
1997	7.0×10^{-5}
1998	5.6×10^{-5}
1999	3.4×10^{-6}

Figure 2.5
Carbon-14 in gaseous effluent from the Bruce-A nuclear generating station (1999)
DRL since 1990: 2.8×10^3 Tbq



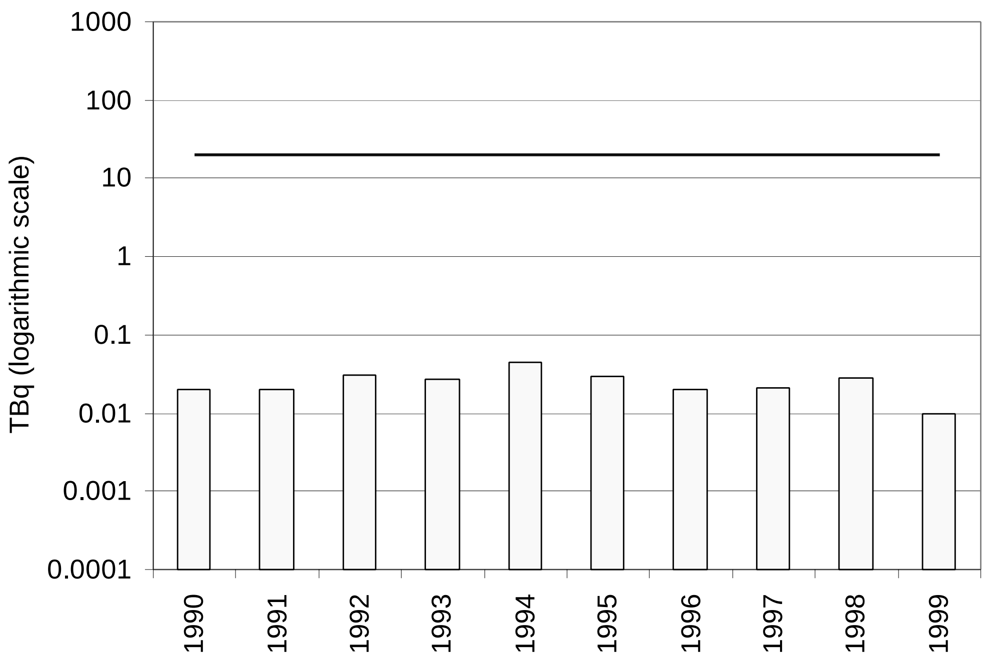
Year	TBq
1999	0.2

Figure 2.6
Tritium oxide in liquid effluent from the Bruce-A nuclear generating station (1990-1999)
DRL since 1990: 1.7×10^6 TBq



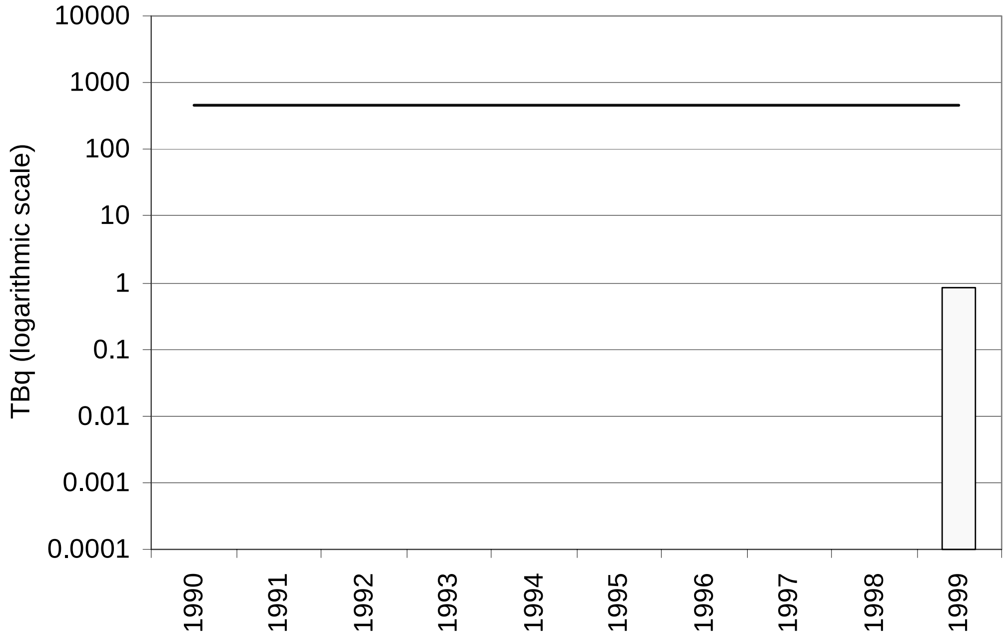
Year	TBq
1990	1.2×10^3
1991	3.2×10^3
1992	1.7×10^3
1993	1.5×10^3
1994	1.4×10^3
1995	1.9×10^3
1996	1.2×10^3
1997	3.1×10^2
1998	7.8×10^1
1999	2.4×10^1

Figure 2.7
Gross beta-gamma activity in liquid effluent from the Bruce-A nuclear generating station (1990-1999)
DRL since 1990: 20 TBq



Year	TBq
1990	2.0×10^{-2}
1991	2.0×10^{-2}
1992	3.0×10^{-2}
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}

Figure 2.8
Carbon-14 in liquid effluent from the Bruce-A nuclear generating station (1999)
DRL since 1990: 4.5×10^2 TBq



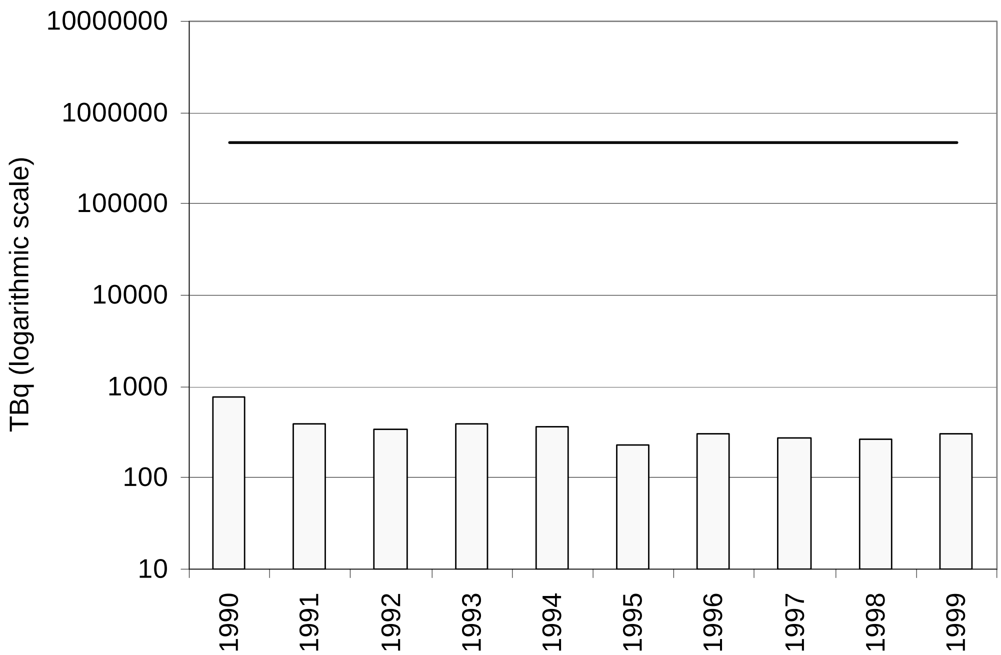
Year	TBq
1999	0.86

The Bruce-B nuclear generating station consists of four nuclear reactors which started up in 1984. It is located in Ontario on the shore of Lake Huron near the town of Kincardine.

Radioactive release data for gaseous and liquid effluents released between 1990 and 1999 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); while those in the liquid effluents are tritium, in the form of tritium oxide (Figure 3.5), gross beta-gamma activity (Figure 3.6) and carbon-14 (Figure 3.7).

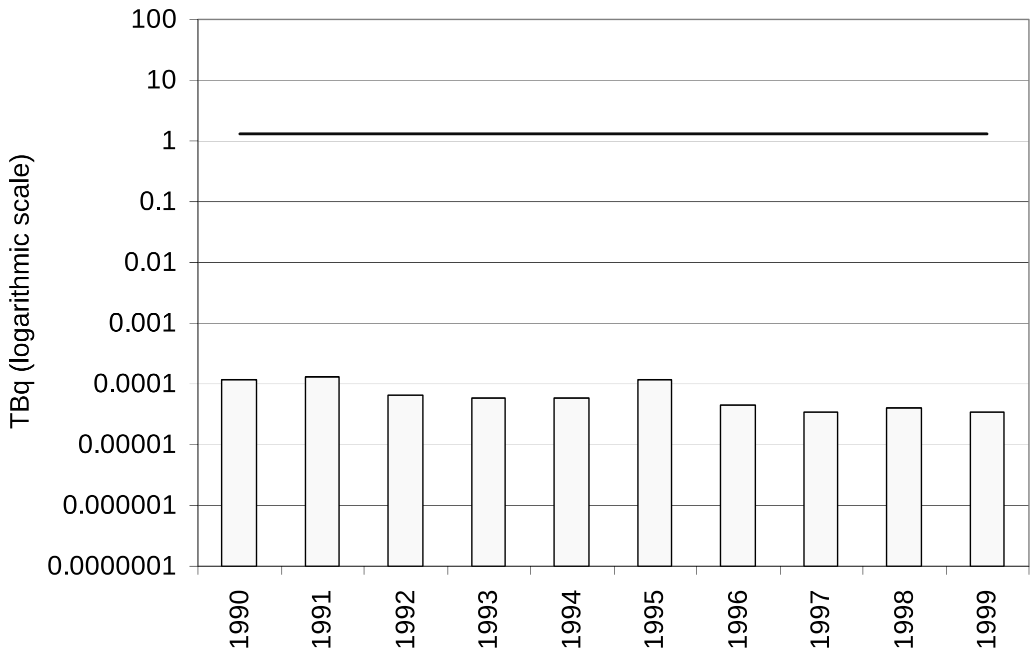
Bruce-B began reporting carbon-14 releases in liquid effluents in 1999, and is expected to report carbon-14 releases in gaseous effluents starting in 2000.

Figure 3.1
Tritium oxide in gaseous effluent from the Bruce-B nuclear generating station (1990-1999)
DRL since 1990: 4.7×10^5 TBq



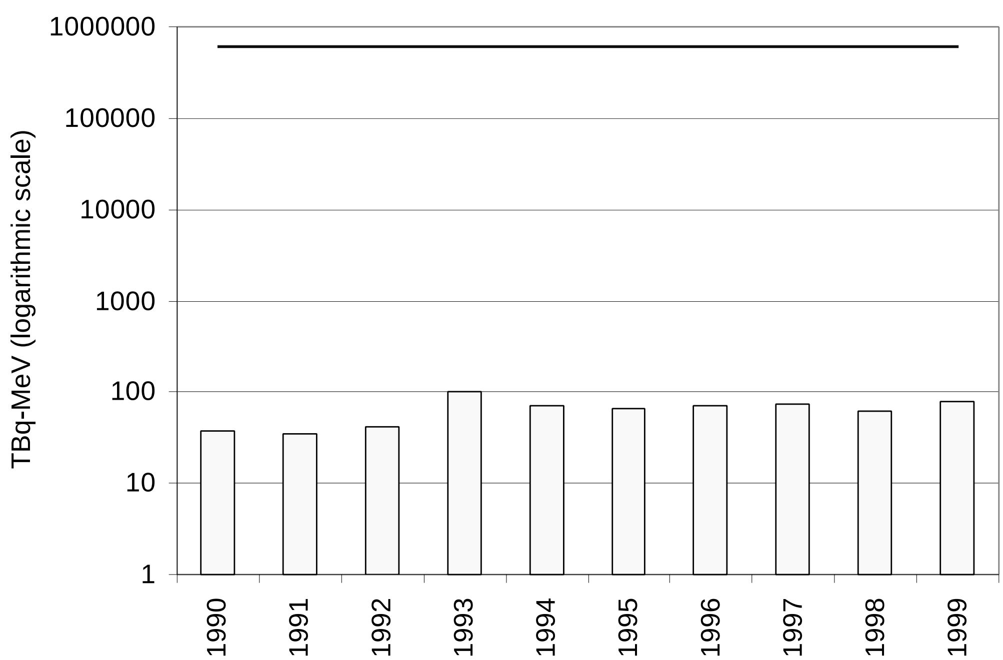
Year	TBq
1990	7.8×10^2
1991	3.9×10^2
1992	3.4×10^2
1993	3.9×10^2
1994	3.7×10^2
1995	2.3×10^2
1996	3.1×10^2
1997	2.7×10^2
1998	2.6×10^2
1999	3.1×10^2

Figure 3.2
Iodine-131 in gaseous effluent from the Bruce-B nuclear generating station (1990-1999)
DRL since 1990: 1.3 TBq



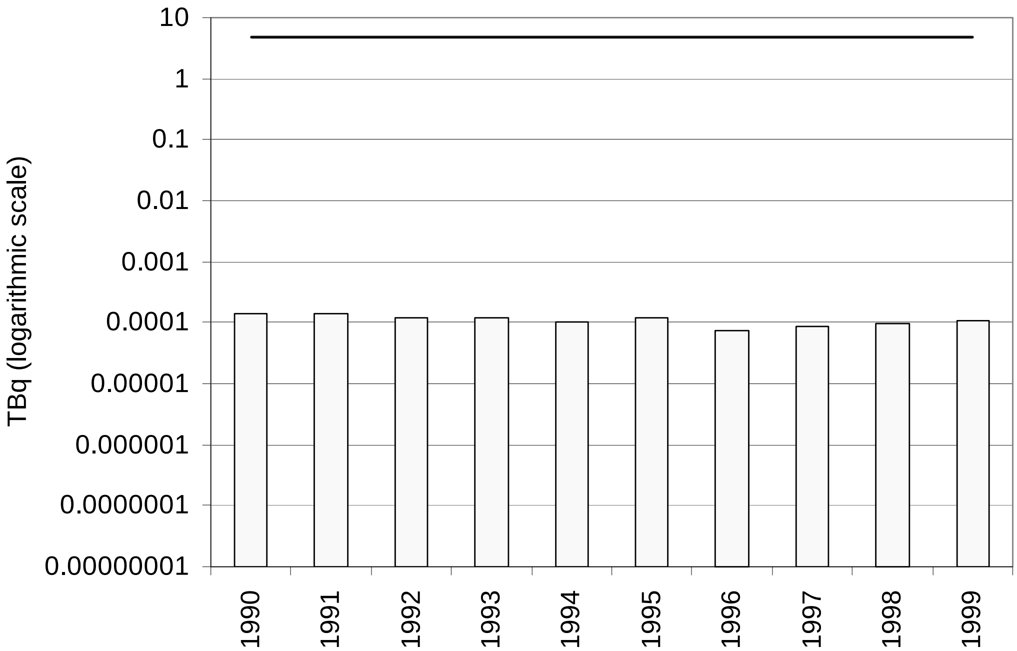
Year	TBq
1990	1.2×10^{-4}
1991	1.3×10^{-4}
1992	6.4×10^{-5}
1993	5.7×10^{-5}
1994	5.9×10^{-5}
1995	1.2×10^{-4}
1996	4.4×10^{-5}
1997	3.5×10^{-5}
1998	4.0×10^{-5}
1999	3.5×10^{-5}

Figure 3.3
Noble gas in effluent from the Bruce-B nuclear generating station (1990-1999)
DRL since 1990: 6.1×10^5 TBq-MeV



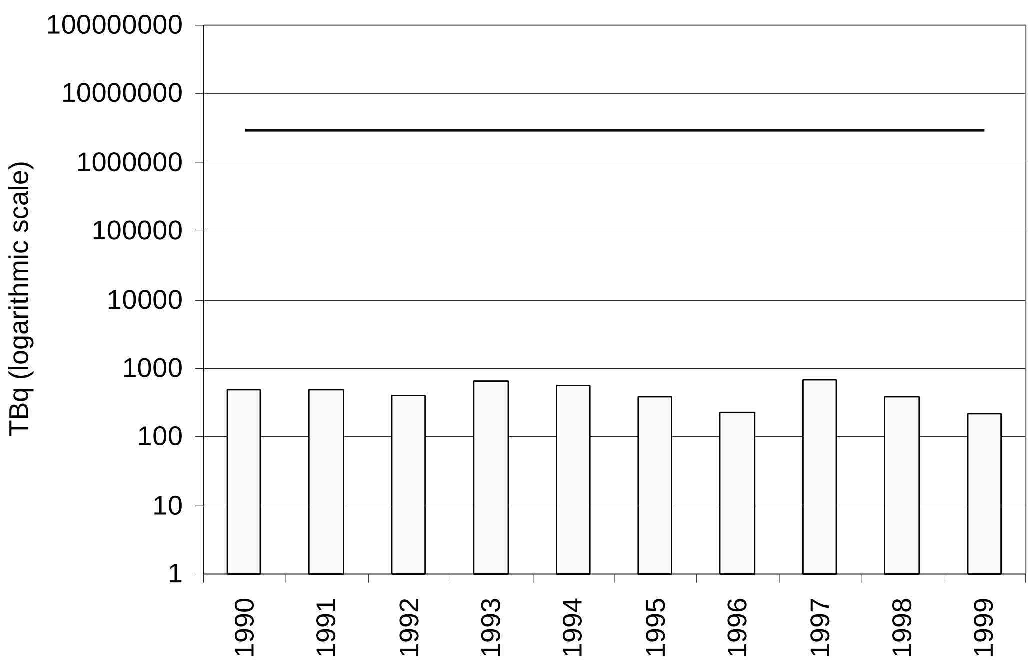
Year	TBq-MeV
1990	37
1991	35
1992	41
1993	100
1994	70
1995	67
1996	70
1997	74
1998	62
1999	79

Figure 3.4
Radioactive particulate in gaseous effluent from the Bruce-B nuclear generating station (1990-1999)
DRL since 1990: 4.8 TBq



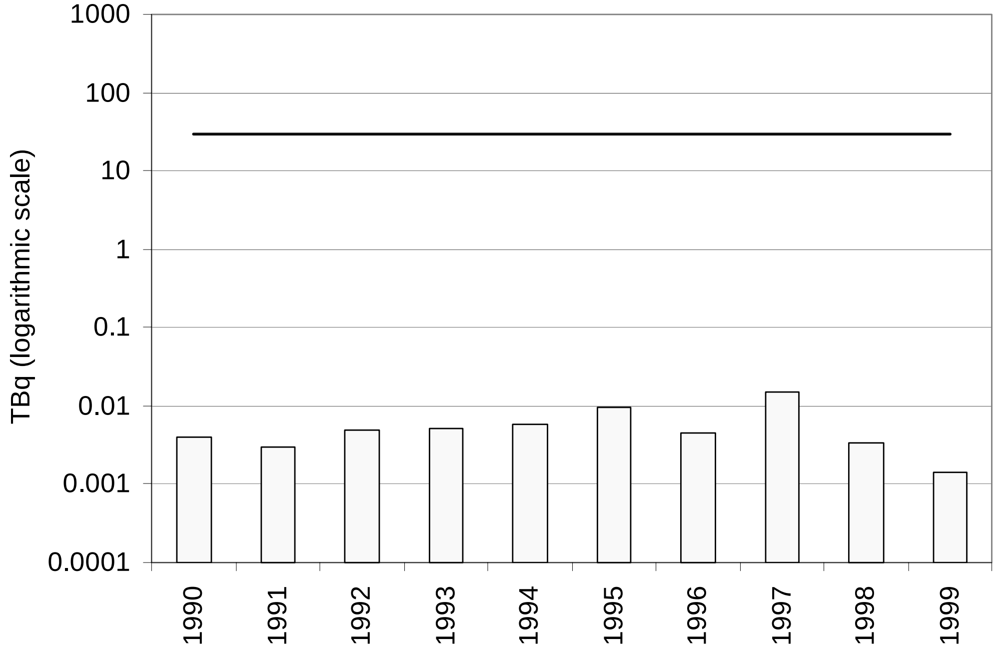
Year	TBq
1990	1.4×10^{-4}
1991	1.4×10^{-4}
1992	1.2×10^{-4}
1993	1.2×10^{-4}
1994	1.0×10^{-4}
1995	1.2×10^{-4}
1996	7.5×10^{-5}
1997	8.8×10^{-5}
1998	9.6×10^{-5}
1999	1.1×10^{-4}

Figure 3.5
Tritium oxide in liquid effluent from the Bruce-B nuclear generating station (1990-1999)
DRL since 1990: 3.0×10^6 TBq



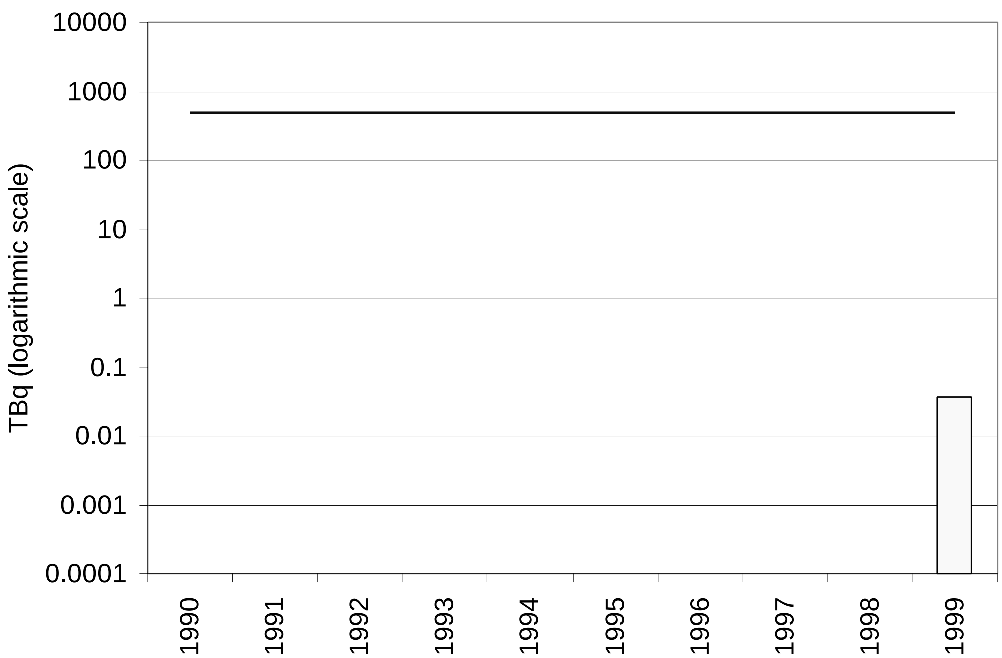
Year	TBq
1990	4.8×10^{2}
1991	4.9×10^{2}
1992	4.1×10^{2}
1993	6.6×10^{2}
1994	5.6×10^{2}
1995	3.8×10^{2}
1996	2.3×10^{2}
1997	6.8×10^{2}
1998	3.8×10^{2}
1999	2.2×10^{2}

Figure 3.6
Gross beta-gamma activity in liquid effluent from the Bruce-B nuclear generating station (1990-1999)
DRL since 1990: 23 TBq



Year	TBq
1990	4.0×10^{-3}
1991	3.0×10^{-3}
1992	5.0×10^{-3}
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}

Figure 3.7
Carbon-14 in liquid effluent from the Bruce-B nuclear generating station (1999)
DRL since 1990: 4.8×10^{2} TBq



Year	TBq
1999	3.6×10^{-2}

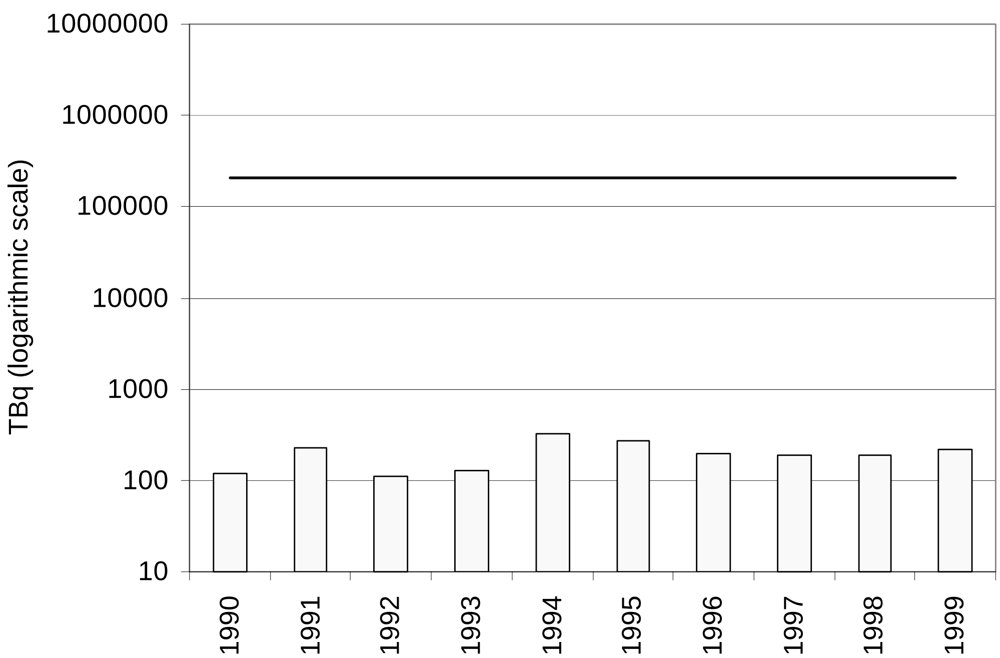
The Darlington nuclear generating station consists of four nuclear reactors, the first of which started up in 1989, and a tritium removal facility which started operations in 1988. Both facilities are located in Ontario on the shore of Lake Ontario near the town of Bowmanville.

Radioactive release data for gaseous and liquid effluents released between 1990 and 1999 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 both elemental and oxide forms occur due to the operation of the tritium removal facility.

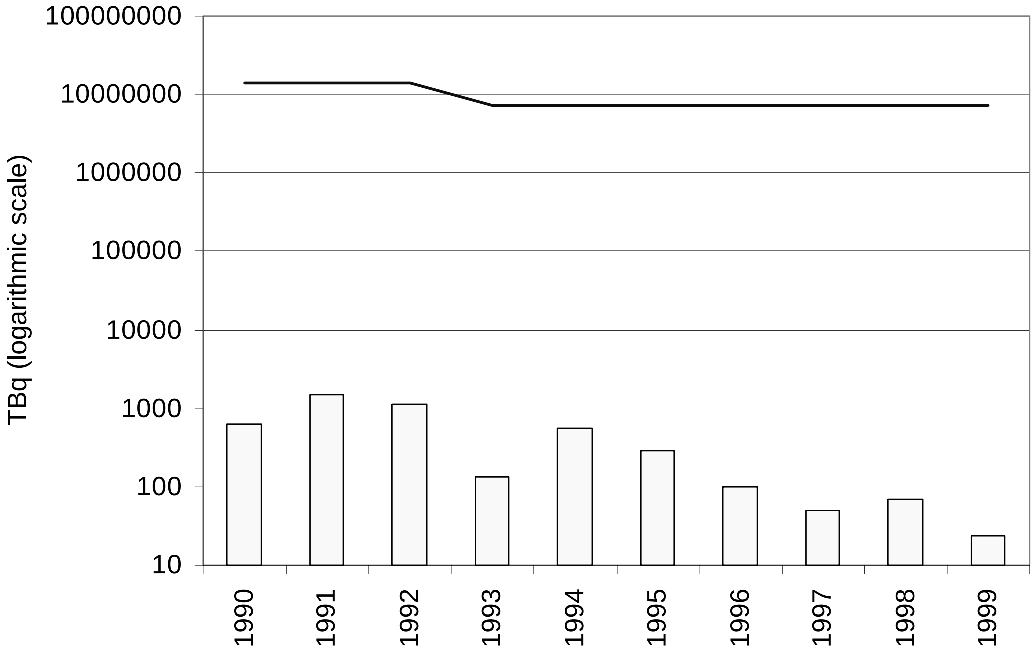
Darlington began reporting carbon-14 releases in gaseous and liquid effluents in 1999.

Figure 4.1
Tritium oxide in gaseous effluent from the Darlington nuclear generating station (1990-1999)
DRL since 1989: 2.1×10^5 TBq



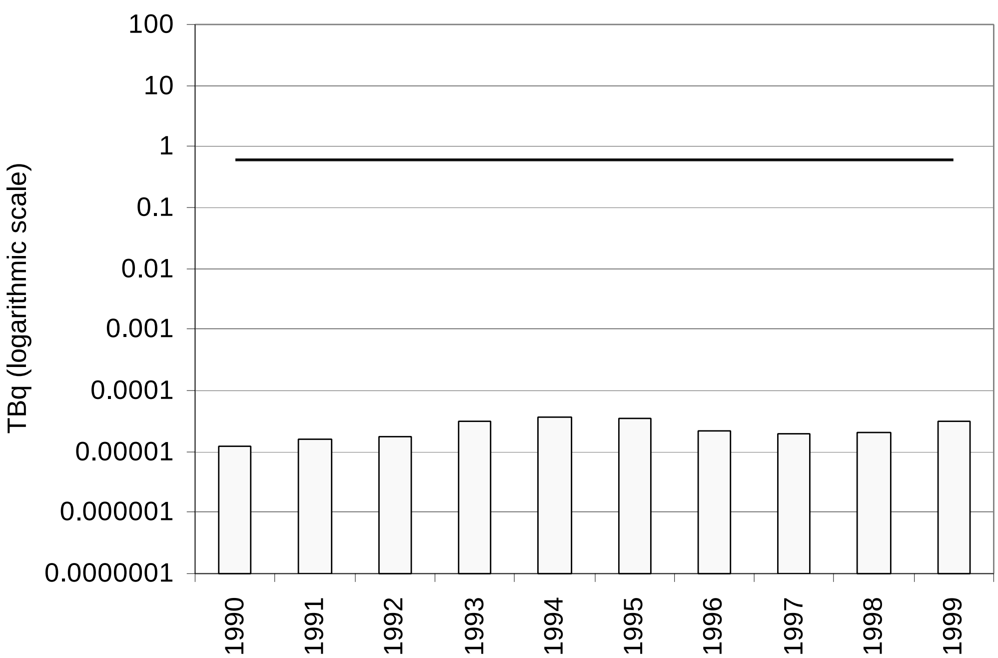
Year	TBq
1990	120
1991	230
1992	110
1993	130
1994	330
1995	270
1996	200
1997	190
1998	190
1999	218

Figure 4.2
Elemental tritium in gaseous effluent from the Darlington nuclear generating station (1990-1999)
DRL since 1993: 7.3×10^6 TBq



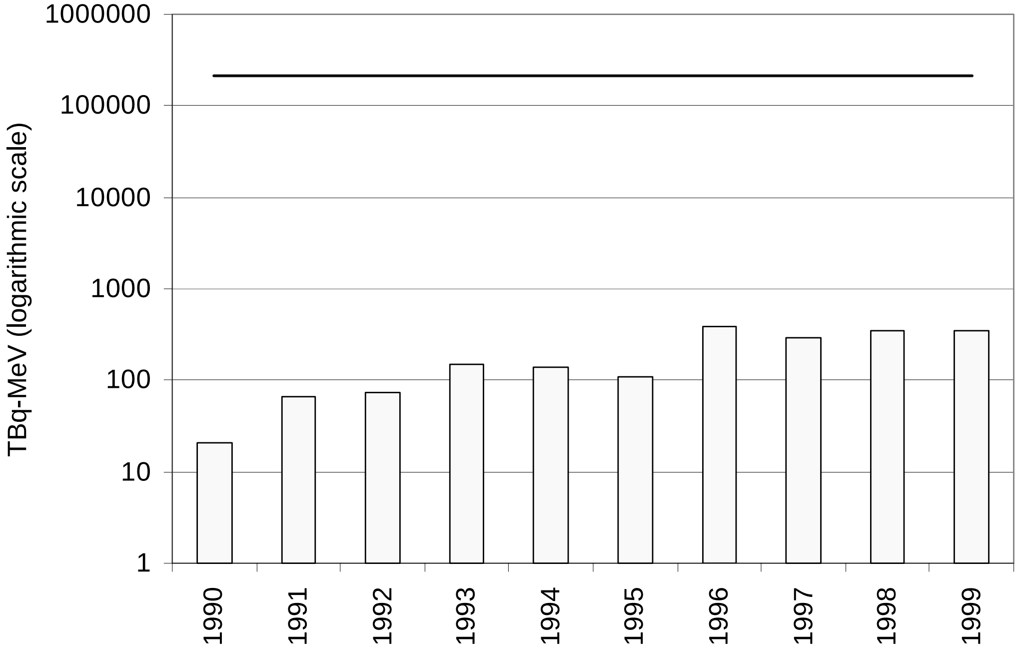
Year	TBq
1990	6.3×10^2
1991	1.5×10^3
1992	1.1×10^3
1993	1.3×10^2
1994	5.6×10^2
1995	2.9×10^2
1996	1.0×10^2
1997	5.0×10^1
1998	7.0×10^1
1999	2.4×10^1

Figure 4.3
Iodine-131 in gaseous effluent from the Darlington nuclear generating station (1990-1999)
DRL since 1989: 0.6 TBq



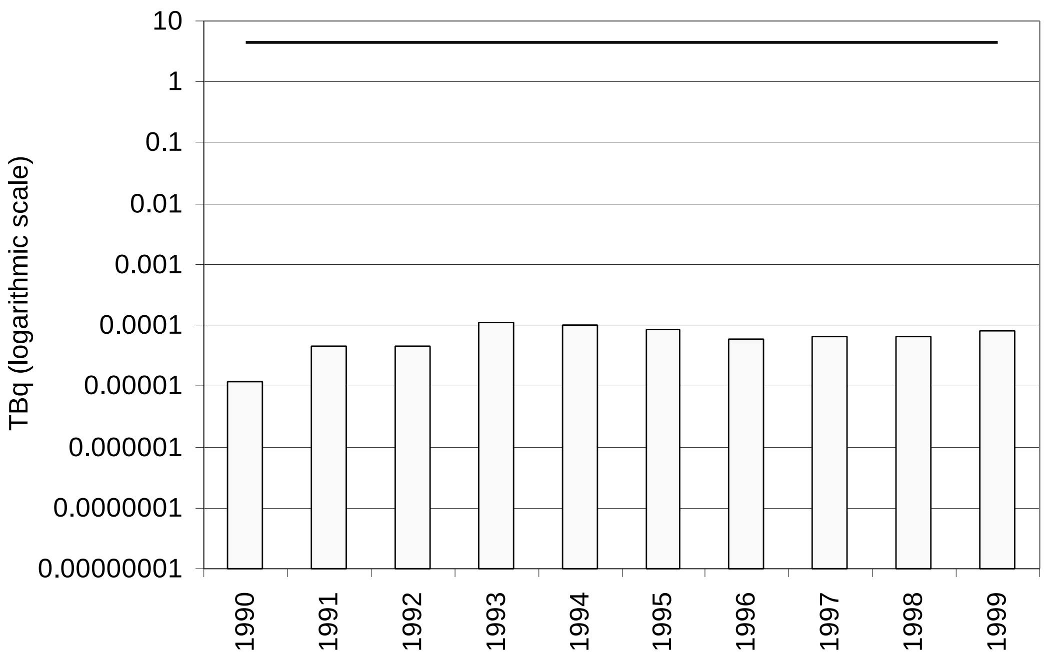
Year	TBq
1990	1.2×10^{-5}
1991	1.6×10^{-5}
1992	1.8×10^{-5}
1993	3.1×10^{-5}
1994	3.6×10^{-5}
1995	3.4×10^{-5}
1996	2.2×10^{-5}
1997	2.0×10^{-5}
1998	2.1×10^{-5}
1999	3.2×10^{-5}

Figure 4.4
Noble gas in effluent from the Darlington nuclear generating station (1990-1999)
DRL since 1989: 2.1×10^5 TBq-MeV



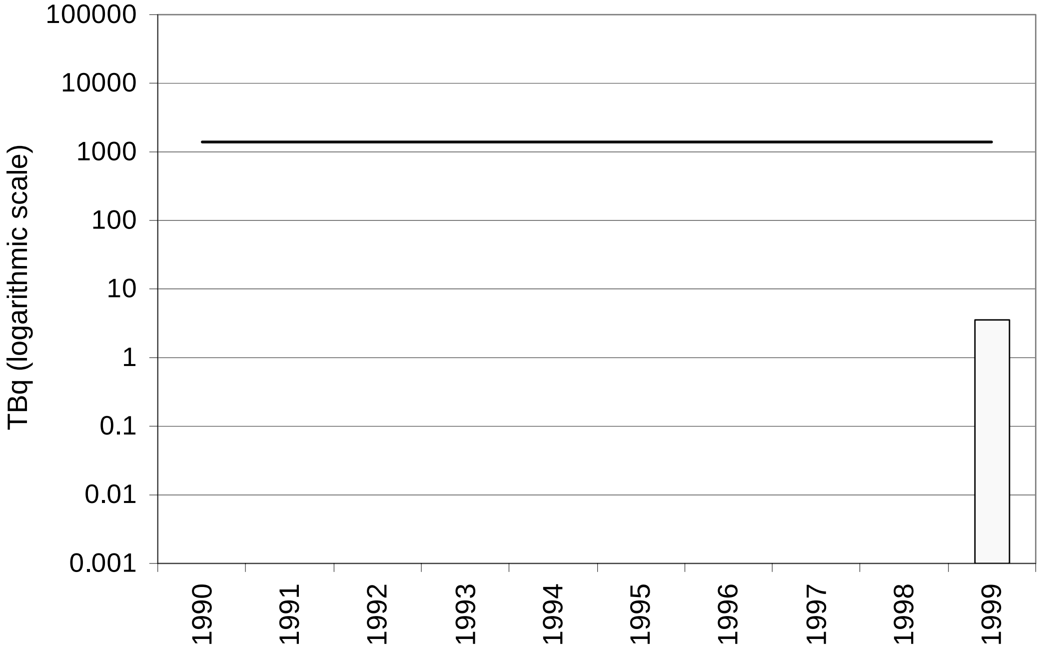
Year	TBq-MeV
1990	21
1991	67
1992	73
1993	150
1994	140
1995	110
1996	380
1997	295
1998	350
1999	344

Figure 4.5
Radioactive particulate in gaseous effluent from the Darlington nuclear generating station (1990-1999)
DRL since 1989: 4.4 TBq



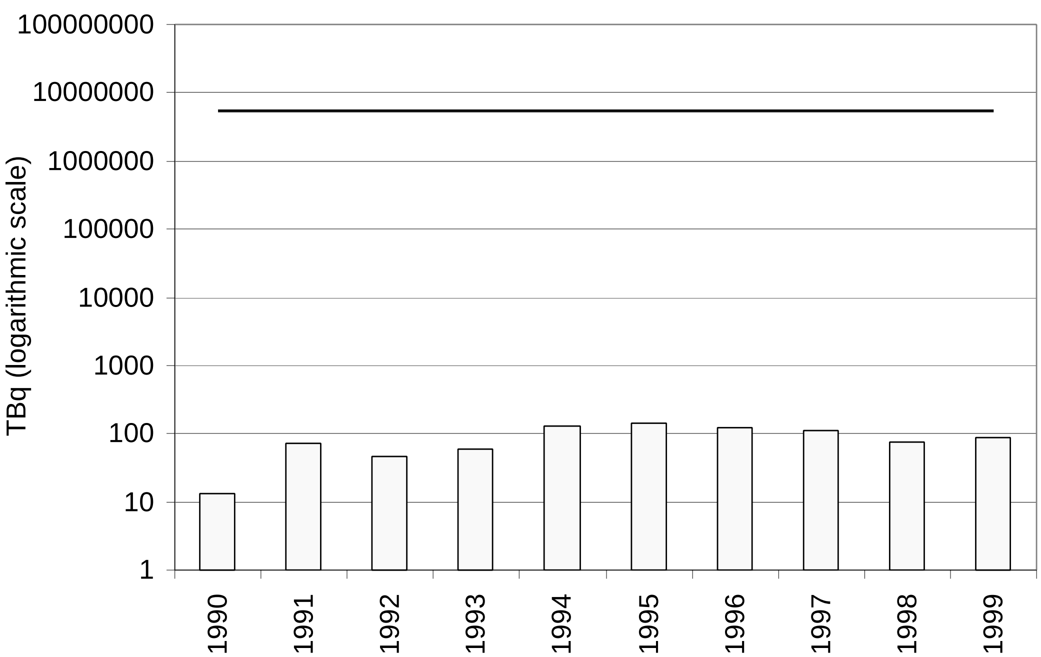
Year	TBq
1990	1.2×10^{-5}
1991	4.6×10^{-5}
1992	4.6×10^{-5}
1993	1.1×10^{-4}
1994	1.0×10^{-4}
1995	8.5×10^{-5}
1996	5.8×10^{-5}
1997	6.5×10^{-5}
1998	6.5×10^{-5}
1999	8.2×10^{-5}

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



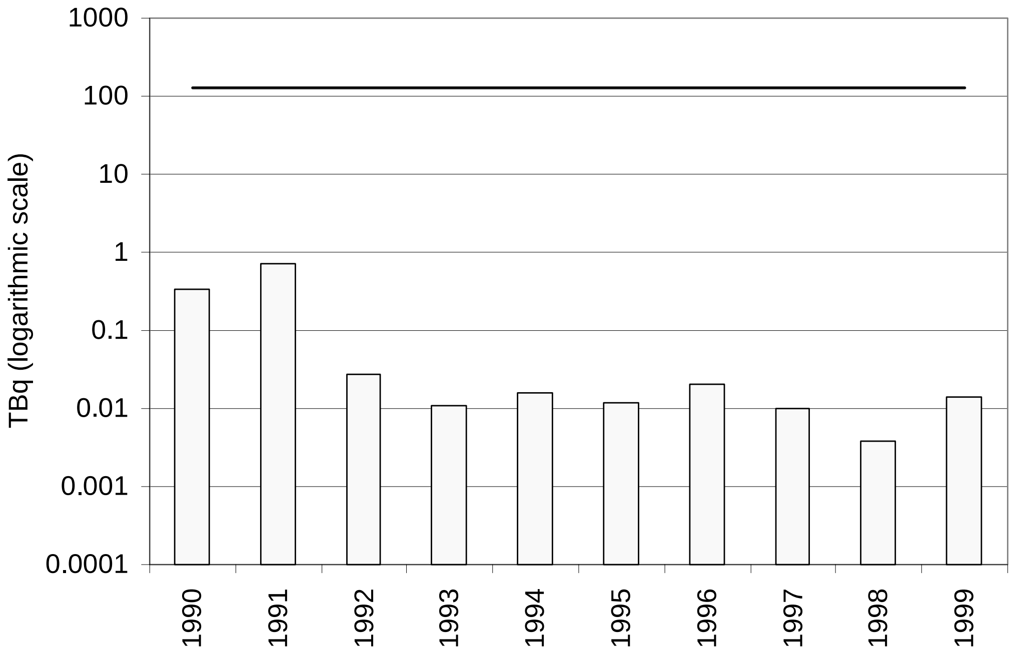
Year	TBq
1999	3.5

Figure 4.7
Tritium oxide in liquid effluent from the Darlington nuclear generating station (1990-1999)
DRL since 1989: 5.3×10^6 TBq



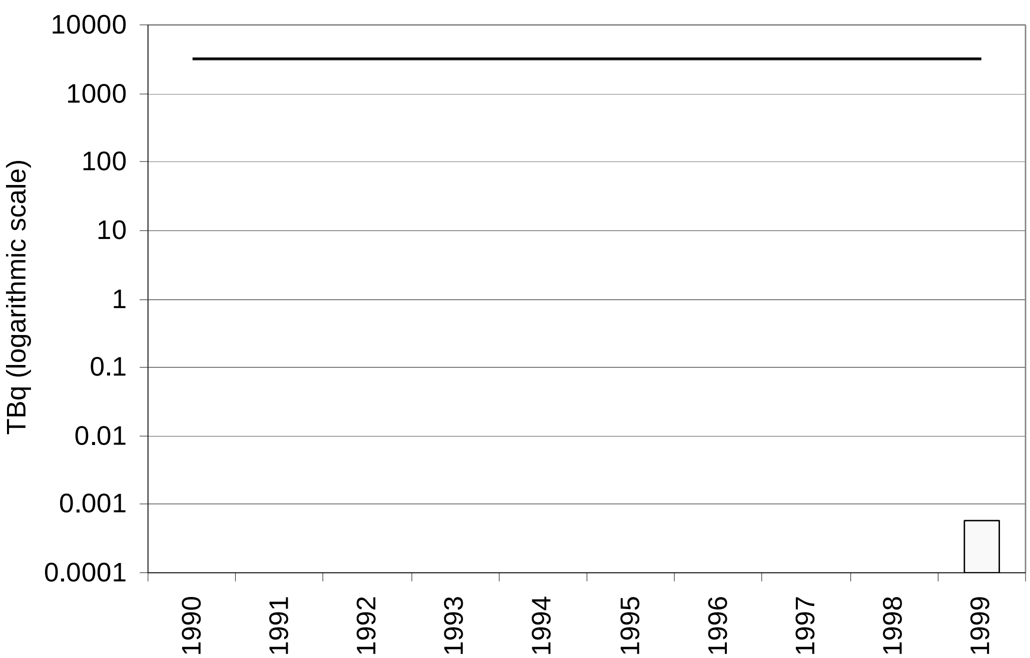
Year	TBq
1990	13
1991	71
1992	46
1993	58
1994	130
1995	140
1996	120
1997	112
1998	75
1999	89

Figure 4.8
Gross beta-gamma activity in liquid effluent from the Darlington nuclear generating station (1990-1999)
DRL since 1989: 130 TBq



Year	TBq
1990	3.3×10^{-1}
1991	7.1×10^{-1}
1992	2.7×10^{-2}
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}

Figure 4.9
Carbon-14 in liquid effluent from the Darlington nuclear generating station (1999)
DRL since 1989: 3.2×10^3 TBq



Year	TBq
1999	5.7×10^{-4}

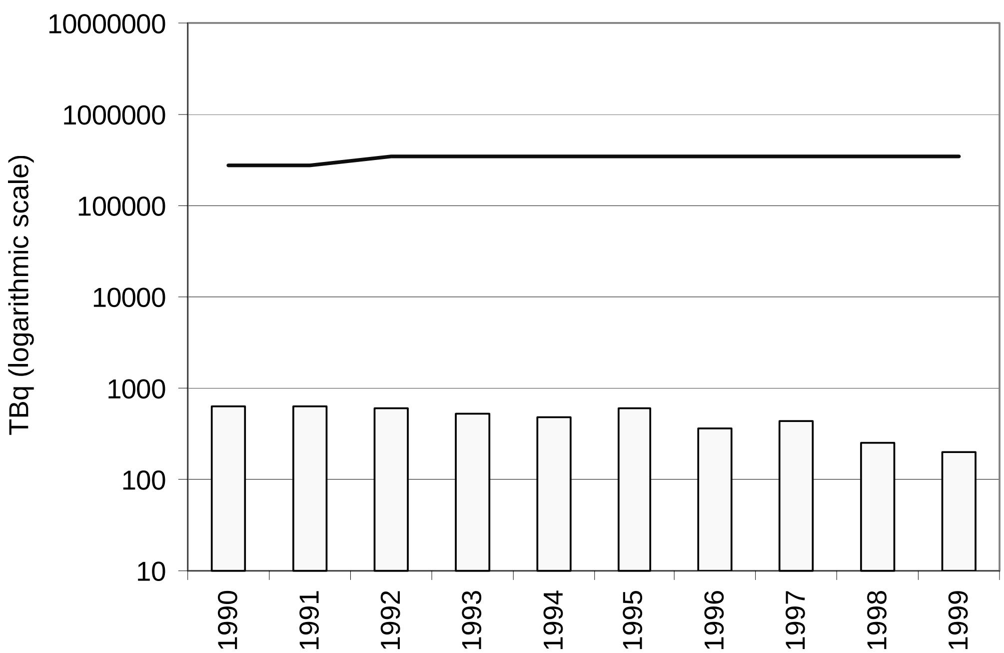
The Pickering-A nuclear generating station consists of four nuclear reactors which started up in 1971. It is located in Ontario on the shore of Lake Ontario near the town of Pickering.

In 1997 as part of its extensive recovery program, Ontario Hydro (now Ontario Power Generation) temporarily shut down all Pickering-A reactors. During 1999 all Pickering-A reactors were maintained in a guaranteed shut-down condition.

Radioactive release data for gaseous and liquid effluents released between 1990 and 1999 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 in the liquid effluents are tritium, in the form of tritium oxide (Figure 5.6) and gross beta-gamma activity (Figure 5.7).

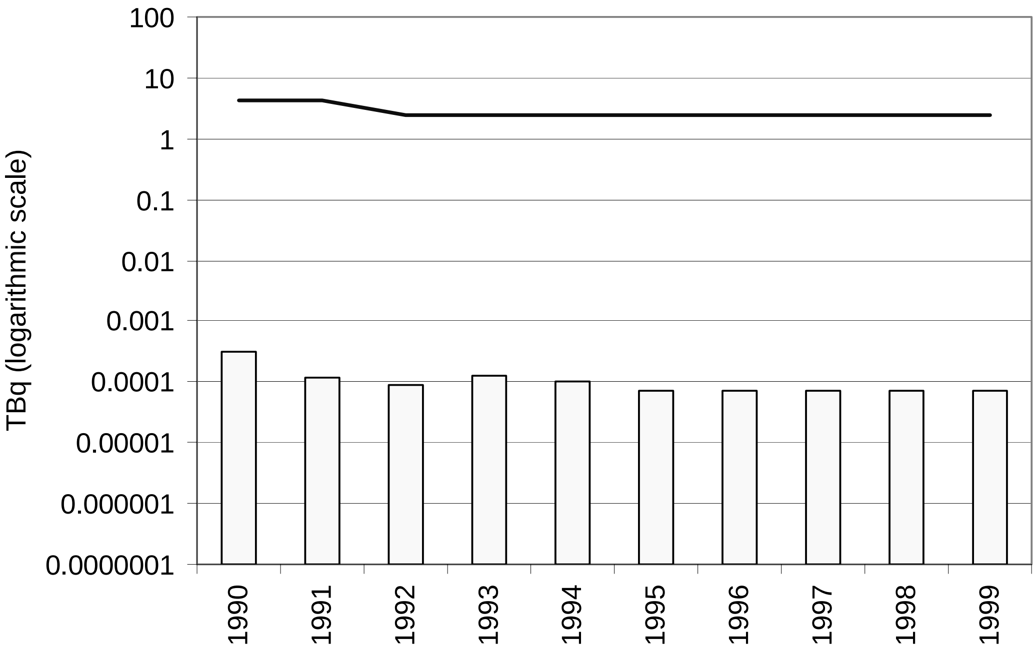
In October 1992, Pickering-A derived release limits were revised and incorporated into its licence. Although in certain instances, the revised DRLs were greater than the existing DRLs (e.g. tritiated water in gaseous effluent), the station operating targets were not permitted to increase. In those cases where the revised DRL was less than the existing DRL, the station operating target was required to decrease proportionately.

Figure 5.1
Tritium oxide in gaseous effluent from the Pickering-A nuclear generating station (1990-1999)
DRL since 1992: 3.4×10^5 TBq



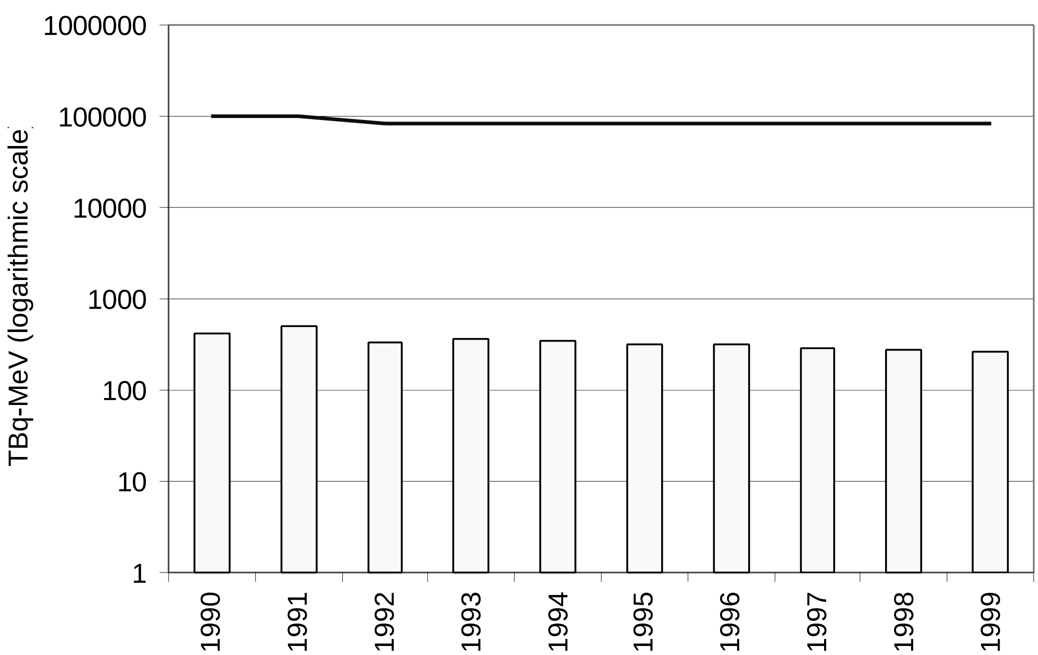
Year	TBq
1990	6.3×10^2
1991	6.4×10^2
1992	5.9×10^2
1993	5.2×10^2
1994	4.8×10^2
1995	5.9×10^2
1996	3.7×10^2
1997	4.4×10^2
1998	2.5×10^2
1999	2.0×10^2

Figure 5.2
Iodine-131 in gaseous effluent from the Pickering-A nuclear generating station (1990-1999)
DRL since 1992: 2.4 TBq



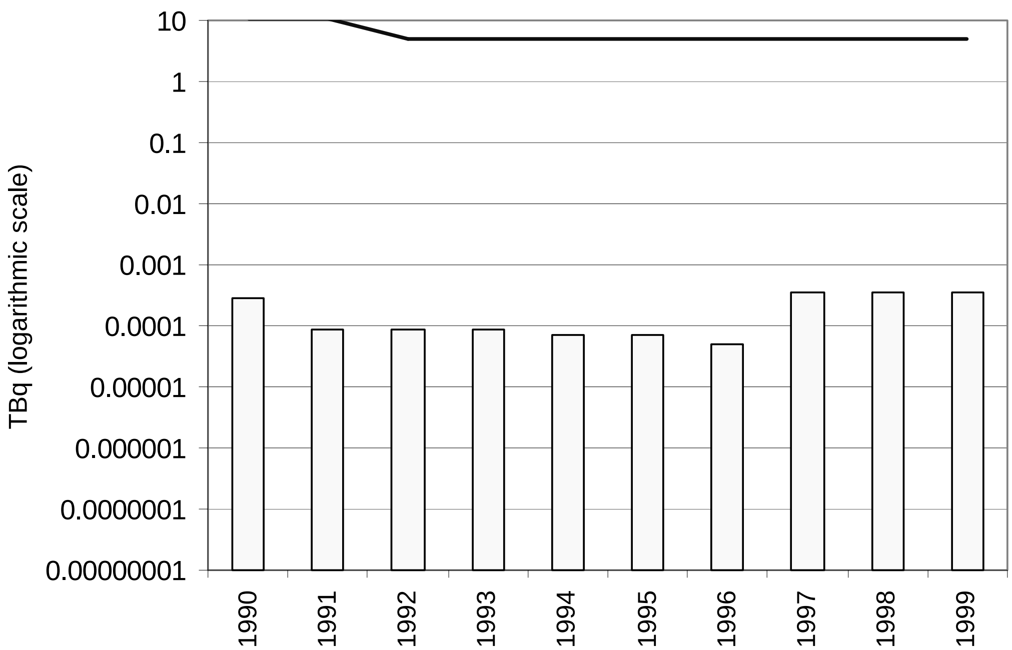
Year	TBq
1990	3.2×10^{-4}
1991	1.2×10^{-4}
1992	8.9×10^{-5}
1993	1.3×10^{-4}
1994	1.0×10^{-4}
1995	7.4×10^{-5}
1996	7.3×10^{-5}
1997	7.4×10^{-5}
1998	7.0×10^{-5}
1999	7.2×10^{-5}

Figure 5.3
Noble gas in effluent from the Pickering-A nuclear generating station (1990-1999)
DRL since 1992: 8.3×10^4 TBq-MeV



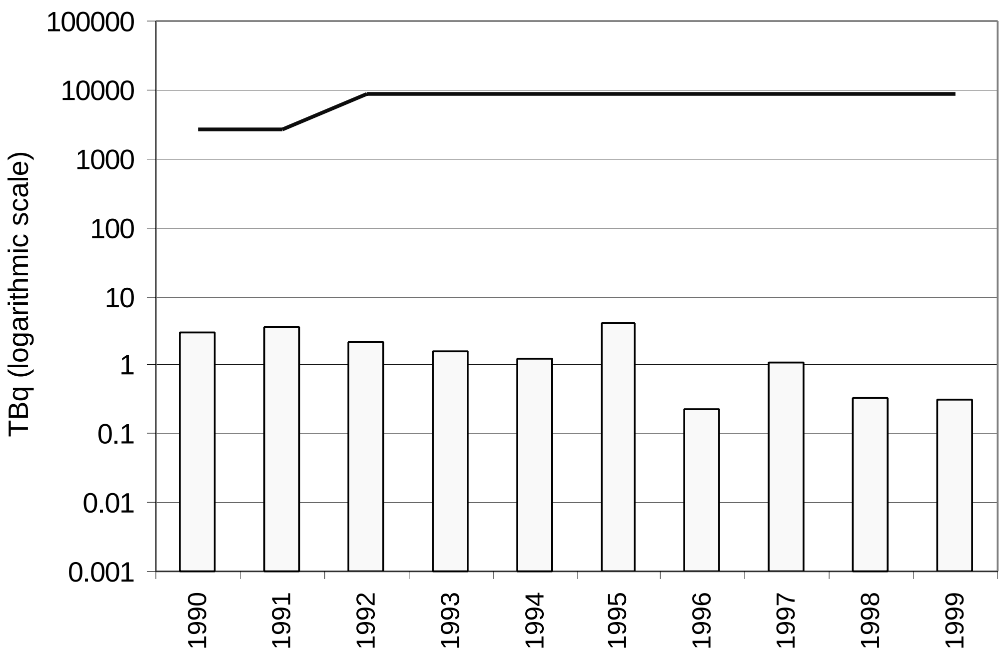
Year	TBq-MeV
1990	4.1×10^{2}
1991	5.0×10^{2}
1992	3.3×10^{2}
1993	3.7×10^{2}
1994	3.4×10^{2}
1995	3.1×10^{2}
1996	3.1×10^{2}
1997	2.9×10^{2}
1998	2.7×10^{2}
1999	2.6×10^{2}

Figure 5.4
Radioactive particulate in gaseous effluent from the Pickering-A nuclear generating station (1990-1999)
DRL since 1992: 5.0 TBq



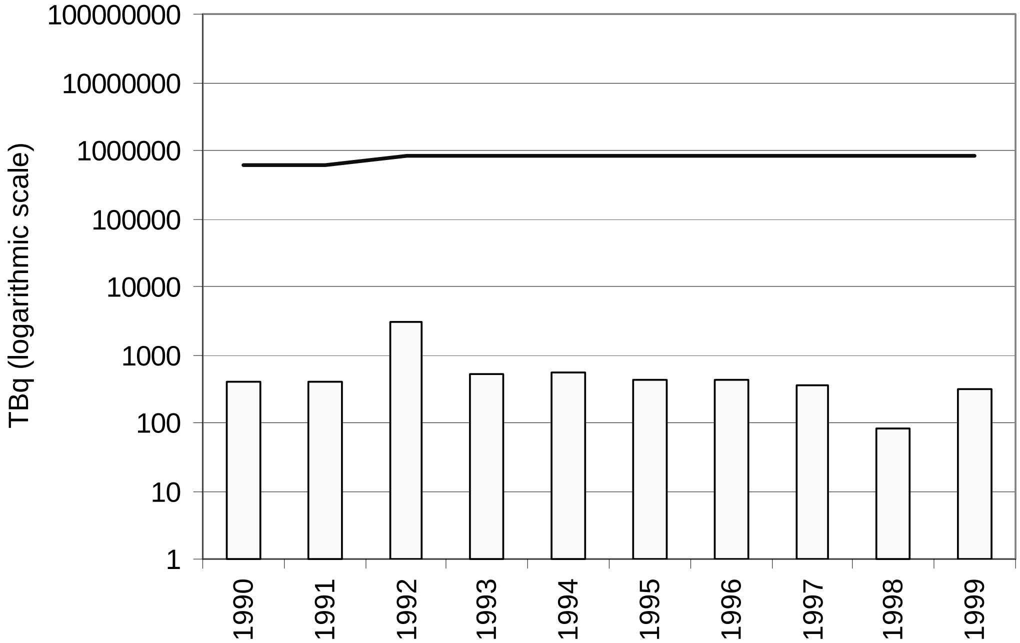
Year	TBq
1990	2.9×10^{-4}
1991	8.7×10^{-5}
1992	8.9×10^{-5}
1993	8.5×10^{-5}
1994	7.0×10^{-5}
1995	7.0×10^{-5}
1996	5.1×10^{-5}
1997	3.6×10^{-4}
1998	3.6×10^{-4}
1999	3.6×10^{-4}

Figure 5.5
Carbon-14 in gaseous effluent from the Pickering-A nuclear generating station (1990-1999)
DRL since 1992: 8800 TBq



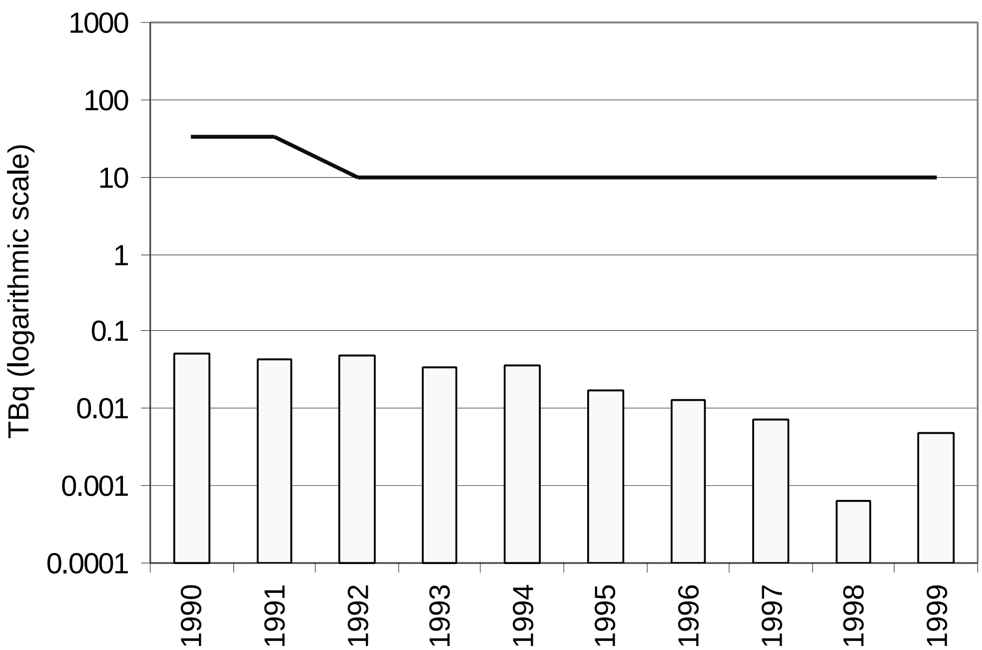
Year	TBq
1990	2.9
1991	3.5
1992	2.1
1993	1.6
1994	1.2
1995	4.1
1996	0.23
1997	1.1
1998	0.33
1999	0.32

Figure 5.6
Tritium oxide in liquid effluent from the Pickering-A nuclear generating station (1990-1999)
DRL since 1992: 8.3×10^5 TBq



Year	TBq
1990	4.1×10^2
1991	4.0×10^2
1992	3.0×10^3
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

Figure 5.7
Gross beta-gamma activity in liquid effluent from the Pickering-A nuclear generating station (1990-1999)
DRL since 1992: 9.7 TBq



Year	TBq
1990	5.2×10^{-2}
1991	4.4×10^{-2}
1992	4.8×10^{-2}
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}

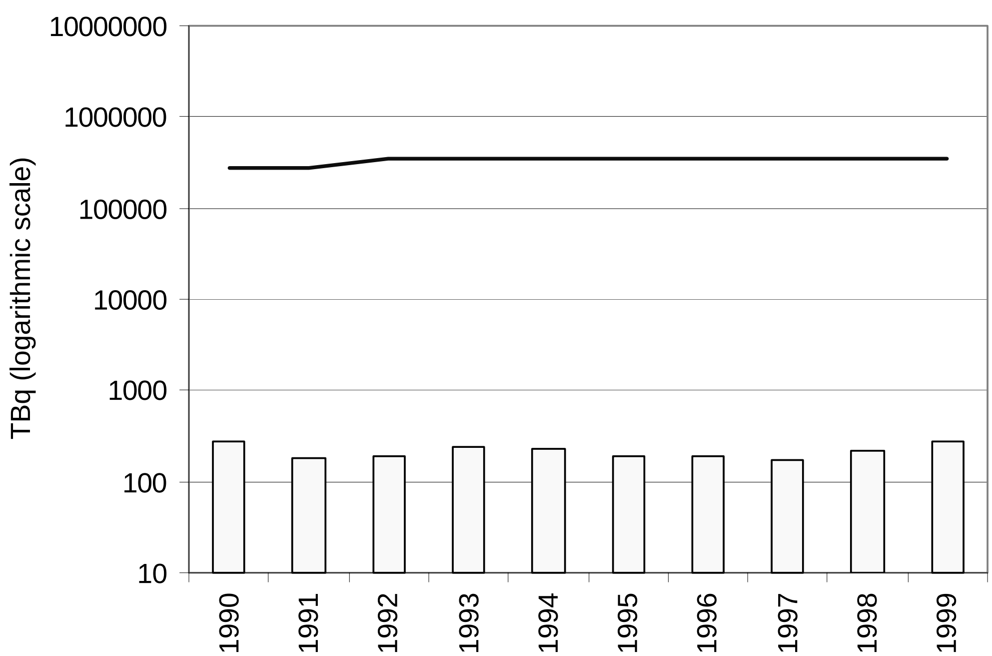
The Pickering-B nuclear generating station consists of four nuclear reactors which started up in 1982. It is located in Ontario on the shore of Lake Ontario near the town of Pickering.

Radioactive release data for gaseous and liquid effluents released between 1990 and 1999 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) and radioactive particulates (Figure 6.4); while those in the liquid effluents are tritium, in the form of tritium oxide (Figure 6.5), gross beta-gamma activity (Figure 6.6) and carbon-14 (Figure 6.7).

Pickering-B began reporting carbon-14 in liquid releases in 1999 and is scheduled to begin reporting carbon-14 in gaseous releases in 2000.

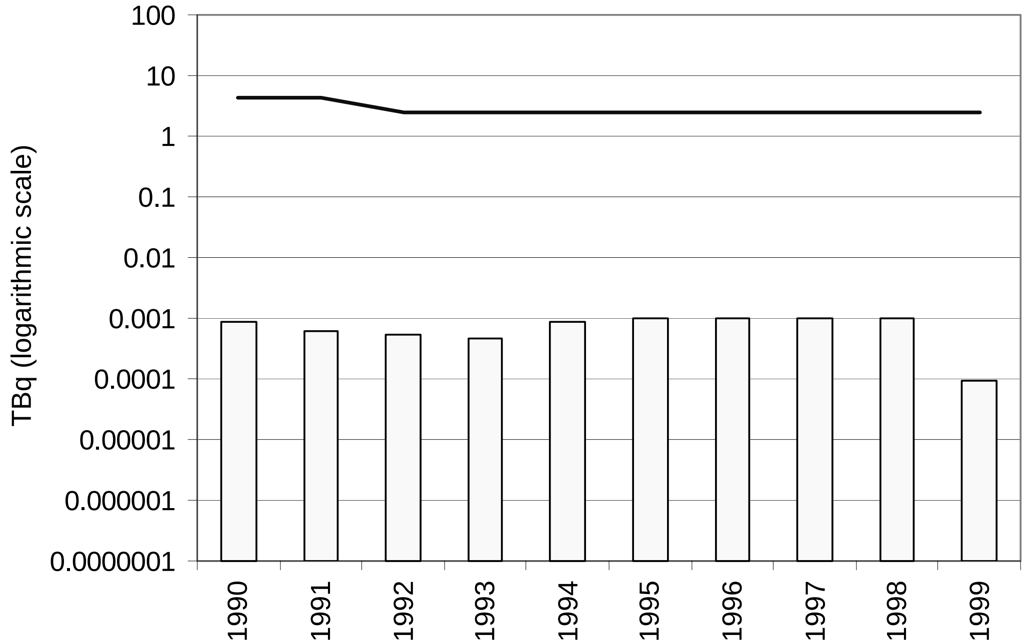
In October 1992, Pickering-B derived release limits were revised and incorporated into its licence. Although in certain instances, the revised DRLs were greater than the existing DRLs (e.g. tritiated water in gaseous effluent), the station operating targets were not permitted to increase. In those cases where the revised DRL was less than the existing DRL, the station operating target was required to decrease proportionately.

Figure 6.1
Tritium oxide in gaseous effluent from the Pickering-B nuclear generating station (1990-1999)
DRL since 1992: 3.4×10^5 TBq



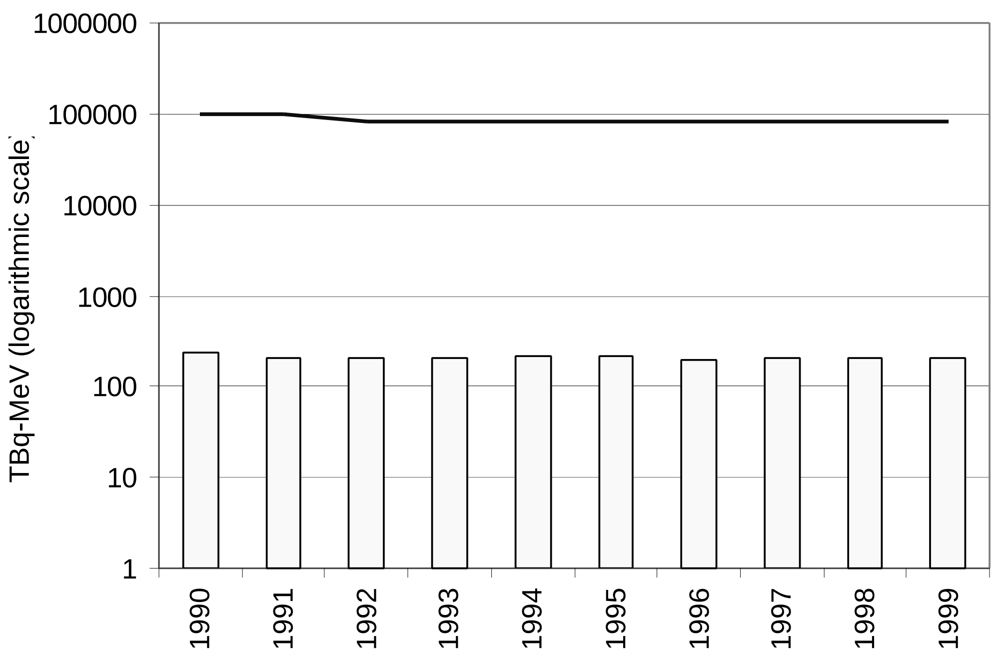
Year	TBq
1990	2.8×10^2
1991	1.8×10^2
1992	1.9×10^2
1993	2.4×10^2
1994	2.3×10^2
1995	1.9×10^2
1996	1.9×10^2
1997	1.7×10^2
1998	2.2×10^2
1999	2.7×10^2

Figure 6.2
Iodine-131 in gaseous effluent from the Pickering-B nuclear generating station (1990-1999)
DRL since 1992: 2.4 TBq



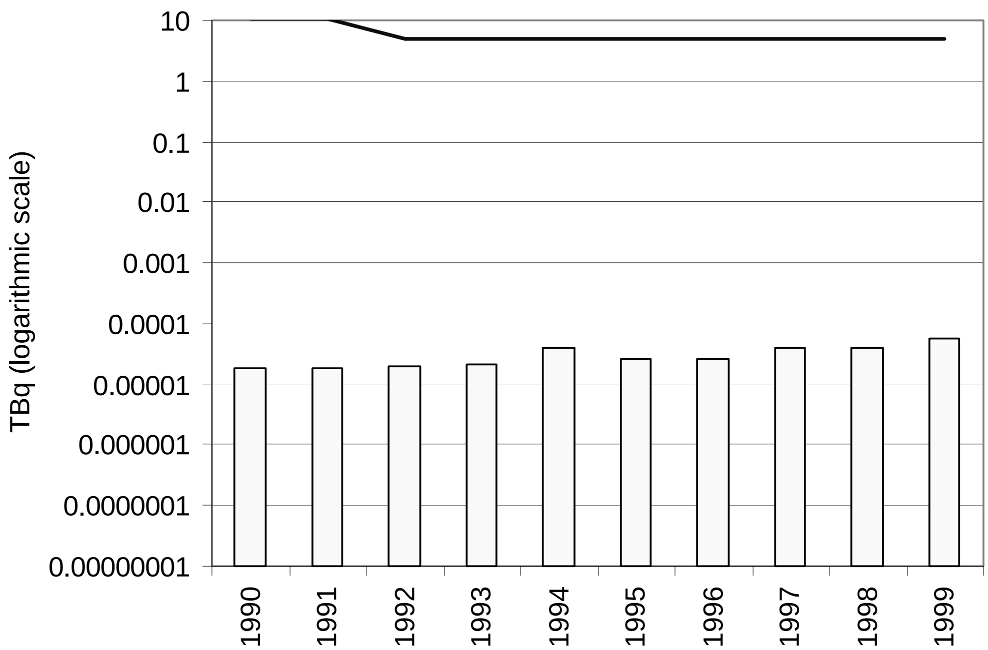
Year	TBq
1990	8.9×10^{-5}
1991	6.3×10^{-5}
1992	5.2×10^{-5}
1993	4.8×10^{-5}
1994	8.5×10^{-5}
1995	1.0×10^{-4}
1996	9.8×10^{-5}
1997	9.9×10^{-5}
1998	9.7×10^{-5}
1999	9.6×10^{-5}

Figure 6.3
Noble gas in effluent from the Pickering-B nuclear generating station (1990-1999)
DRL since 1992: 8.3×10^4 TBq-MeV



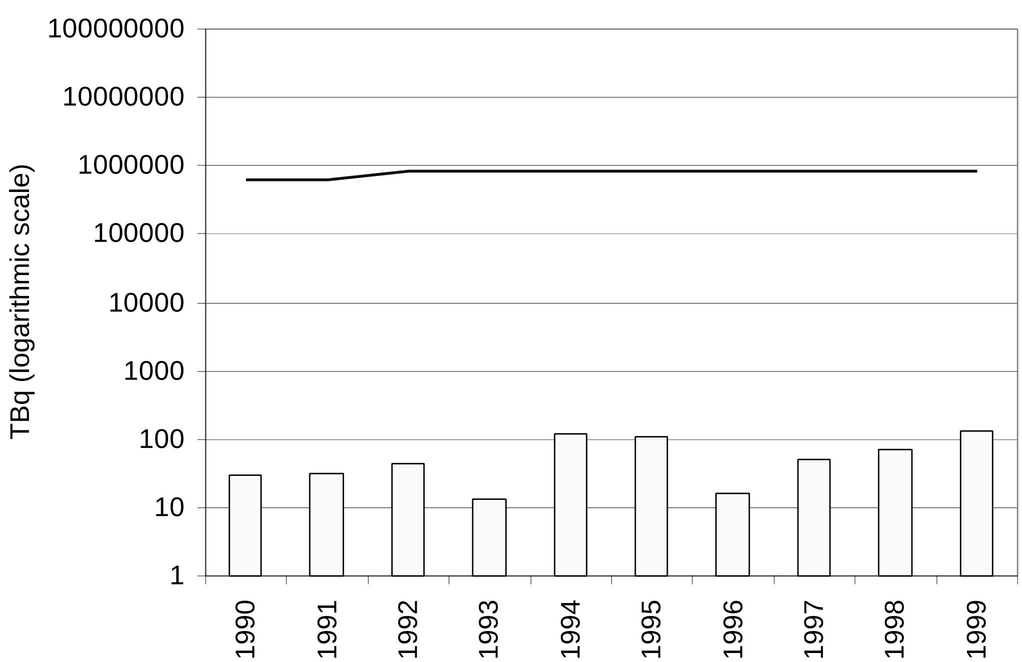
Year	TBq-MeV
1990	2.4×10^{2}
1991	2.1×10^{2}
1992	2.1×10^{2}
1993	2.1×10^{2}
1994	2.2×10^{2}
1995	2.2×10^{2}
1996	2.0×10^{2}
1997	2.1×10^{2}
1998	2.2×10^{2}
1999	2.1×10^{2}

Figure 6.4
Radioactive particulate in gaseous effluent from the Pickering-B nuclear generating station (1990-1999)
DRL since 1992: 5.0 TBq



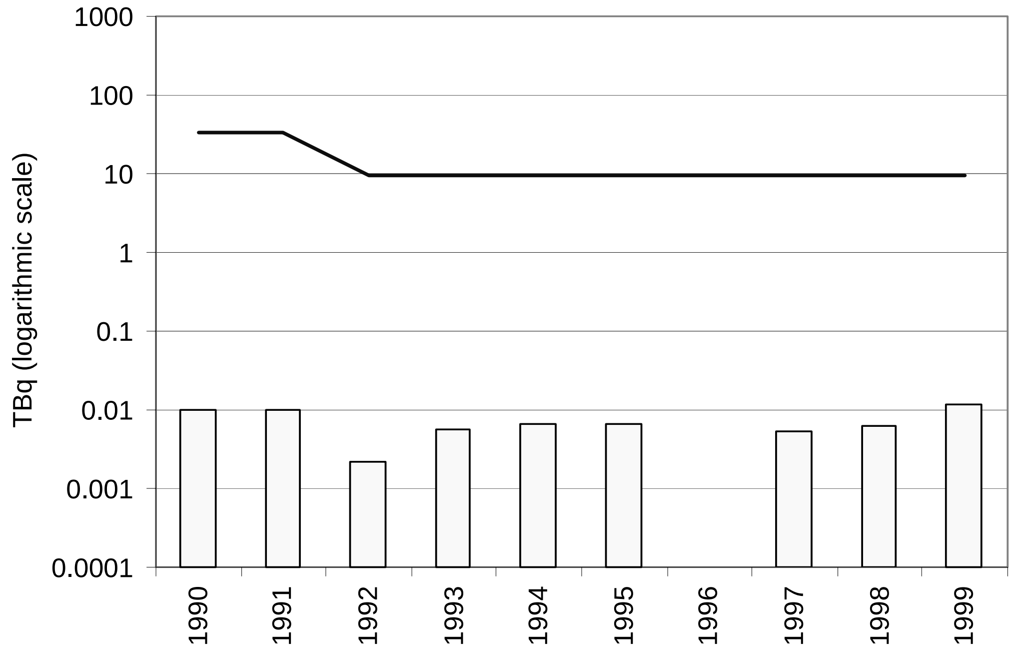
Year	TBq
1990	1.8×10^{-5}
1991	1.9×10^{-5}
1992	2.0×10^{-5}
1993	2.1×10^{-5}
1994	4.1×10^{-5}
1995	2.6×10^{-5}
1996	2.7×10^{-5}
1997	3.9×10^{-5}
1998	4.0×10^{-5}
1999	5.7×10^{-5}

Figure 6.5
Tritium oxide in liquid effluent from the Pickering-B nuclear generating station (1990-1999)
DRL since 1992: 8.3×10^5 TBq



Year	TBq
1990	30
1991	32
1992	44
1993	13
1994	120
1995	110
1996	16
1997	50
1998	71
1999	130

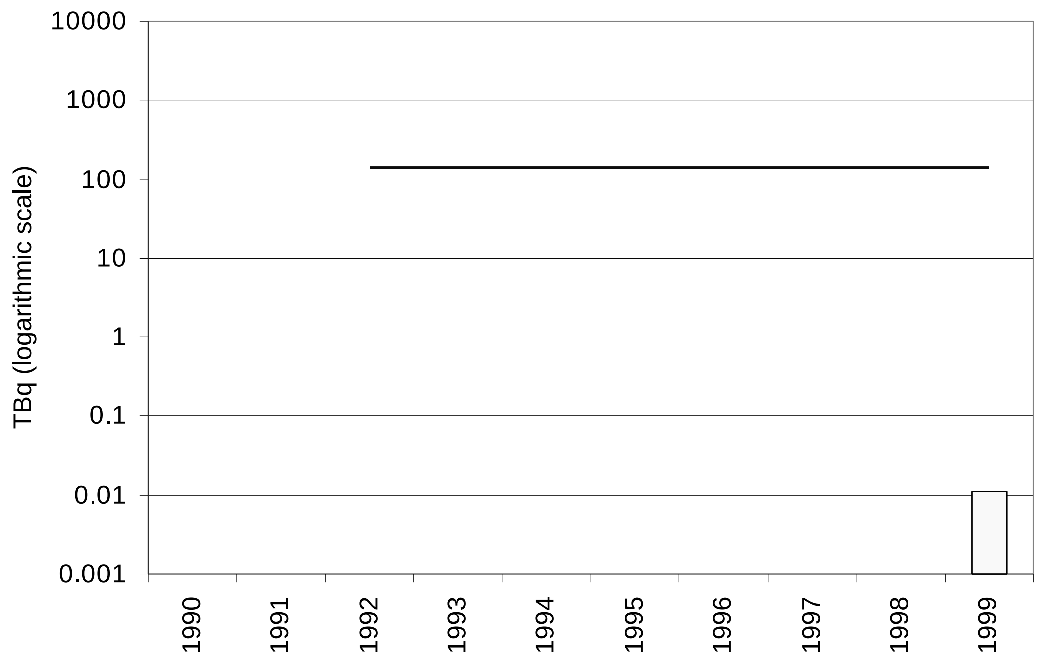
Figure 6.6
Gross beta-gamma activity in liquid effluent from the Pickering-B nuclear generating station (1990-1999)
DRL since 1992: 9.7 TBq



Year	TBq
1990	1.0×10^{-2}
1991	1.0×10^{-2}
1992	2.2×10^{-3}
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}

*ND: not detected

Figure 6.7
Carbon-14 in liquid effluent from the Pickering-B nuclear generating station (1999)
DRL since 1992: 1.4×10^2 TBq



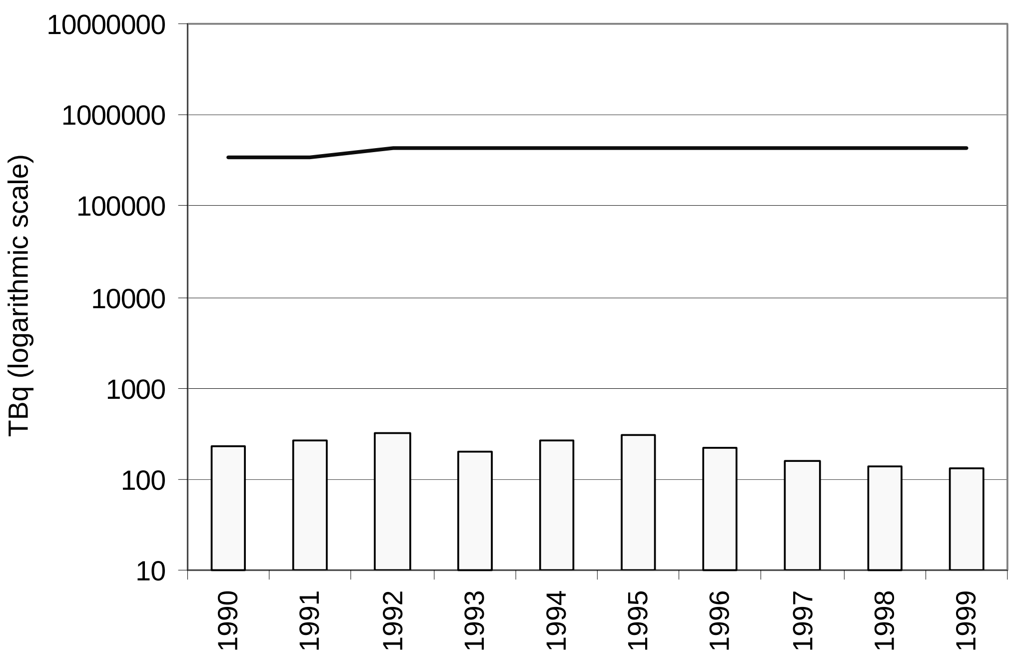
Year	TBq
1999	1.1×10^{-2}

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

Radioactive release data for gaseous and liquid effluents released between 1990 and 1999 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).

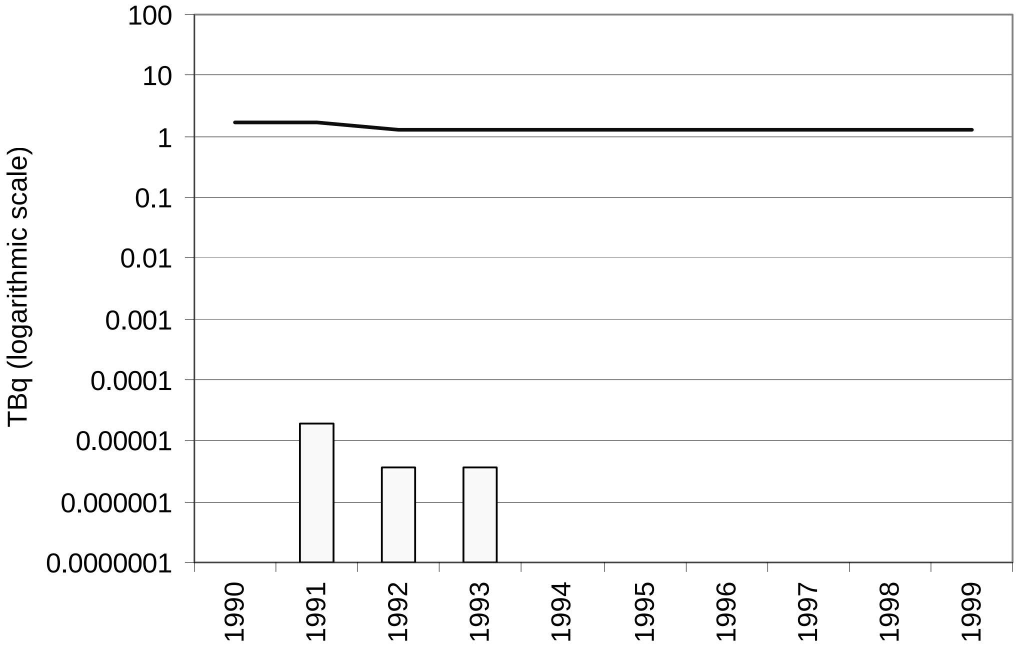
In May 1992, Gentilly-2 derived release limits were revised and incorporated into its licence. DRLs for carbon-14 in gaseous and liquid effluents were introduced in 1992, and therefore only data from 1992 forward appear in Figures 7.5 and 7.8.

Figure 7.1
Tritium oxide in gaseous effluent from the Gentilly-2 nuclear generating station (1990-1999)
DRL since 1992: 4.4×10^5 TBq



Year	TBq
1990	230
1991	270
1992	320
1993	200
1994	260
1995	310
1996	220
1997	160
1998	140
1999	131

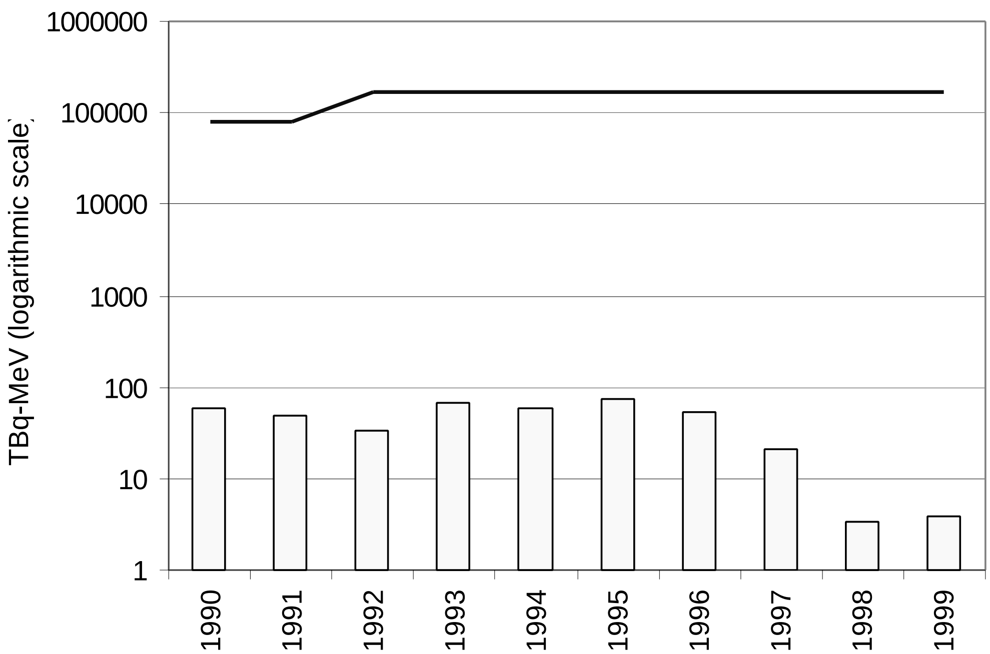
Figure 7.2
Iodine-131 in gaseous effluent from the Gentilly-2 nuclear generating station (1990-1999)
DRL since 1992: 1.3 TBq



Year	TBq
1990	ND*
1991	1.9×10^{-5}
1992	3.7×10^{-6}
1993	3.7×10^{-6}
1994	ND*
1995	ND*
1996	ND*
1997	ND*
1998	ND*
1999	ND*

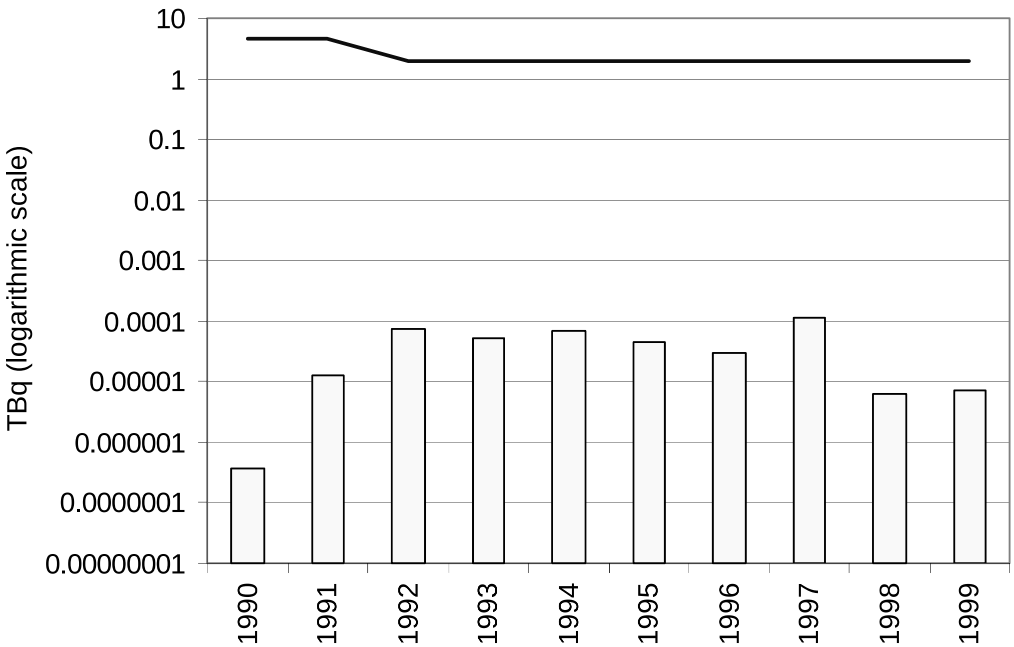
*ND: not detected.

Figure 7.3
Noble gas in effluent from the Gentilly-2 nuclear generating station (1990-1999)
DRL since 1992: 1.7×10^5 TBq-MeV



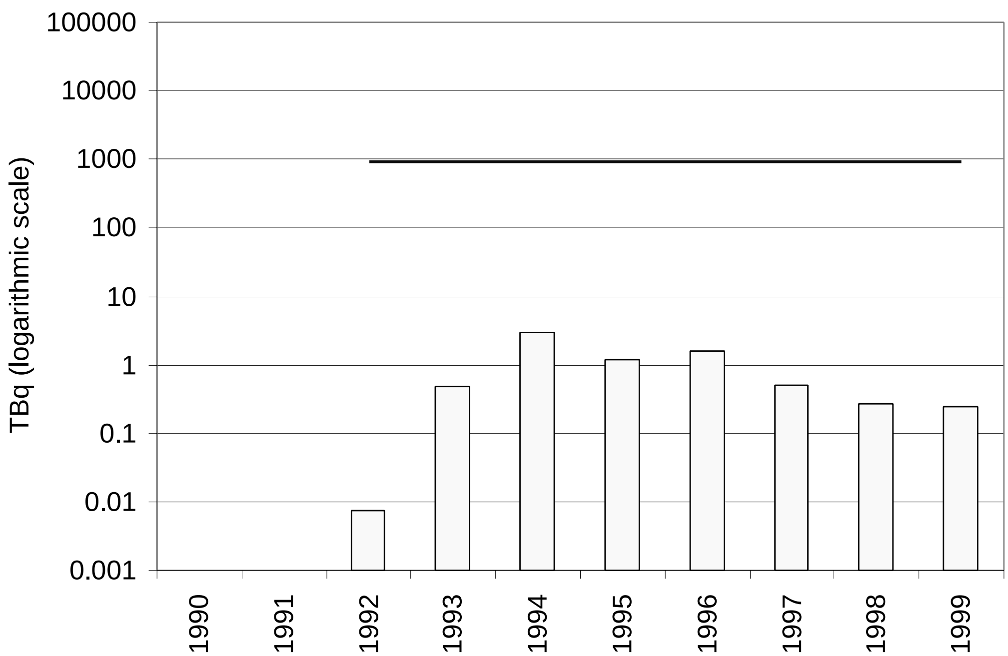
Year	TBq-MeV
1990	60
1991	48
1992	33
1993	69
1994	59
1995	73
1996	54
1997	21
1998	3.4
1999	3.8

Figure 7.4
Radioactive particulate in gaseous effluent from the Gentilly-2 nuclear generating station (1990-1999)
DRL since 1992: 1.9 TBq



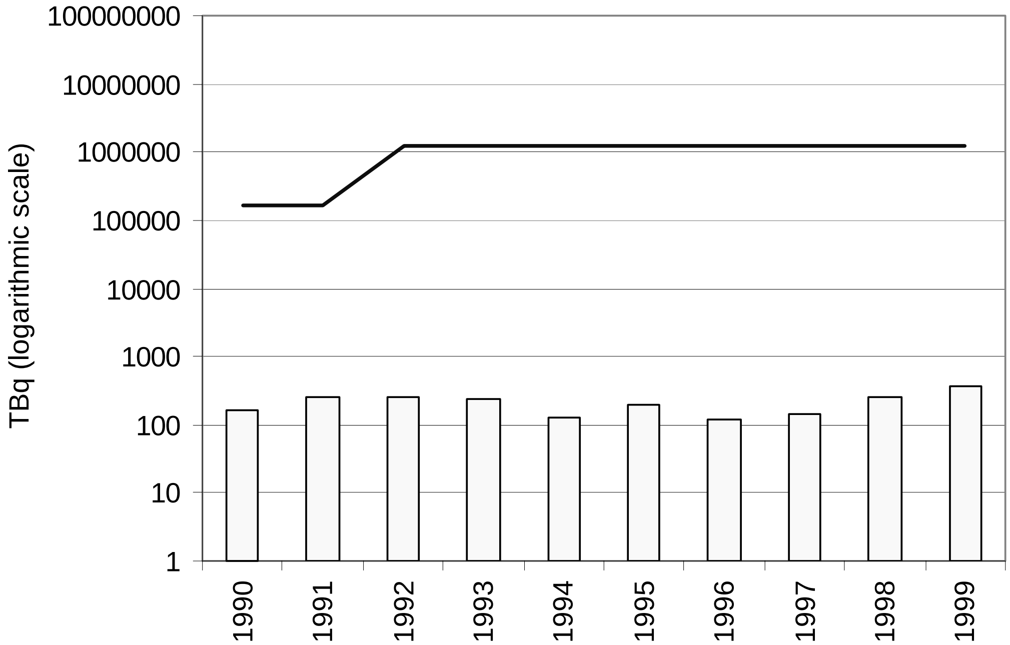
Year	TBq
1990	3.7×10^{-7}
1991	1.3×10^{-5}
1992	7.4×10^{-5}
1993	5.2×10^{-5}
1994	7.0×10^{-5}
1995	4.5×10^{-5}
1996	3.0×10^{-5}
1997	1.1×10^{-4}
1998	6.4×10^{-6}
1999	7.4×10^{-6}

Figure 7.5
Carbon-14 in gaseous effluent from the Gentilly-2 nuclear generating station (1992-1999)
DRL since 1992: 910 TBq



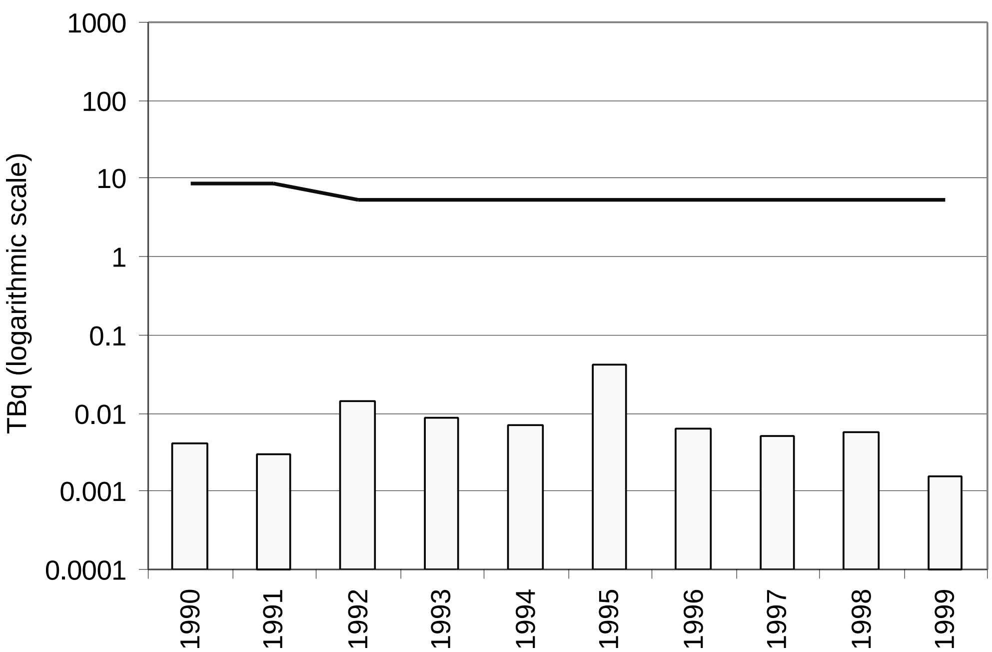
Year	TBq
1992	7.4×10^{-3}
1993	0.48
1994	2.9
1995	1.2
1996	1.6
1997	0.50
1998	0.27
1999	0.25

Figure 7.6
Tritium oxide in liquid effluent from the Gentilly-2 nuclear generating station (1990-1999)
DRL since 1992: 1.2×10^6 TBq



Year	TBq
1990	160
1991	250
1992	260
1993	240
1994	130
1995	200
1996	120
1997	140
1998	250
1999	361

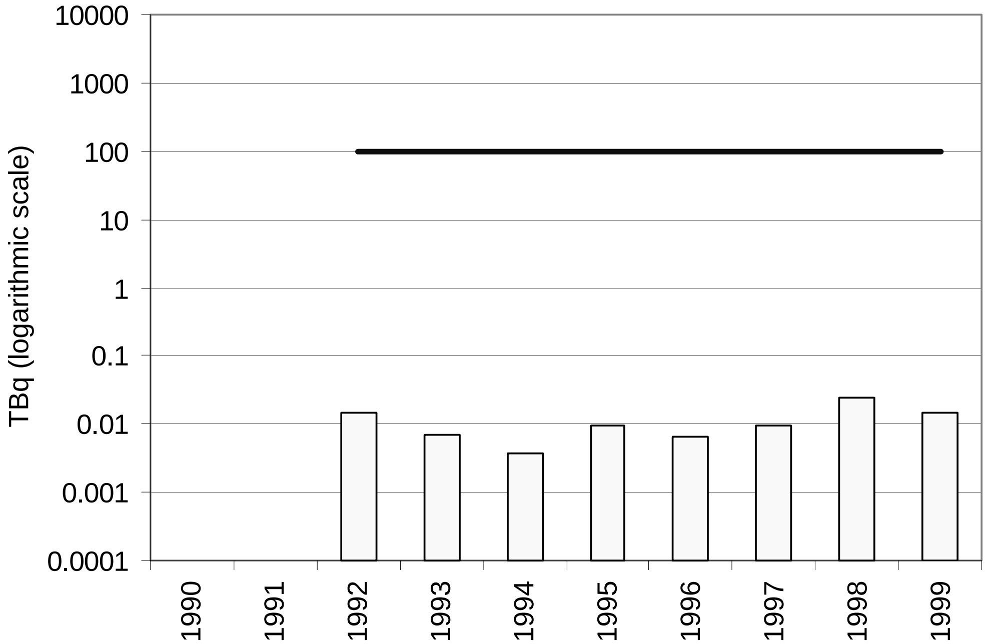
Figure 7.7
Gross beta-gamma activity in liquid effluent from the Gentilly-2 nuclear generating station (1990-1999)
DRL since 1992: 5.3 TBq



Year	TBq
1990	4.2×10^{-3}
1991	3.0×10^{-3}
1992	1.4×10^{-2}
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}

Figure 7.8

Carbon-14 in liquid effluent from the Gentilly-2 nuclear generating station (1992-1999)
DRL since 1992: 100 TBq



Year	TBq
1992	1.5×10^{-2}
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}

GLOSSARY

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

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 AECB 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 AECB 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 *Atomic Energy Control Regulations*, prior to June 2000.

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 5 mSv for a member of the public with respect to any licensed nuclear activity. The limit for atomic radiation workers is 50 mSv per year.

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.