



# Radioactive Release Data from Canadian Nuclear Power Plants 2001-10

INFO-0210/Rev. 14



January 2012



***Radioactive Release Data from Canadian Nuclear Power Plants 2001-10***

© Minister of Public Works and Government Services Canada (PWGSC) 2012  
PWGSC catalogue number CC172-13/2010E-PDF  
ISBN 978-1-100-19909-2

Published by the Canadian Nuclear Safety Commission (CNSC)  
CNSC catalogue number: INFO-0210 Revision 14

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*Également publié en français sous le titre de : Données sur les rejets radioactifs des centrales nucléaires canadiennes de 2001 à 2010*

**Document availability**

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**Cover images from left to right:**

Gentilly-2 Nuclear Generating Station  
Point Lepreau Generating Station  
Pickering A and B Nuclear Generating Stations  
Bruce A and B Nuclear Generating Stations  
Darlington Nuclear Generating Station

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## Executive Summary

The Canadian Nuclear Safety Commission (CNSC) regulates the use of nuclear energy and materials to protect the health, safety and security of Canadians and the environment; and to implement Canada's international commitments on the peaceful use of nuclear energy.

As part of normal operations, nuclear power plants (NPPs) release, in a controlled manner, small quantities of radioactive substances into the atmosphere and bodies of water. These releases are regulated and carefully monitored by the CNSC. CNSC staff verify that NPP licensees have programs in place to identify, control and monitor both gaseous and aqueous releases. CNSC staff also assess environmental performance by reviewing release monitoring data and public radiation doses, among other indicators.

This document presents the results of the effluent monitoring programs of licensees for the 10-year period from 2001 to 2010. During this time, levels of radioactive materials released in the environment from all Canadian NPPs were far below both the derived release limits (DRLs) and the regulatory dose limit to the members of the public.

## Introduction

Nuclear power plants, also called 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 levels of these releases for each operational nuclear power plant in Canada. This report also indicates how these releases compare with the limits imposed by the CNSC as part of its regulatory program. The data show that the levels of gaseous and liquid effluents from all operating nuclear power plants were well below limits during the reporting period covered in this document.

This 14<sup>th</sup> revision of *Radioactive Releases from Canadian Nuclear Power Plants* presents data for the 10-year period from 2001 to 2010. The CNSC collects the data from quarterly operations reports and annual environmental monitoring reports submitted by power reactor licensees to meet requirements of the CNSC regulatory standard S-99, *Reporting Requirements for Operating Nuclear Power Plants*. CNSC staff verify this data through desktop reviews (reviews of paperwork and reports submitted by licensees) and through on-site inspections of licensee monitoring and measuring programs.

This report presents graphs that show both gaseous and liquid effluent releases for each nuclear generating station. Gaseous release data include information on the following substances: tritium in the form of tritium oxide (HTO), iodine-131, noble gases, radioactive particulate and carbon-14. Liquid effluent release data provide information on tritium in the form of tritium oxide (HTO), gross beta-gamma activity and carbon-14. In the case of the Darlington Nuclear Generating Station, airborne releases of elemental tritium (HT) are also given, because the plant includes a tritium removal facility.

Each facility is unique in terms of the type of work performed there, as well its current lifecycle stage (i.e., operating at reduced or full capacity, or in a phase of refurbishment). Therefore, direct comparisons between facilities are not possible, since one facility may have different release quantities of radioactive materials than any other. However, to place the data in perspective, each nuclear generating station's release data are compared to DRLs.

### **Derived Release Limits**

Doses received by members of the public from routine releases at nuclear power plants are too low to be measured directly. Therefore, a quantity known as a derived release limit (DRL) is calculated based on the regulatory dose limit of 1 millisievert per year (1 mSv/y).

DRLs are required because radioactive materials released into the environment, through gaseous and liquid effluents from nuclear power plants, can expose members of the public to low radiation doses via external and internal pathways. External exposure occurs from direct contact with radionuclide-contaminated ground surfaces, or by immersion into contaminated water and air clouds; internal exposure occurs through the intake of radionuclides by inhalation (breathing) and/or intake of contaminated foods. Such radiation doses to members of the public are subject to statutory limits, which are set out in sections 13 and 14 of the *Radiation Protection Regulations*.

On May 31, 2000, the *Nuclear Safety and Control Act* (NSCA) and its associated Regulations came into force in Canada, replacing the *Atomic Energy Control Act* and its Regulations. The *Radiation Protection Regulations* introduced new dose limits to protect the public and environment, which reflect the recommendations of the International Commission on Radiation Protection in its Publication 60. In May 2000, the annual Canadian public dose limit was reduced from 5 mSv to 1 mSv for a whole-body dose.

Furthermore, sections 12(1)(c) and 12(1)(f) of the *General Nuclear Safety and Control Regulations* require every CNSC licensee to take all reasonable precautions to protect the environment and the health and safety of people. Every licensee shall also take all reasonable precautions to control the release of radioactive nuclear substances into the environment, as a result of the licensed activity.

### **Methodology for Establishing Derived Release Limits**

When the CNSC approved DRLs for each Canadian nuclear generating station, it considered the environmental and exposure pathways through which radioactive material could reach the most exposed members of the public after this material was released from each facility. The most exposed members of the public are known as the “representative person” (formerly defined as the “critical group”), and are defined as those individuals expected to receive the highest doses of radiation based on considerations such as age, diet, lifestyle and location relative to the nuclear facility.

Since 1987, DRL calculations have been based on a method recommended by the Canadian Standards Association (CSA) in the standard published as CAN/CSA N288.1-M87, *Guidelines for calculating derived release limits for radioactive material in airborne and liquid effluents for normal operation of nuclear facilities*. In 2008, a new revision of this CSA standard was published as CSA-N288.1-08.

Darlington, Pickering, and Bruce have submitted revised DRLs based on CSA-N288.1-08, which CNSC staff have reviewed and approved. The revised DRLs for Bruce A, Bruce B, and Pickering A have been implemented as part of the facilities' current operating licences, and Darlington's revised DRLs will be implemented in 2011.

The DRLs for the Point Lepreau generating station were last revised in 1996, and an update is expected for 2012.

The DRLs for the Gentilly-2 Nuclear Generating Station were last revised in 1992, and take into account the previous annual statutory public dose limit of 5 mSv. Gentilly-2 has submitted new DRLs based on the current annual statutory public dose limit of 1 mSv and according to the updated CSA standard. These new DRLs were approved by CNSC staff in March 2011 and have been incorporated into the new licence issued in July 2011. They will be presented in future revisions of INFO-0210.

Table 1 and Table 2 present DRLs for gaseous emissions and liquid effluents released by Canadian nuclear power plants. The differences among stations are due to site-specific characteristics such as the location of the "representative person" relative to the nuclear facility, differences in the pathways modelled, and differences in the individual characteristics of the "representative person" such as age, diet, and lifestyle.

**Table 1: DRLs for gaseous effluents**

Nuclear Power Plant	Tritium* (TBq)	Iodine-131 (TBq)	Noble Gases (TBq-MeV**)	Particulates (TBq)	Carbon-14 (TBq)
Point Lepreau <sup>1</sup>	$4.3 \times 10^5$	10	$7.3 \times 10^4$	5.4	$3.3 \times 10^3$
Bruce A <sup>2</sup>	$1.3 \times 10^5$	1.2	$4.7 \times 10^4$	0.31	$1.0 \times 10^3$
Bruce B <sup>3</sup>	$2.7 \times 10^5$	0.91	$1.1 \times 10^5$	0.74	$1.1 \times 10^3$
Darlington <sup>4</sup>	$4.3 \times 10^4$ (HTO) $8.1 \times 10^5$ (HT)***	4.7	$3.9 \times 10^4$	2.4	$1.8 \times 10^3$
Pickering A <sup>5</sup>	$5.5 \times 10^4$	9.7	$2.9 \times 10^4$	2.1	$6.3 \times 10^3$
Pickering B <sup>6</sup>	$5.5 \times 10^4$	9.7	$2.9 \times 10^4$	2.1	$6.3 \times 10^3$
Gentilly-2 <sup>7</sup>	$4.4 \times 10^5$	1.3	$1.7 \times 10^5$	1.9	$8.8 \times 10^2$

\* Tritium oxide (HTO)

\*\* Terabecquerel-million electron volts

\*\*\* For elemental tritium (HT) resulting from operations at the tritium removal facility at the Darlington Nuclear Generating Station

1. New Brunswick Power Nuclear Corporation. (1996). Point Lepreau Generating Station Reference Document: *Derived Emission Limits for Radionuclides in Airborne and Liquid Effluents*, RD-01364-L1, Revision 2 (as referenced in PROL 17.08/2011).
2. Canadian Nuclear Safety Commission. (November 2009). Nuclear Power Reactor Operating Licence Bruce Nuclear Generating Station A (PROL 15.00/2014), Appendix C: Derived Release Limits.
3. Canadian Nuclear Safety Commission. (November 2009). Nuclear Power Reactor Operating Licence Bruce Nuclear Generating Station B (PROL 16.00/2014), Appendix C: Derived Release Limits.
4. Ontario Power Generation. (April 2006). *Derived Release Limits for Darlington Nuclear Generating Station*, NK38-REP-03482-10001-R01 (as referenced in PROL 13.03/2013).
5. Canadian Nuclear Safety Commission. (October 2010). Nuclear Power Reactor Operating Licence Pickering Nuclear Generating Station A (PROL 04.01/2013), Appendix A.3: Derived Release Limits.
6. Ontario Power Generation. (April 2006). *Derived Release Limits for Pickering Nuclear Generating Station B*, NK30-REP-03482-00001-R001 (as referenced in PROL 08.04/2013).
7. Hydro-Québec. (2003). *Limites opérationnelles dérivées pour les rejets aériens de Gentilly-2* (as referenced in PERP 10.04/2010).

**Table 2: DRLs for liquid effluents**

Nuclear Power Plant	Tritium* (TBq)	Gross Beta-Gamma Activity (TBq)	Carbon-14 (TBq)
Point Lepreau <sup>1</sup>	$1.6 \times 10^7$	$1.5 \times 10^1$	$3.0 \times 10^2$
Bruce A <sup>2</sup>	$2.1 \times 10^6$	$1.0 \times 10^2$	$2.6 \times 10^3$
Bruce B <sup>3</sup>	$2.3 \times 10^6$	$1.1 \times 10^2$	$2.8 \times 10^3$
Darlington <sup>4</sup>	$4.3 \times 10^6$	$7.1 \times 10^1$	$9.7 \times 10^2$
Pickering A <sup>5</sup>	$5.1 \times 10^5$	4.7	$6.4 \times 10^1$
Pickering B <sup>6</sup>	$5.1 \times 10^5$	4.7	$6.4 \times 10^1$
Gentilly-2 <sup>7</sup>	$1.2 \times 10^6$	5.3	$1.0 \times 10^2$

\* Tritium oxide (HTO)

### Internal Operating Targets

Nuclear generating stations maintain their own internal operating targets, which equate to approximately 1% of the specified DRLs. Although DRLs are expressed as an annual release limit, the weekly and monthly rates of release are further controlled. For gaseous releases, the maintained limit is the annual DRL divided by 52 weeks, while liquid release limits represent the annual DRL divided by 12 months. Weekly airborne releases and monthly liquid releases at each nuclear generating station are compared to the respective weekly and monthly DRLs, and are reported to the CNSC on a quarterly basis. Also, nuclear generating stations use environmental action levels developed based on the CNSC Regulatory Guide G-228, *Developing and Using Action Levels*.

1. New Brunswick Power Nuclear Corporation. (1996). Point Lepreau Generating Station Reference Document: *Derived Emission Limits for Radionuclides in Airborne and Liquid Effluents*, RD-01364-L1, Revision 2 (as referenced in PROL 17.08/2011).
2. Canadian Nuclear Safety Commission. (November 2009). Nuclear Power Reactor Operating Licence Bruce Nuclear Generating Station A (PROL 15.00/2014), Appendix C: Derived Release Limits.
3. Canadian Nuclear Safety Commission. (November 2009). Nuclear Power Reactor Operating Licence Bruce Nuclear Generating Station B (PROL 16.00/2014), Appendix C: Derived Release Limits.
4. Ontario Power Generation. (April 2006). *Derived Release Limits for Darlington Nuclear Generating Station*, NK38-REP-03482-10001-R01 (as referenced in PROL 13.03/2013).
5. Canadian Nuclear Safety Commission. (October 2010). Nuclear Power Reactor Operating Licence Pickering Nuclear Generating Station A (PROL 04.01/2013), Appendix A.3: Derived Release Limits.
6. Ontario Power Generation. (April 2006). *Derived Release Limits for Pickering Nuclear Generating Station B*, NK30-REP-03482-00001-R001 (as referenced in PROL 08.04/2013).
7. Hydro-Québec. (2003). *Limites opérationnelles dérivées pour les rejets liquides de Gentilly-2* (as referenced in PERP 10.04/2010).

## Release Data

Licensees measure and report their releases in different ways. Most licensees report the radionuclides representing 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. Since particulate and gross beta-gamma consist of mixtures of radionuclides, the most dose-restrictive radionuclide is chosen to represent the mixture as the basis for comparison with the DRL.

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

The “ND” mention in the following graphs and tables indicates that radioactive releases were not detected in that particular year. The horizontal lines at the top of the graphs show the DRL for the element in question.

## Terminology

A brief glossary at the end of this report defines specific terms and expressions related to radioactive release data.

## Scientific Notation

The magnitude of the numbers in this report makes it more convenient to express this data in scientific notation. In most cases, numbers are rounded to two significant figures.

Examples follow:

$$\begin{aligned}100,000 &= 10^5 \\1,260,000 &= 1.3 \times 10^6 \text{ (two significant figures)} \\0.003473 &= 3.5 \times 10^{-3} \text{ (two significant figures)}\end{aligned}$$

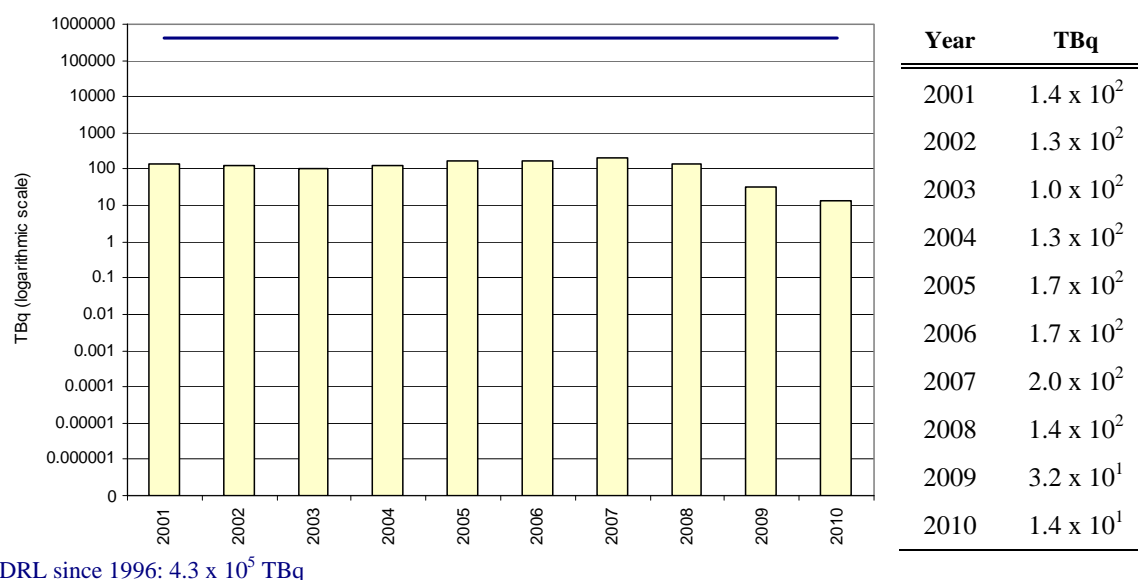
## New Brunswick

### Point Lepreau Generating Station

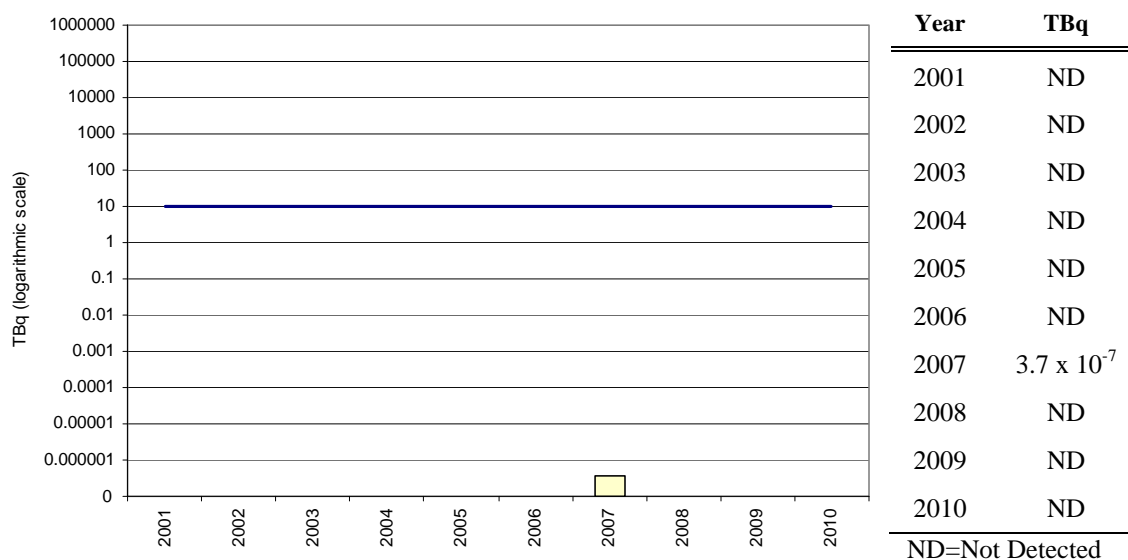
The Point Lepreau Generating Station consists of one nuclear reactor, which began operation in 1982. It is located in New Brunswick on Point Lepreau, which extends into the Bay of Fundy.

The data for radioactive gaseous and liquid effluents released between 2001 and 2010 is presented in the graphs below. 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 particulates (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).

The Point Lepreau Generating Station has been shut down for refurbishment since 2008.

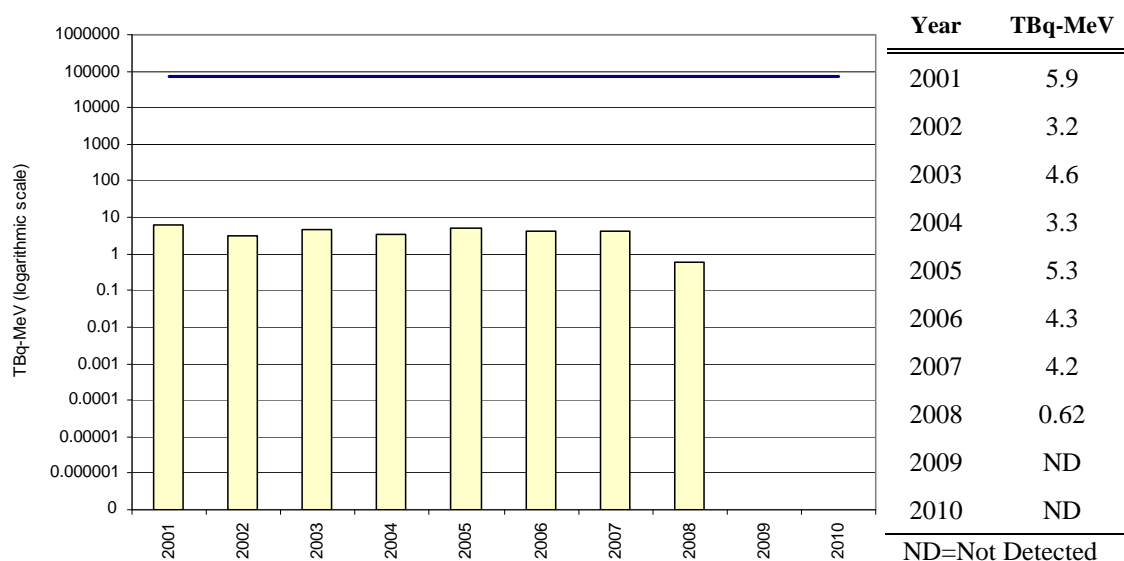


**Figure 1.1: Tritium oxide in gaseous effluent from the Point Lepreau Generating Station (2001–10)**



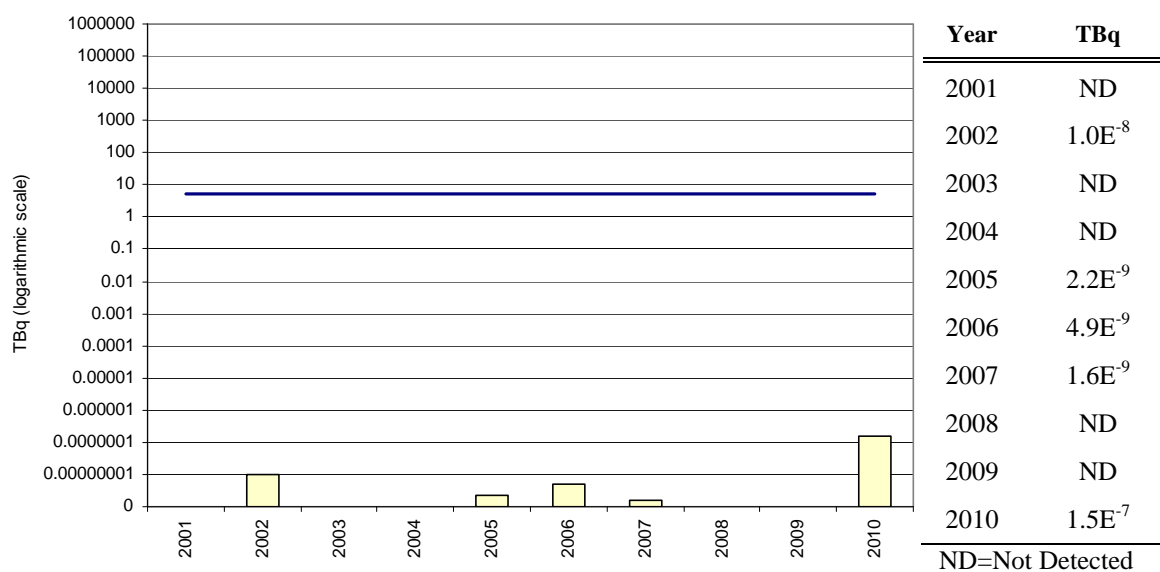
DRL since 1998: 10 TBq

**Figure 1.2: Iodine-131 in gaseous effluent from the Point Lepreau Generating Station (2001–10)**



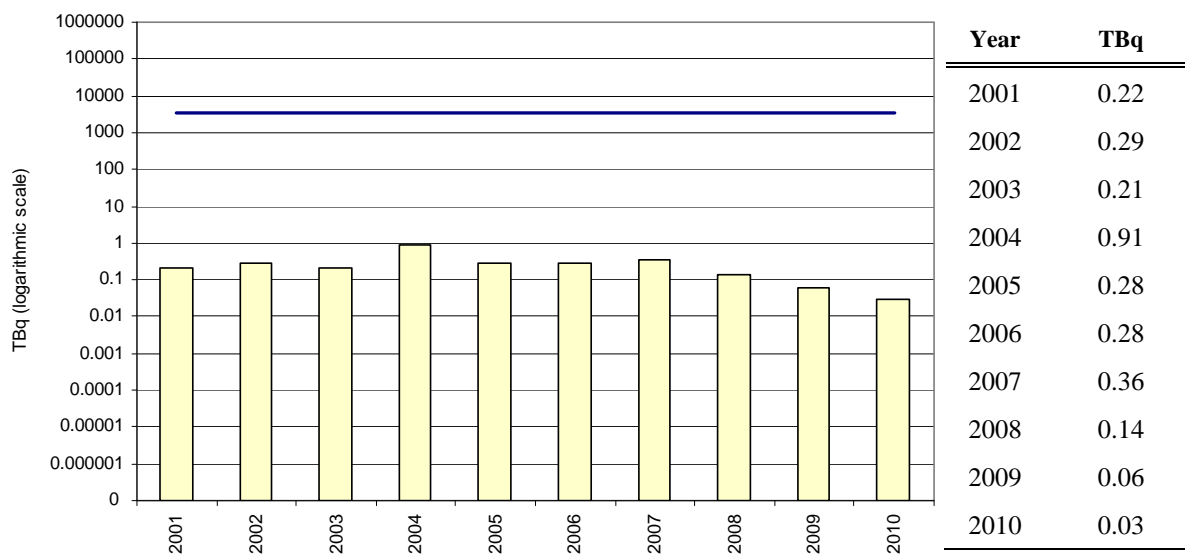
DRL since 1996:  $7.3 \times 10^4$  TBq-MeV

**Figure 1.3: Noble gas in gaseous effluent from the Point Lepreau Generating Station (2001–10)**



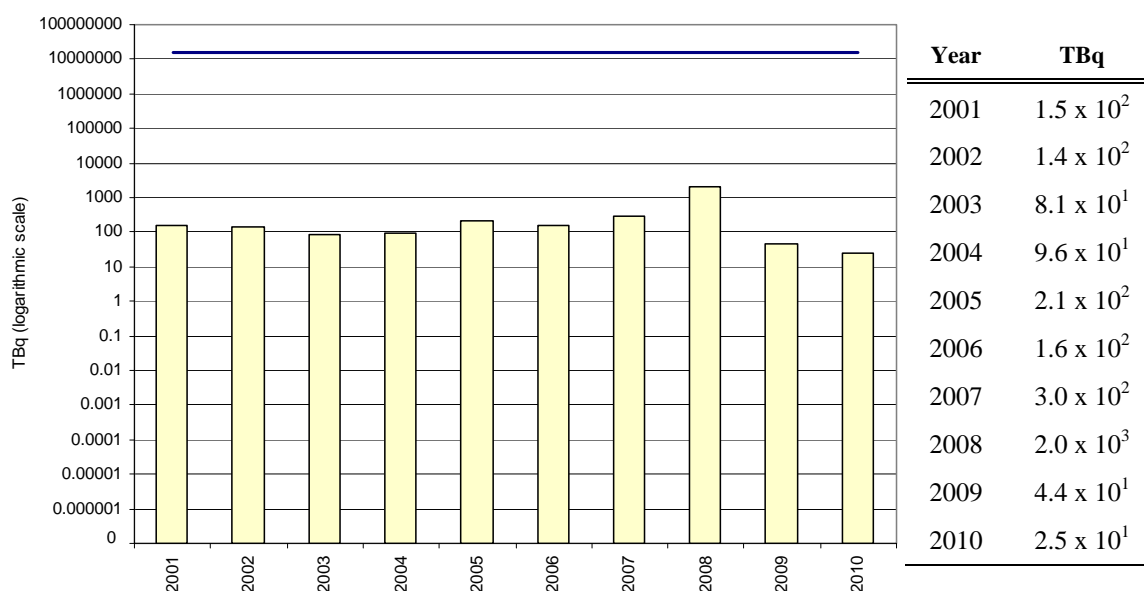
DRL since 1996: 5.2 TBq

**Figure 1.4: Radioactive particulate in gaseous effluent from the Point Lepreau Generating Station (2001–10)**



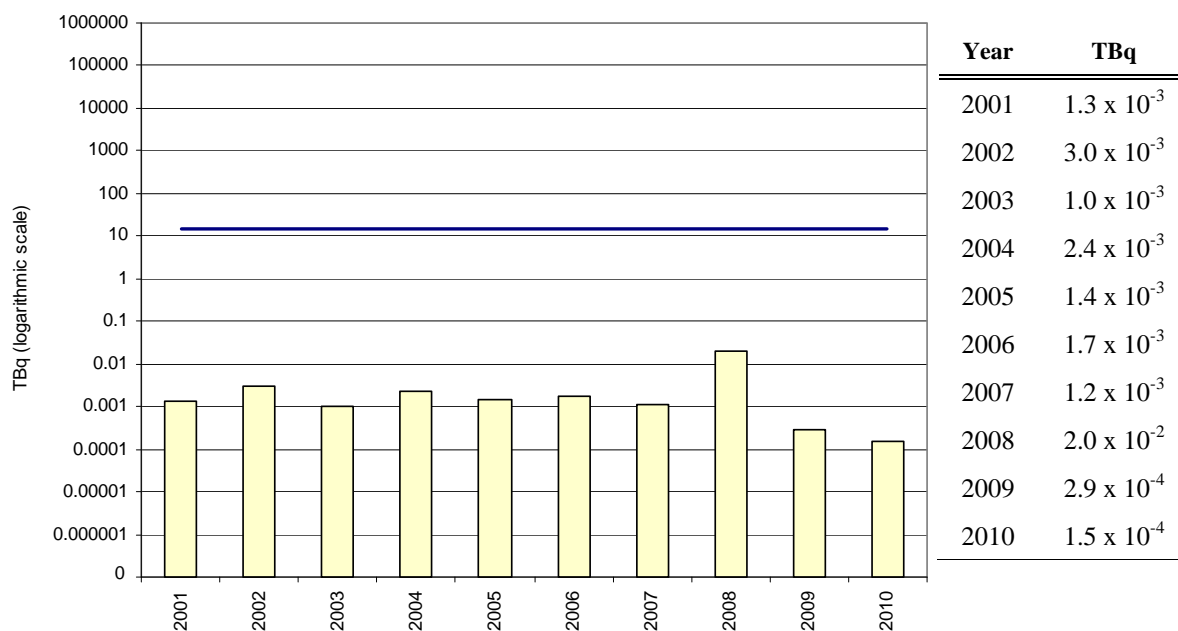
DRL since 1996: 3.3 x 10<sup>3</sup> Bq

**Figure 1.5: Carbon-14 in gaseous effluent from the Point Lepreau Generating Station (2001–10)**



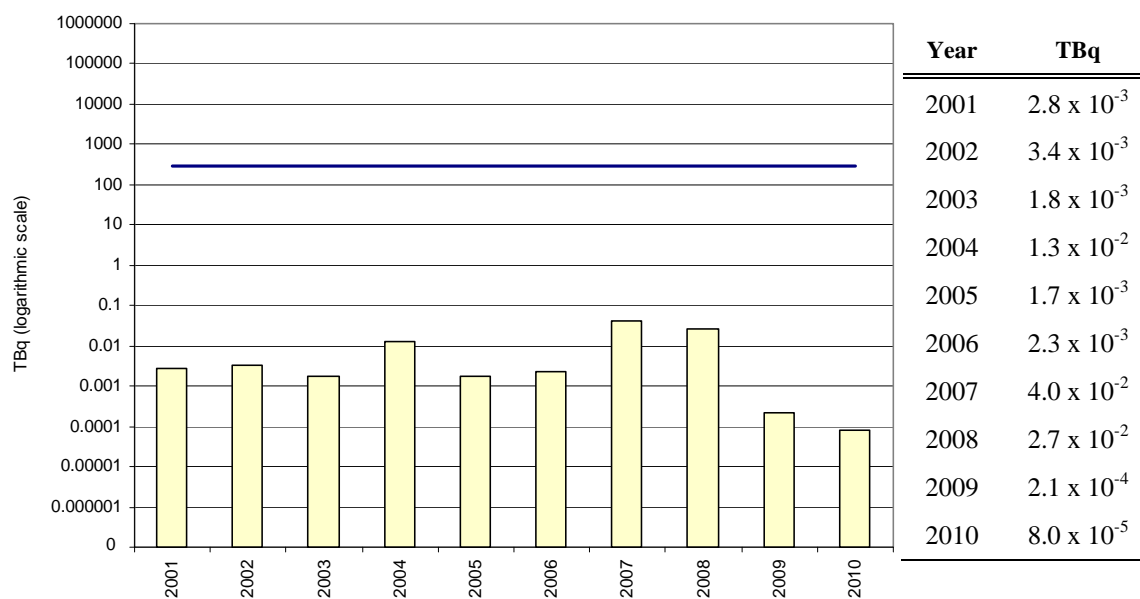
DRL since 1996:  $1.6 \times 10^7$  Tbq

**Figure 1.6: Tritium oxide in liquid effluent from the Point Lepreau Generating Station (2001–10)**



DRL since 1996:  $1.5 \times 10^1$  Tbq

**Figure 1.7: Gross beta-gamma activity in liquid effluent from the Point Lepreau Generating Station (2001–10)**



DRL since 1996:  $3.0 \times 10^2$  TBq

**Figure 1.8: Carbon-14 in liquid effluent from the Point Lepreau Generating Station (2001–10)**

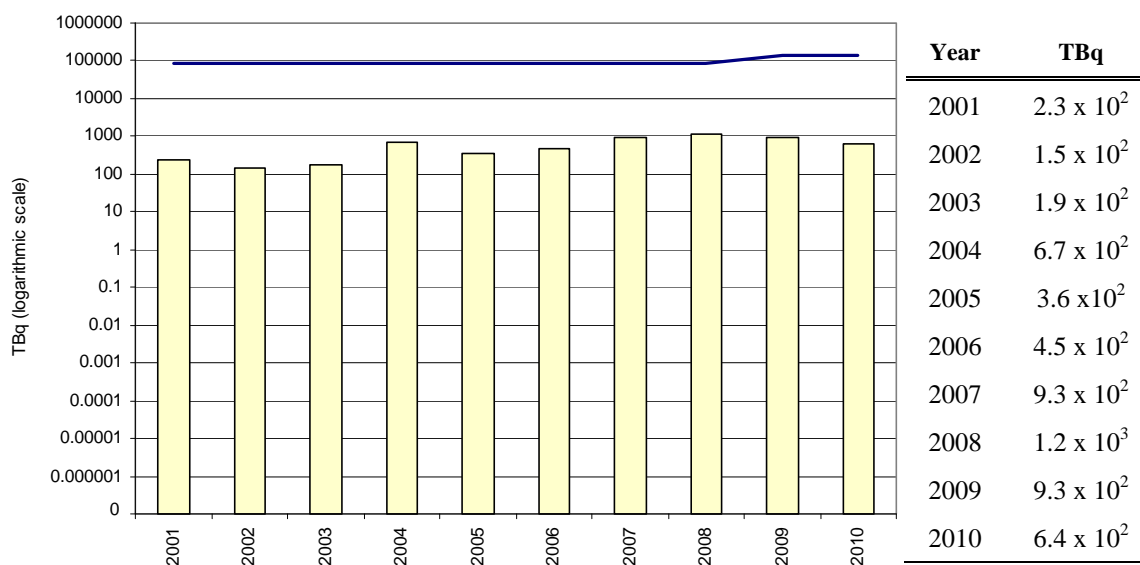
## Ontario

### Bruce A Nuclear Generating Station

The Bruce-A Nuclear Generating Station consists of four nuclear reactors (units 1 to 4), which began operating in 1976. It is located in Ontario, on the shore of Lake Huron, in the Municipality of Kincardine.

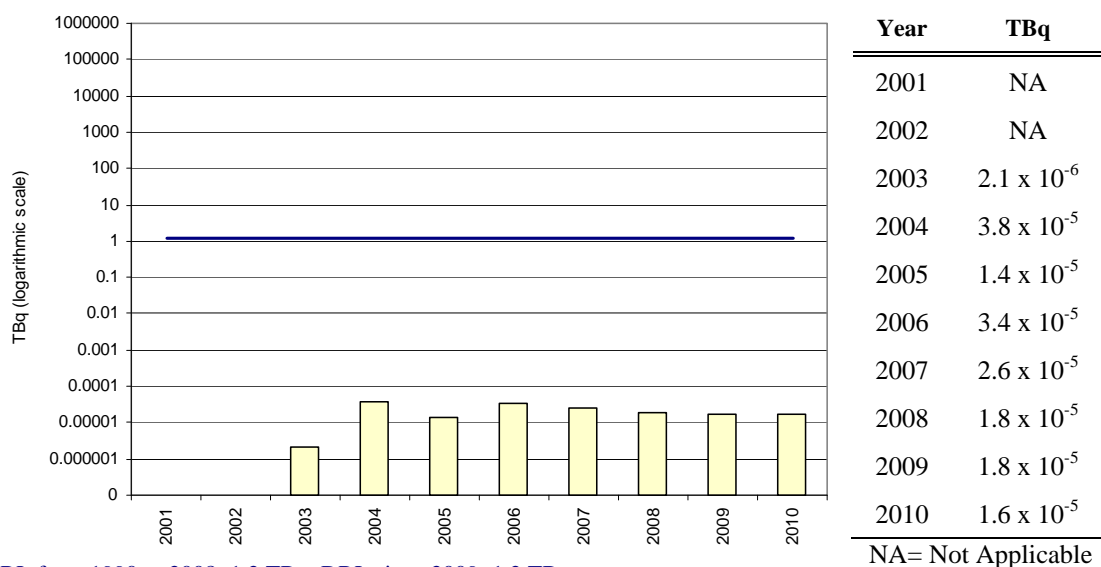
In 1997, as part of its extensive recovery program, Ontario Hydro (now Ontario Power Generation) temporarily shut down the Bruce A reactors, and all the units were maintained in a guaranteed shutdown state. Since then, unit 4 was restarted in October 2003, while unit 3 was restarted in January 2004. The Bruce A Nuclear Generating Station is currently operated by Bruce Power.

Data for radioactive gaseous and liquid effluents released between 2001 and 2010 from the Bruce A Nuclear Generating Station are presented in the graphs below. 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). 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).



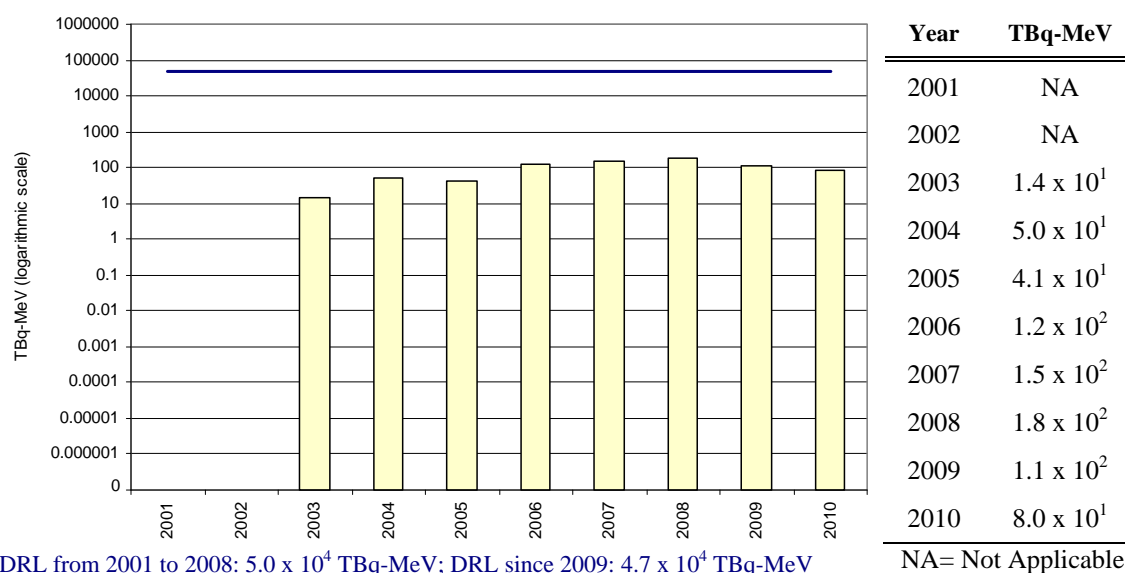
DRL from 1990 to 2008:  $8.8 \times 10^4$  TBq; DRL since 2009:  $1.3 \times 10^5$  TBq

**Figure 2.1: Tritium oxide in gaseous effluent from the Bruce A Nuclear Generating Station (2001–10)**



DRL from 1990 to 2008: 1.2 TBq; DRL since 2009: 1.2 TBq

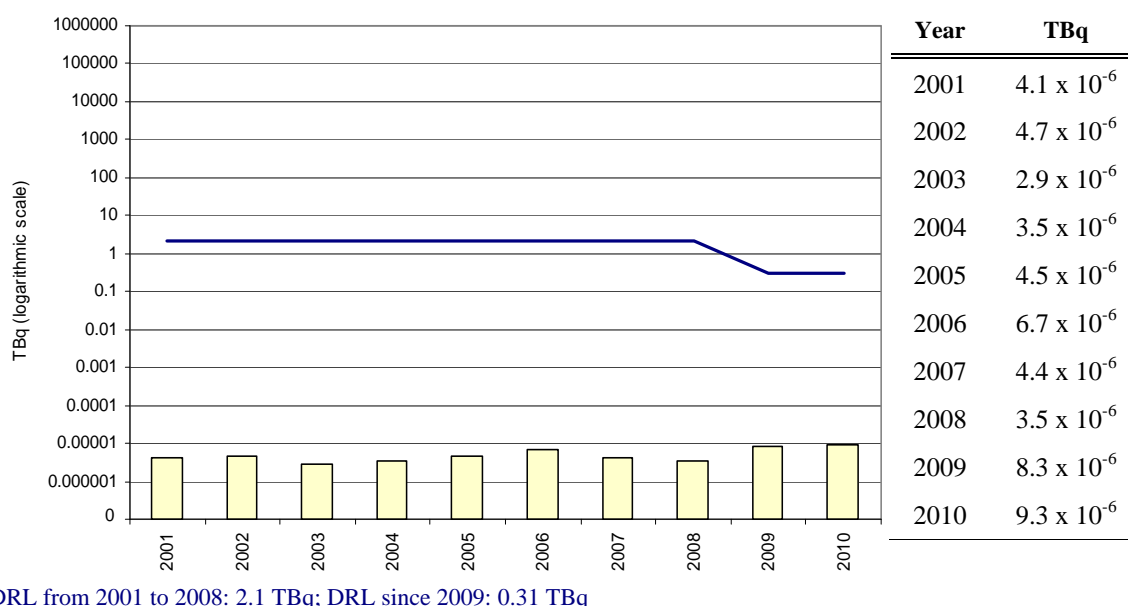
**Figure 2.2: Iodine-131 in gaseous effluent from the Bruce A Nuclear Generating Station (2001–10)<sup>1</sup>**



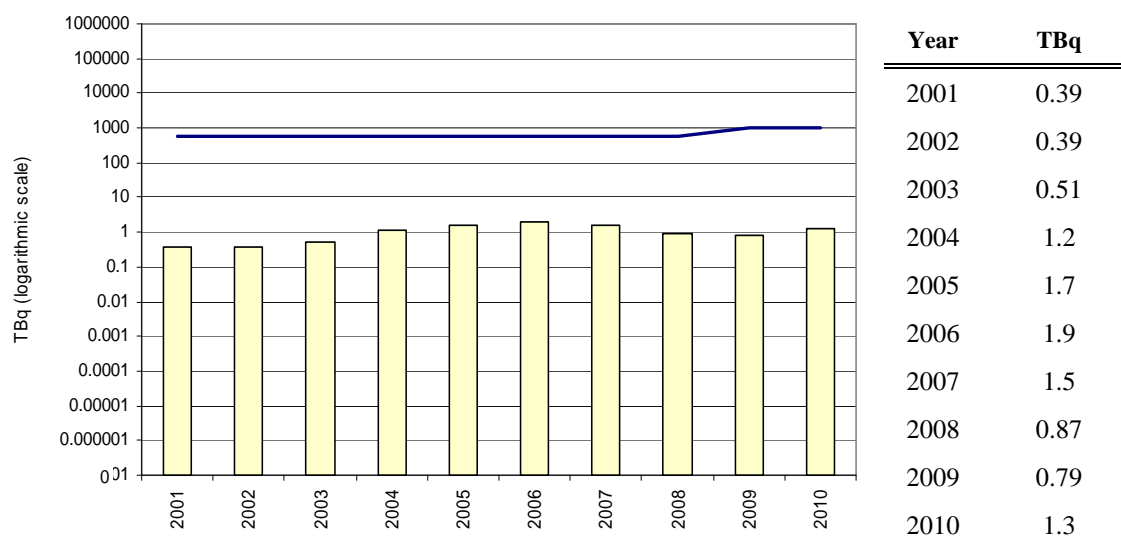
DRL from 2001 to 2008:  $5.0 \times 10^4$  TBq-MeV; DRL since 2009:  $4.7 \times 10^4$  TBq-MeV

**Figure 2.3: Noble gas in gaseous effluent from the Bruce A Nuclear Generating Station (2001–10)<sup>1</sup>**

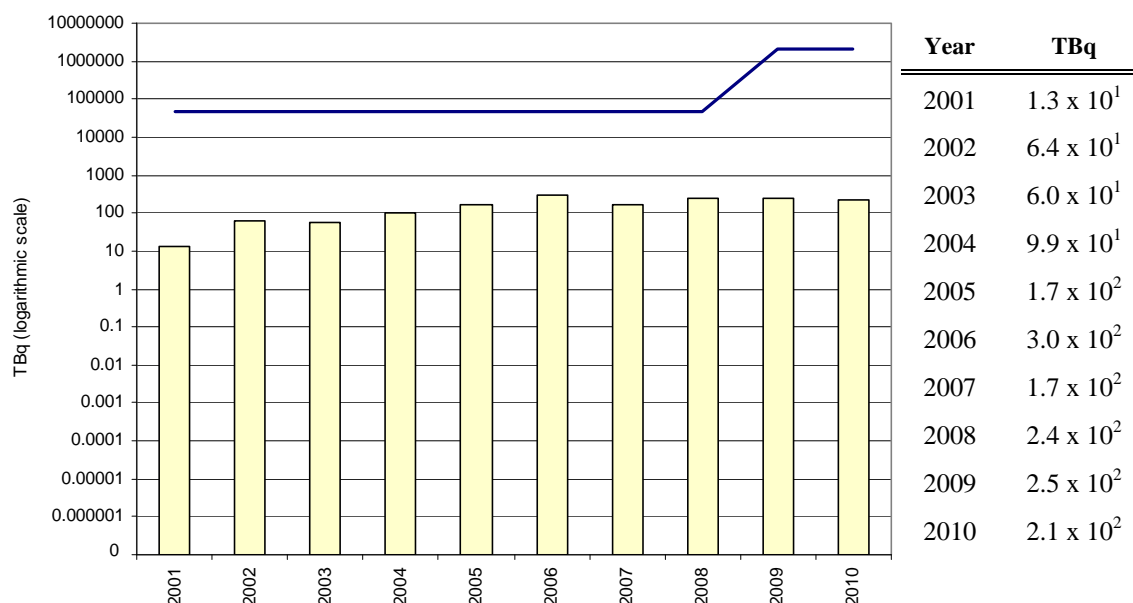
1. In 2000, OPG shut down all non-contaminated stack monitors and noble gas and iodine monitors for contaminated stacks at Bruce A for two years.



**Figure 2.4: Radioactive particulate in gaseous effluent from the Bruce A Nuclear Generating Station (2001–10)**

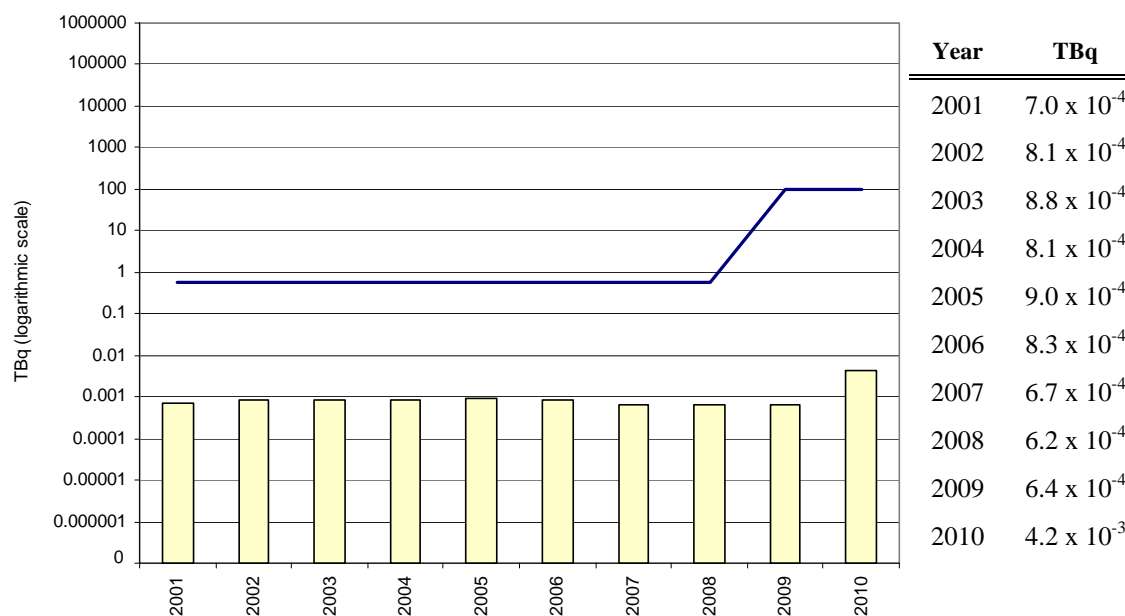


**Figure 2.5: Carbon-14 in gaseous effluent from the Bruce A Nuclear Generating Station (2001–10)**



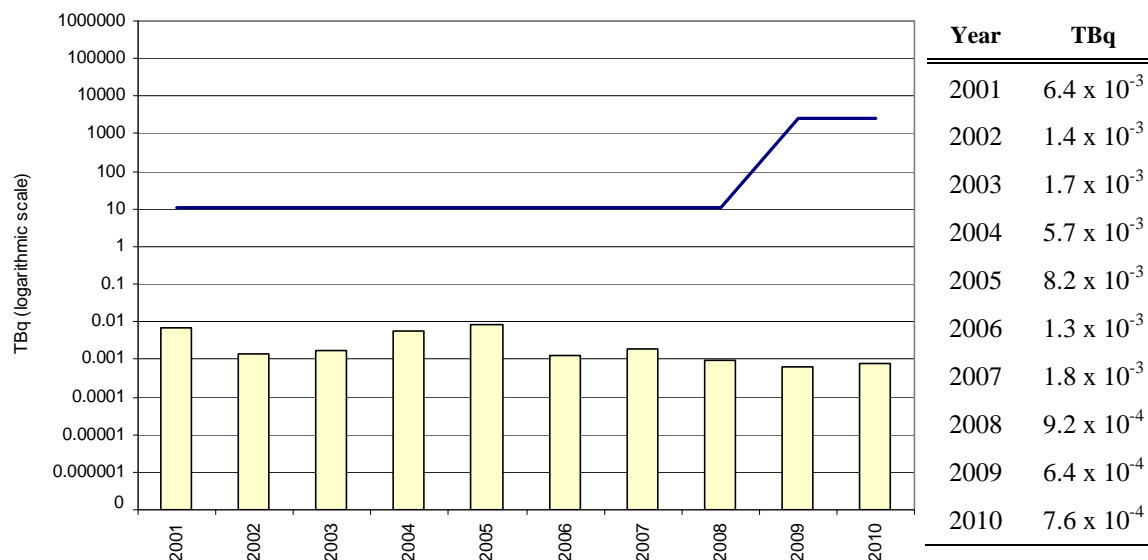
DRL from 2001 to 2008:  $4.5 \times 10^4$  TBq; DRL since 2009:  $2.1 \times 10^6$  TBq

**Figure 2.6: Tritium oxide in liquid effluent from the Bruce A Nuclear Generating Station (2001–10)**



DRL from 2001 to 2008:  $5.8 \times 10^{-1}$  TBq; DRL since 2009:  $1.0 \times 10^2$  TBq

**Figure 2.7: Gross beta-gamma activity in liquid effluent from the Bruce A Nuclear Generating Station (2001–10)**



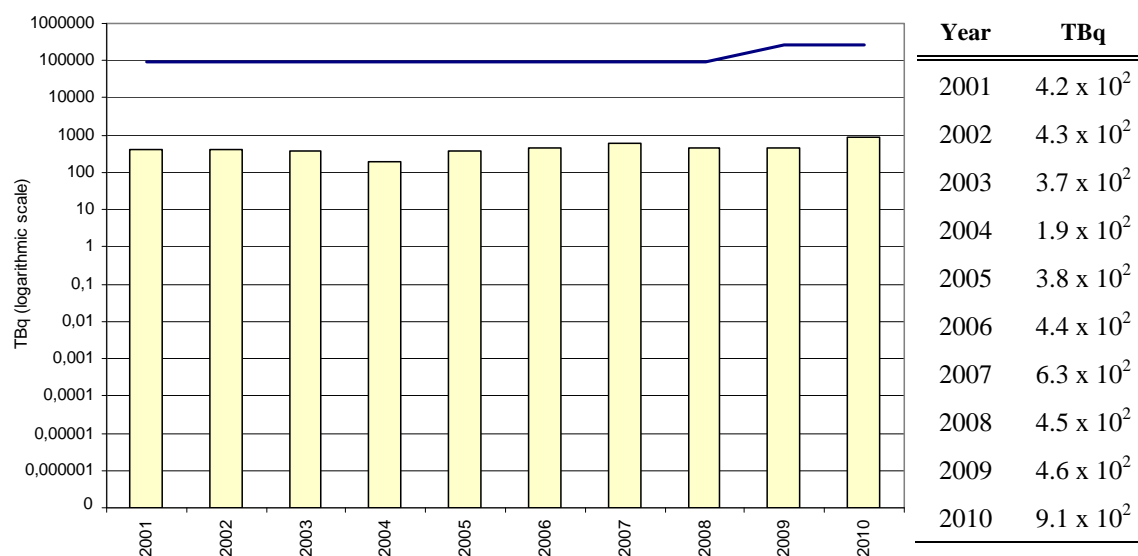
DRL from 2001 to 2008:  $1.1 \times 10^1$  TBq; DRL since 2009:  $2.6 \times 10^3$  TBq

**Figure 2.8: Carbon-14 in liquid effluent from the Bruce A Nuclear Generating Station (2001–10)**

## Bruce B Nuclear Generating Station

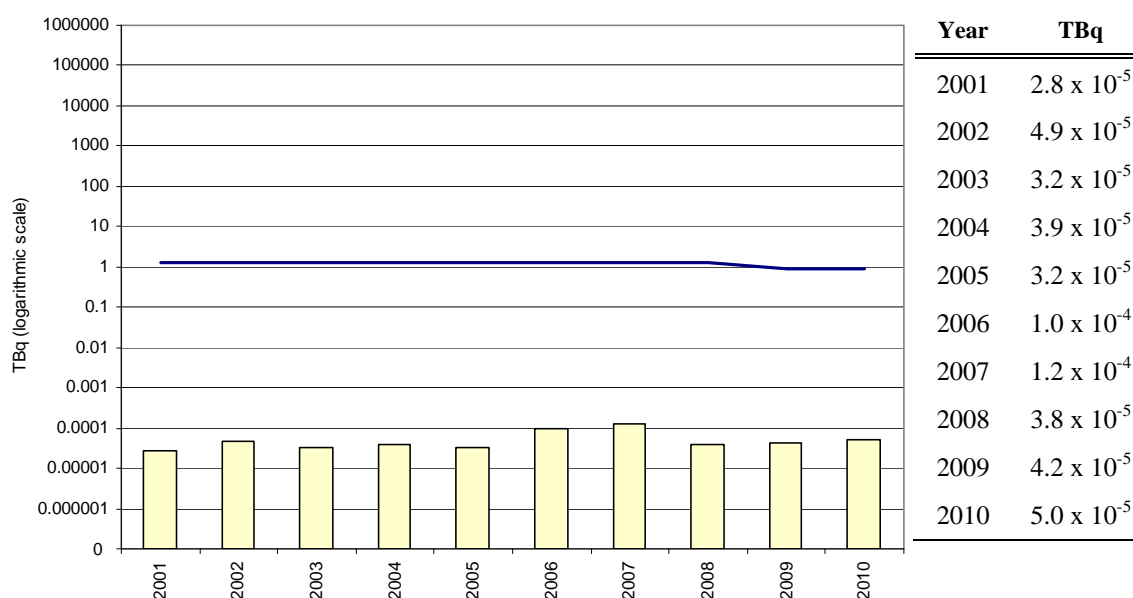
The Bruce B Nuclear Generating Station consists of four nuclear reactors (units 5 to 8), which began operation in 1984. It is located in Ontario, on the shore of Lake Huron, in the Municipality of Kincardine. The Bruce B Nuclear Generating Station is currently operated by Bruce Power Inc.

Radioactive gaseous and liquid effluents released between 2001 and 2010 from the Bruce B Nuclear Generating Station are represented in the graphs below. 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), radioactive particulates (Figure 3.4) and carbon-14 (Figure 3.5). 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).



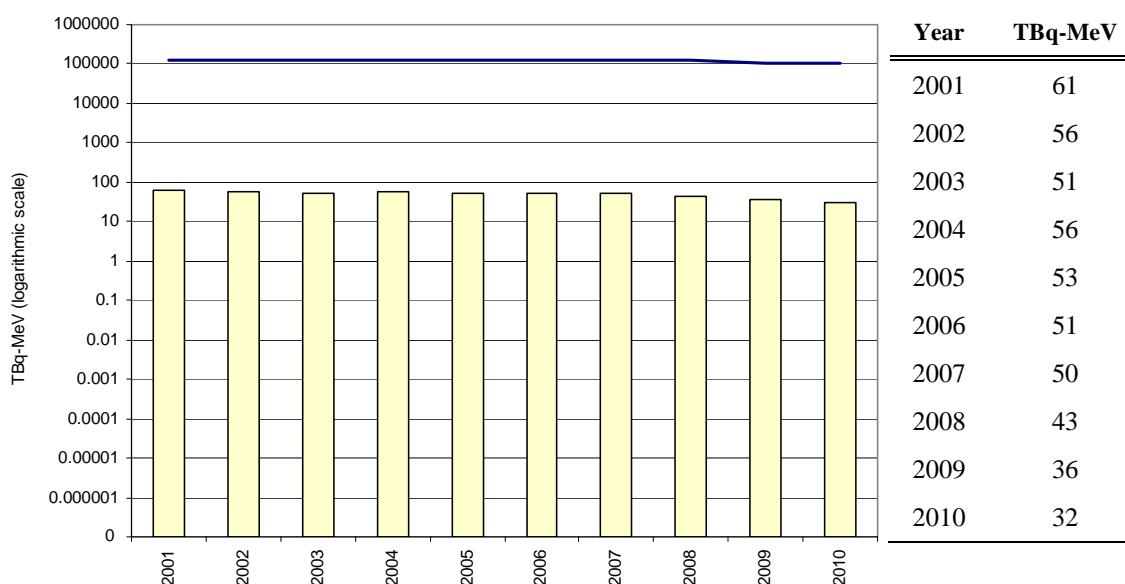
DRL from 2001 to 2008:  $9.3 \times 10^4$  TBq; DRL since 2009:  $2.7 \times 10^5$  TBq

**Figure 3.1: Tritium oxide in gaseous effluent from the Bruce B Nuclear Generating Station (2001–10)**



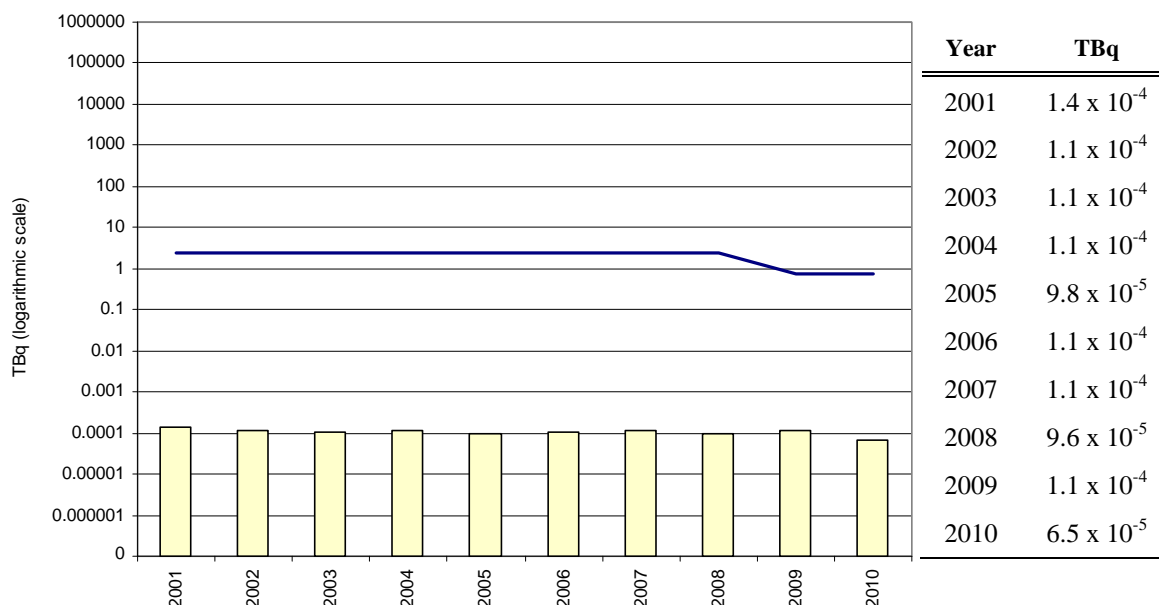
DRL from 1990 to 2008: 1.3 TBq; DRL since 2009: 0.91TBq

**Figure 3.2: Iodine-131 in gaseous effluent from the Bruce B Nuclear Generating Station (2001–10)**



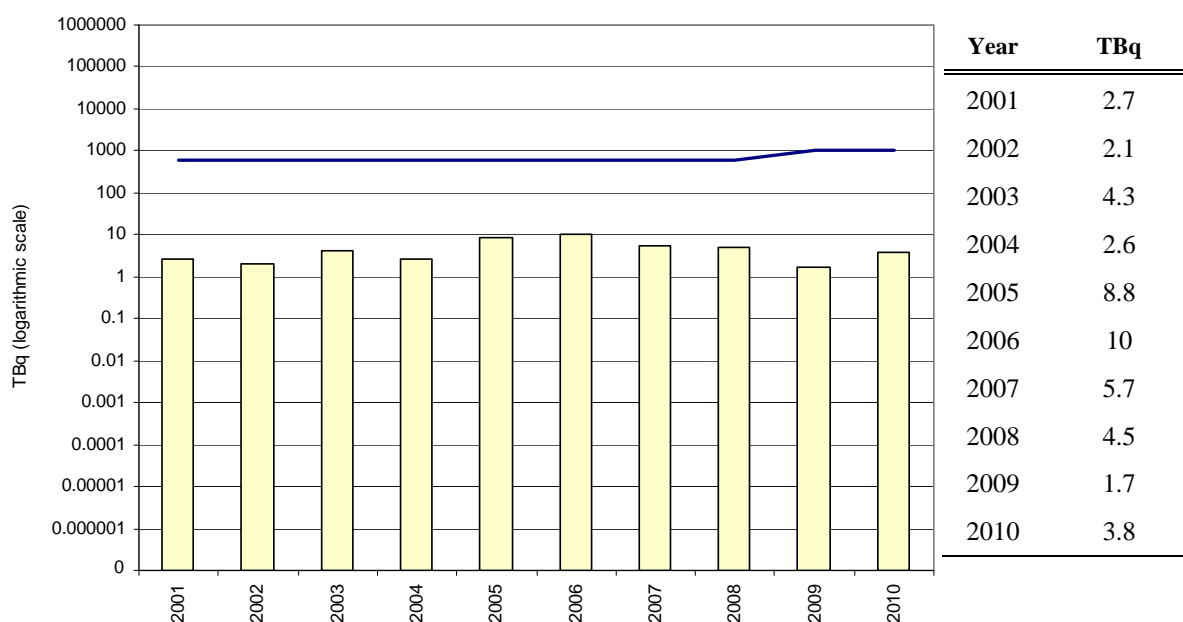
DRL from 2001 to 2008:  $1.2 \times 10^5$  TBq-MeV; DRL since 2009:  $1.1 \times 10^5$  TBq-MeV

**Figure 3.3: Noble gas in gaseous effluent from the Bruce B Nuclear Generating Station (2001–10)**



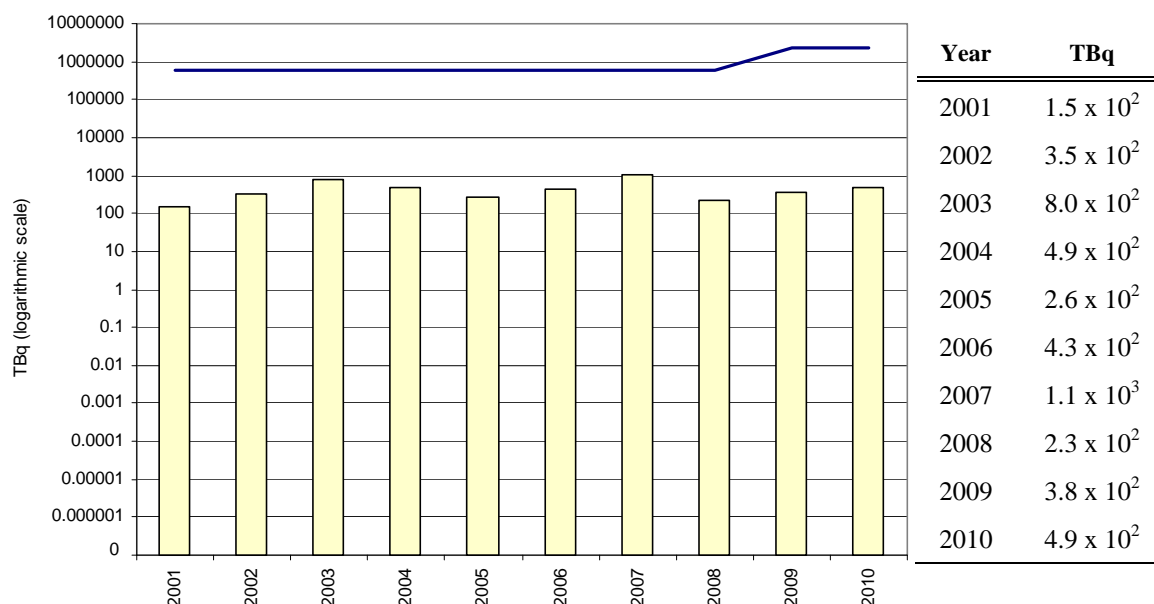
DRL from 2001 to 2008: 2.5 TBq; DRL since 2009: 0.74 TBq

**Figure 3.4: Radioactive particulate in gaseous effluent from the Bruce B Nuclear Generating Station (2001–10)**



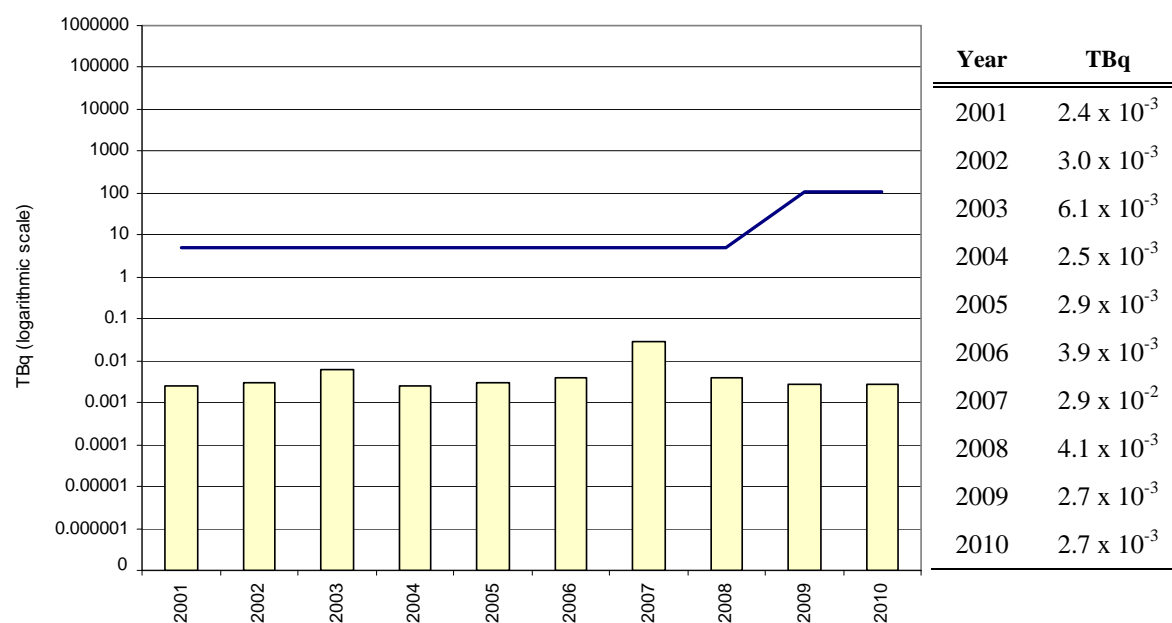
DRL from 2001 to 2008:  $6.0 \times 10^2$  TBq; DRL since 2009:  $1.1 \times 10^3$  TBq

**Figure 3.5: Carbon-14 in gaseous effluent from the Bruce B Nuclear Generating Station (2001–10)**



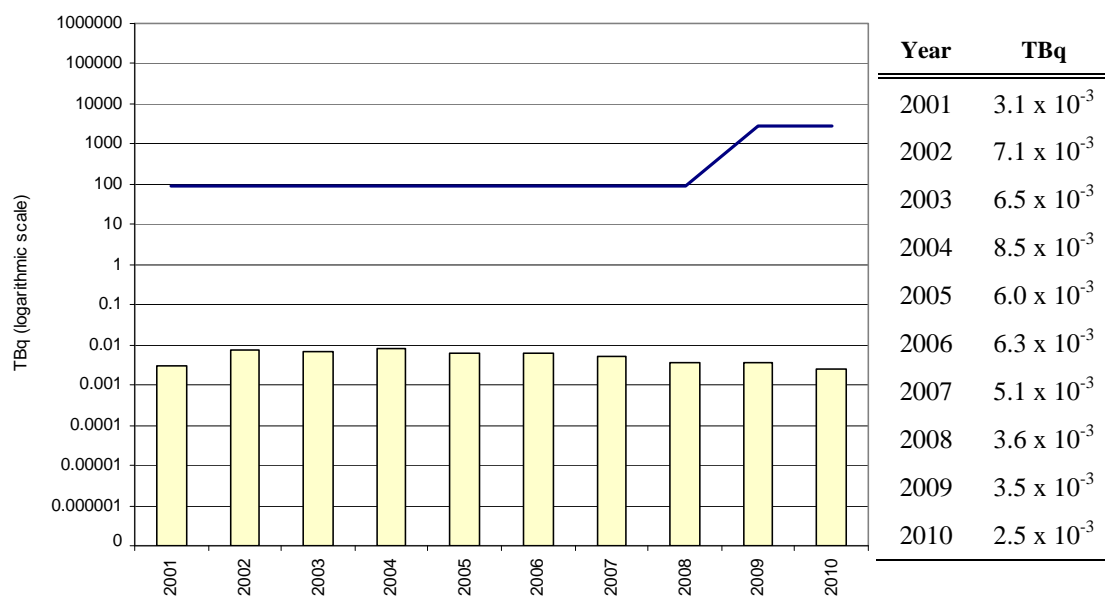
DRL from 2001 to 2008:  $6.0 \times 10^5$  TBq; DRL since 2009:  $2.3 \times 10^6$  TBq

**Figure 3.6: Tritium oxide in liquid effluent from the Bruce B Nuclear Generating Station (2001–10)**



DRL from 2001 to 2008: 4.9 TBq; DRL since 2009:  $1.1 \times 10^2$  TBq

**Figure 3.7: Gross beta-gamma activity in liquid effluent from the Bruce B Nuclear Generating Station (2001–10)**



DRL from 2001 to 2008:  $9.1 \times 10^1$  TBq; DRL since 2009:  $2.8 \times 10^3$  TBq

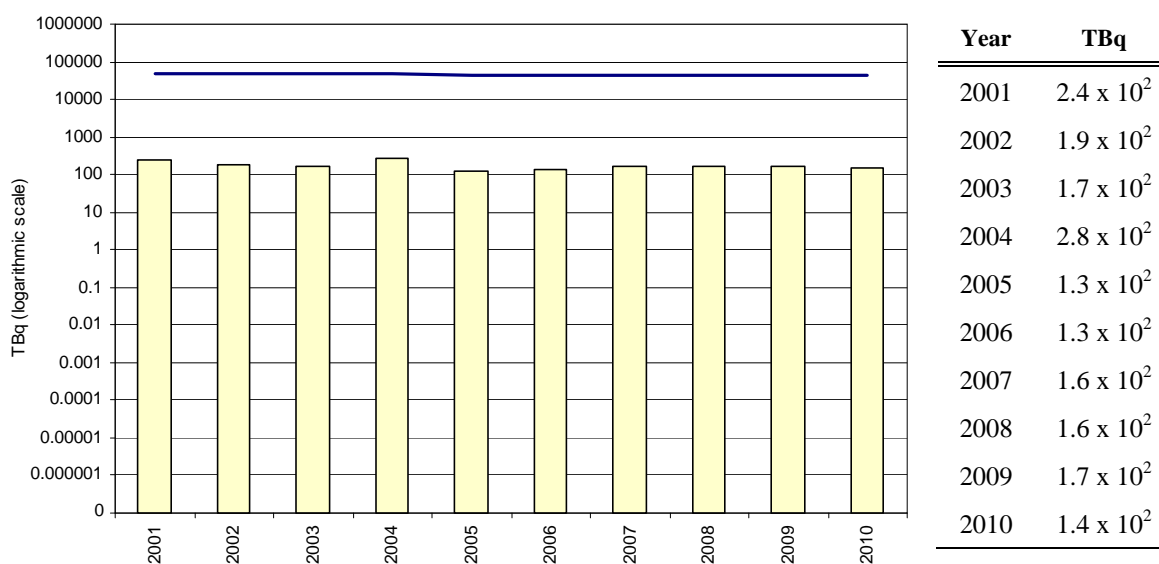
**Figure 3.8: Carbon-14 in liquid effluent from the Bruce B Nuclear Generating Station (2001–10)**

## Darlington Nuclear Generating Station

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

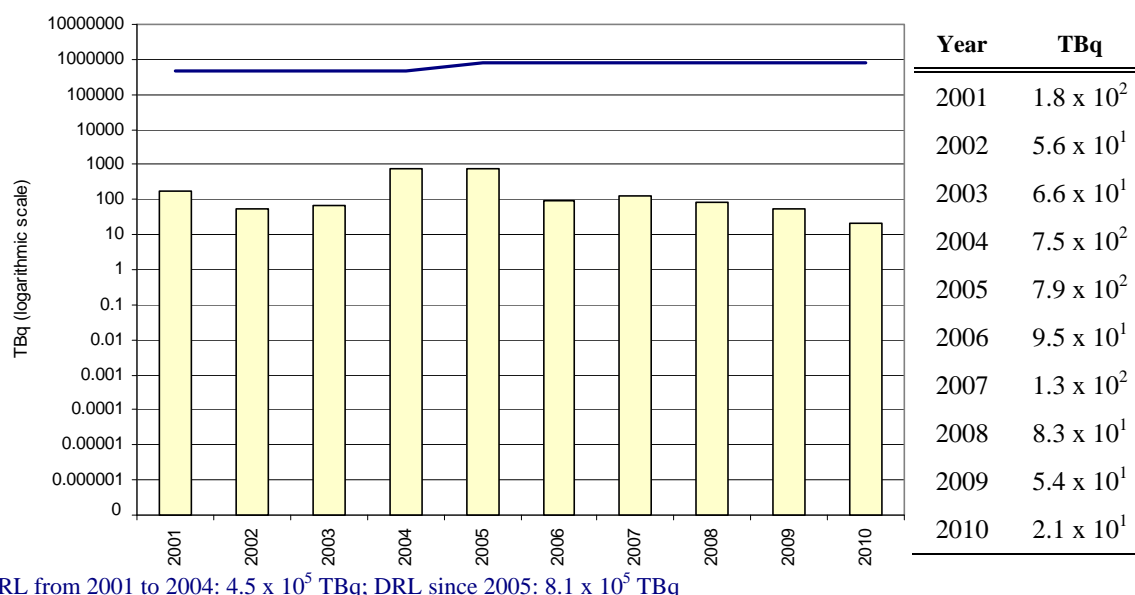
Data for radioactive gaseous and liquid effluents released between 2001 and 2010 from the Darlington Nuclear Generating Station are presented in the graphs below. The pertinent items in the gaseous effluents are tritium in the form of tritium oxide (Figure 4.1) and elemental tritium (Figure 4.2), iodine-131 (Figure 4.3), noble gases (Figure 4.4), radioactive particulates (Figure 4.5) and carbon-14 (Figure 4.6). 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 are due to the operation of the tritium removal facility.

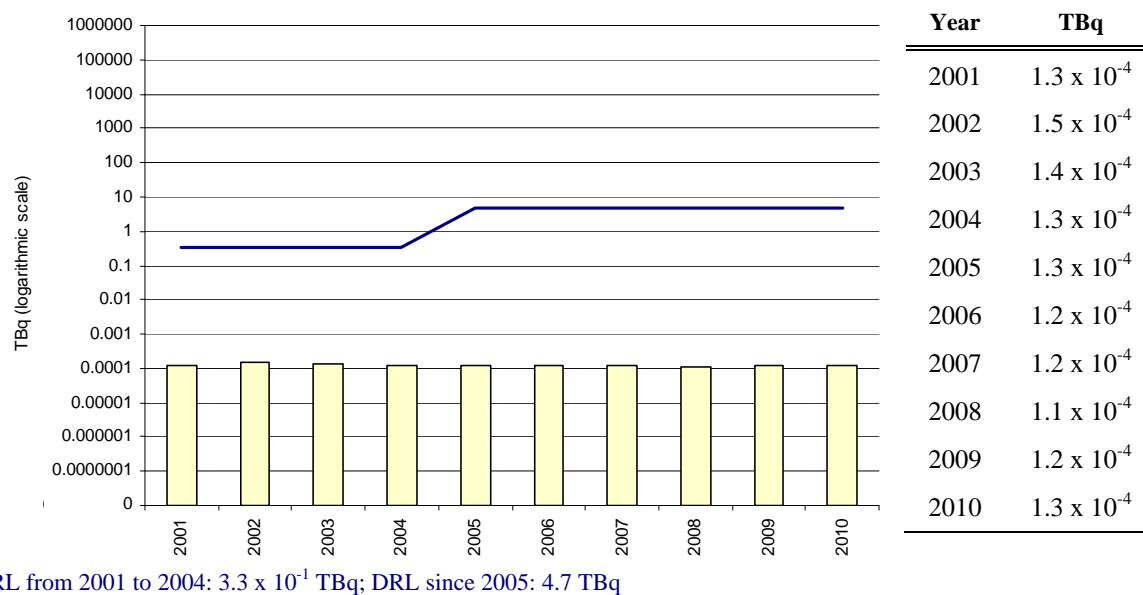


DRL from 2001 to 2004:  $4.6 \times 10^4$  TBq; DRL since 2005:  $4.3 \times 10^4$  TBq

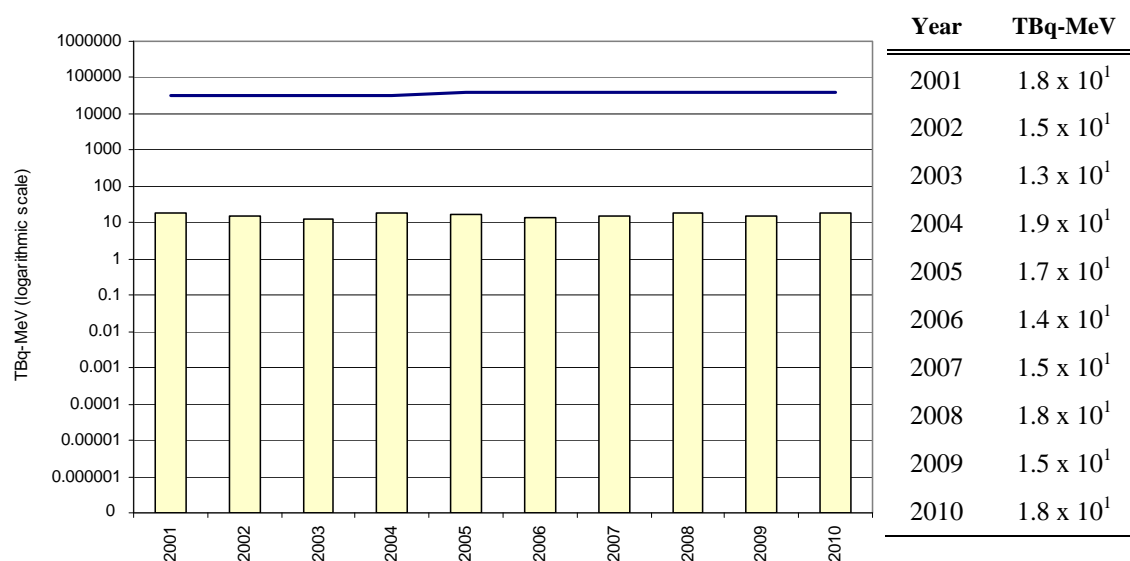
**Figure 4.1: Tritium oxide in gaseous effluent from the Darlington Nuclear Generating Station (2001–10)**



**Figure 4.2: Elemental tritium in gaseous effluent from the Darlington Nuclear Generating Station (2001–10)**

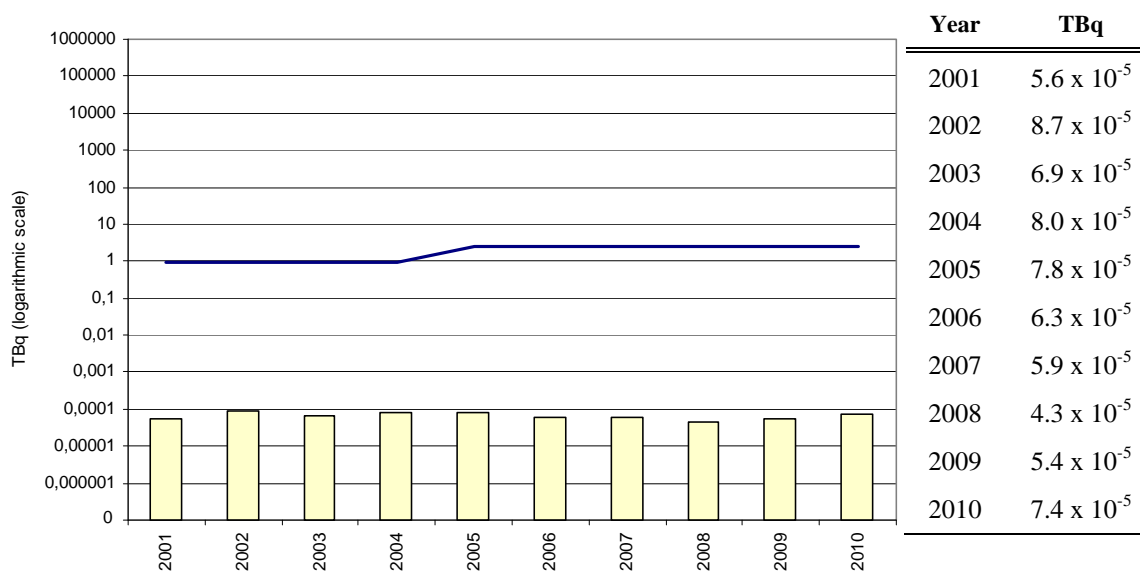


**Figure 4.3: Iodine-131 in gaseous effluent from the Darlington Nuclear Generating Station (2001–10)**



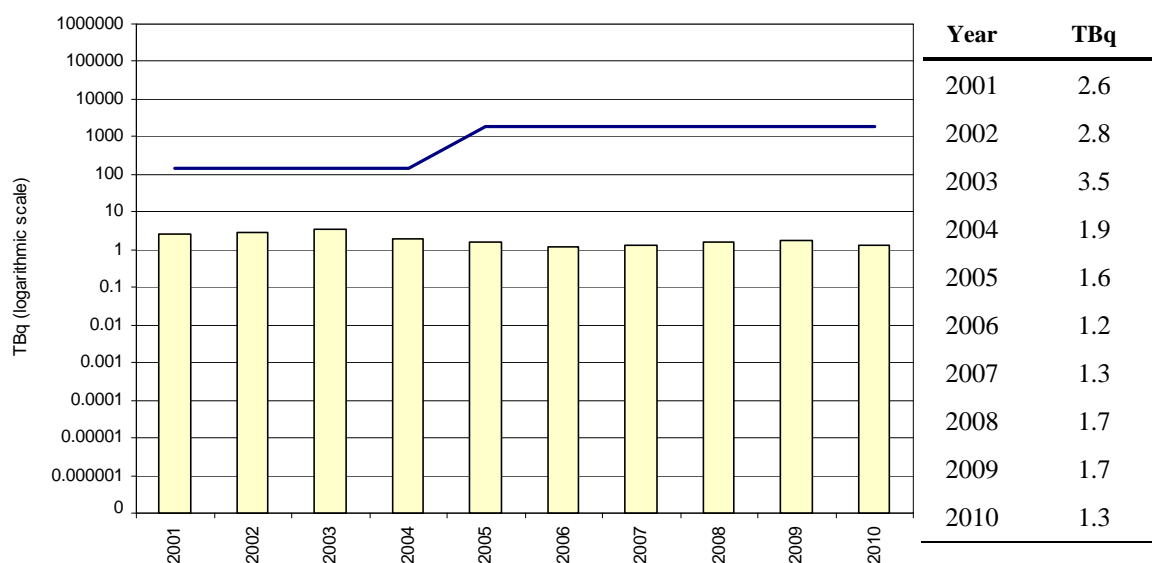
DRL from 2001 to 2004:  $3.1 \times 10^4$  TBq-MeV; DRL since 2005:  $3.9 \times 10^4$  TBq-MeV

**Figure 4.4: Noble gas in effluent from the Darlington Nuclear Generating Station (2001–10)**



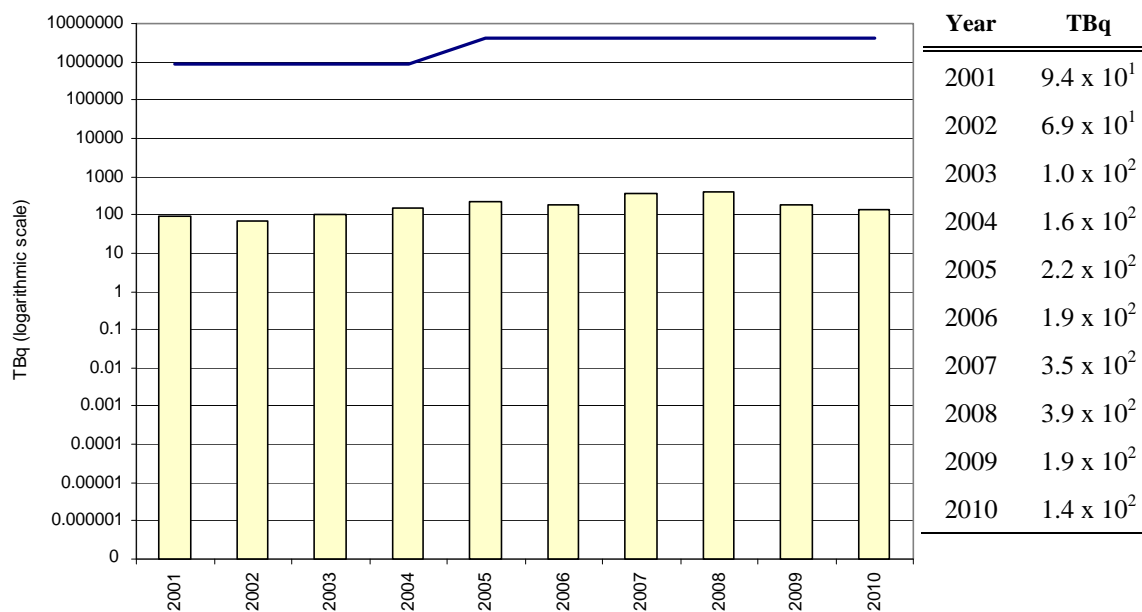
DRL from 2001 to 2004:  $9.4 \times 10^{-1}$  TBq; DRL since 2005: 2.4 TBq

**Figure 4.5: Radioactive particulate in gaseous effluent from the Darlington Nuclear Generating Station (2001–10)**



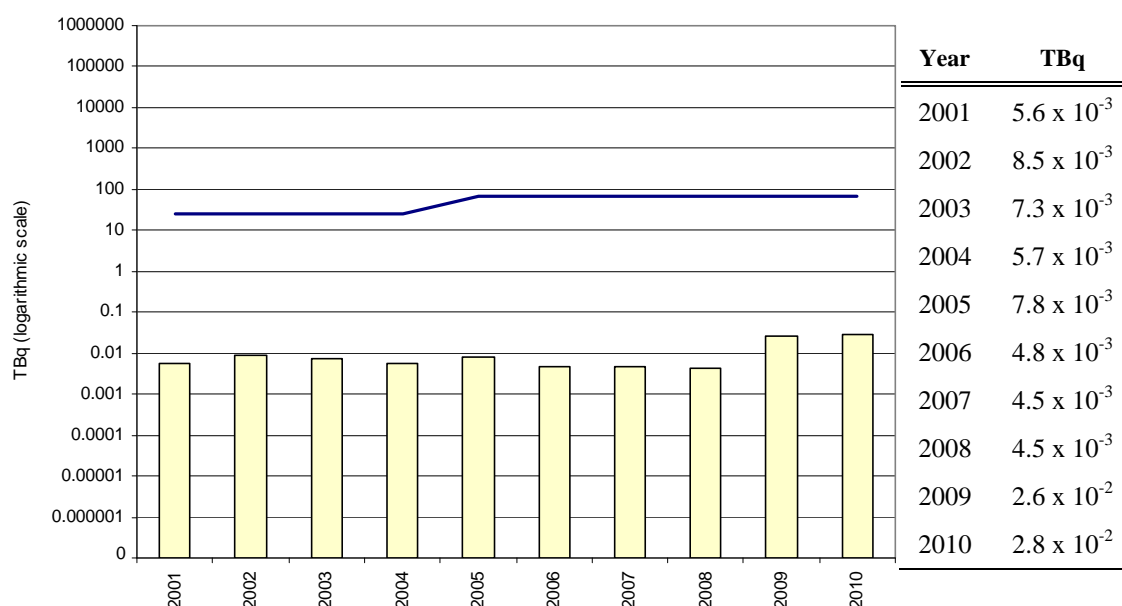
DRL from 2001 to 2004:  $1.5 \times 10^2$  TBq; DRL since 2005:  $1.8 \times 10^3$  TBq

**Figure 4.6: Carbon-14 in gaseous effluent from the Darlington Nuclear Generating Station (2001–10)**



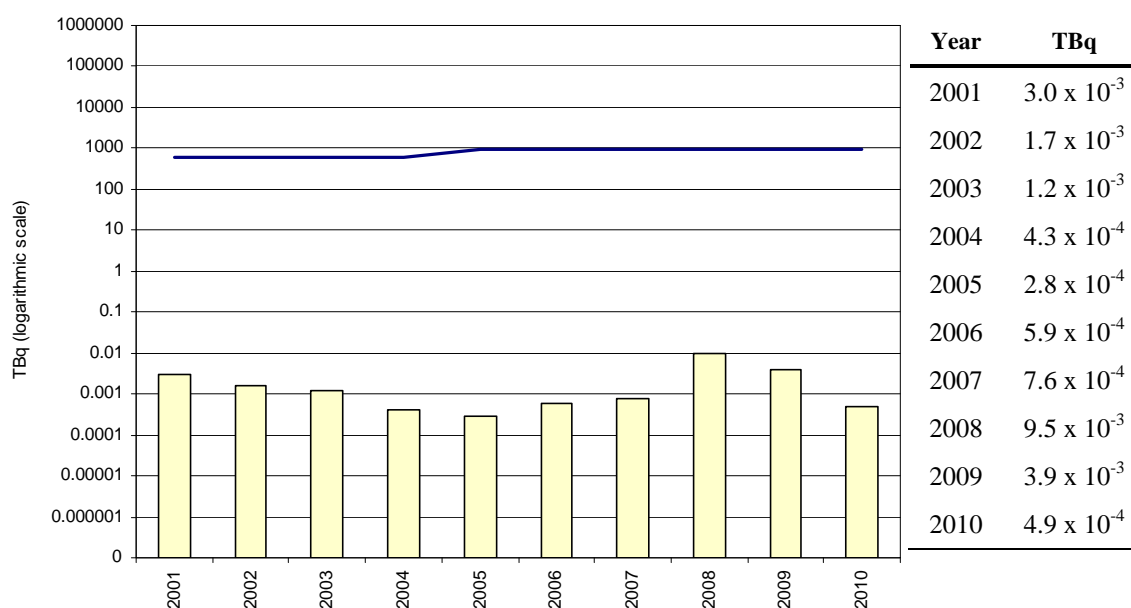
DRL from 2001 to 2004:  $8.8 \times 10^5$  TBq; DRL since 2005:  $4.3 \times 10^6$  TBq

**Figure 4.7: Tritium oxide in liquid effluent from the Darlington Nuclear Generating Station (2001–10)**



DRL from 2001 to 2004:  $2.6 \times 10^1$  TBq; DRL since 2005:  $7.1 \times 10^1$  TBq

**Figure 4.8: Gross beta-gamma activity in liquid effluent from the Darlington Nuclear Generating Station (2001–10)**



DRL from 2001 to 2004:  $6.0 \times 10^2$  TBq; DRL since 2005:  $9.7 \times 10^2$  TBq

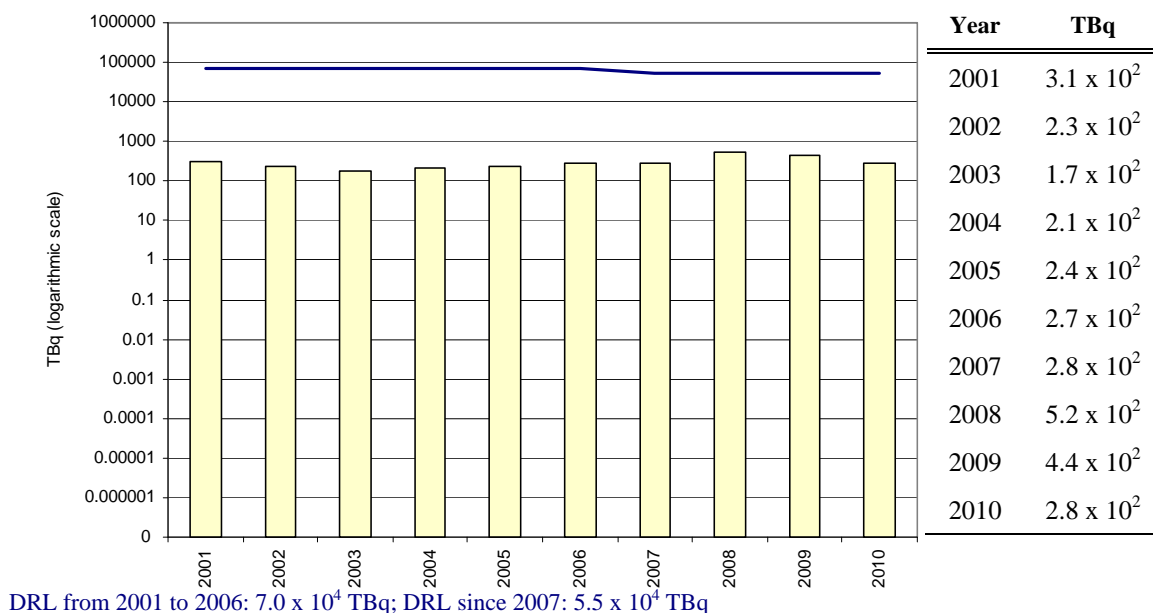
**Figure 4.9: Carbon-14 in liquid effluent from the Darlington Nuclear Generating Station (2001–10)**

## Pickering A Nuclear Generating Station

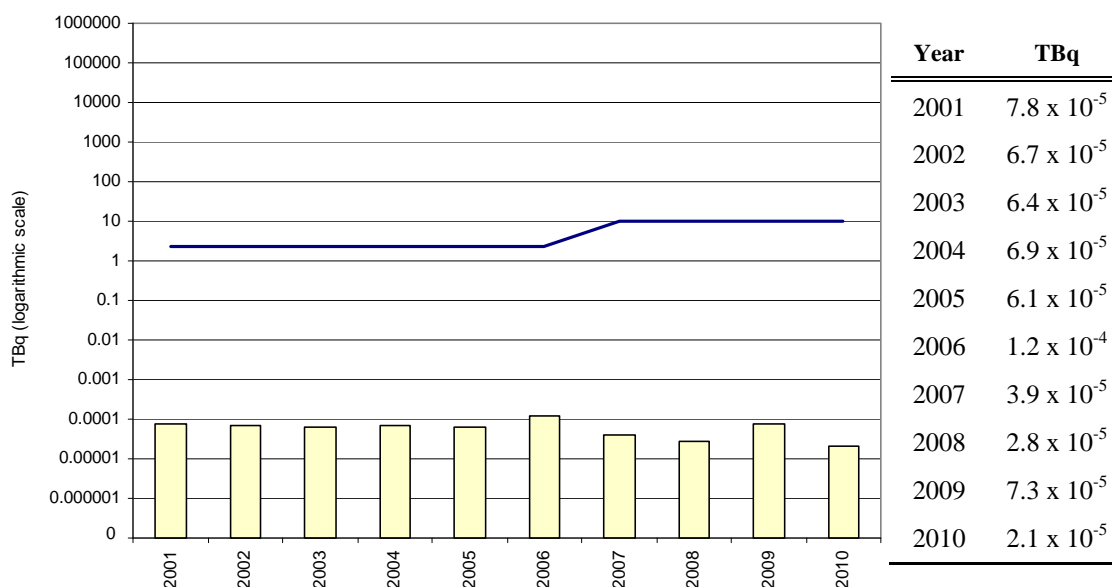
The Pickering A Nuclear Generating Station consists of four nuclear reactors (units 1 to 4), which began operation in 1971. It is located on the shores of Lake Ontario, near the town of Pickering, Ontario.

In 1997, as part of its extensive recovery program, Ontario Hydro (now Ontario Power Generation) temporarily shut down all Pickering-A reactors, and the reactors were maintained in a guaranteed shut-down state. Unit 4 was restarted in September 2003, and unit 1 was returned to service in 2005.

Data for radioactive gaseous and liquid effluents released between 2001 and 2010 from the Pickering-A nuclear generating station are presented in the graphs below. 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). Those in the liquid effluents are tritium in the form of tritium oxide (Figure 5.6) and gross beta-gamma activity (Figure 5.7).

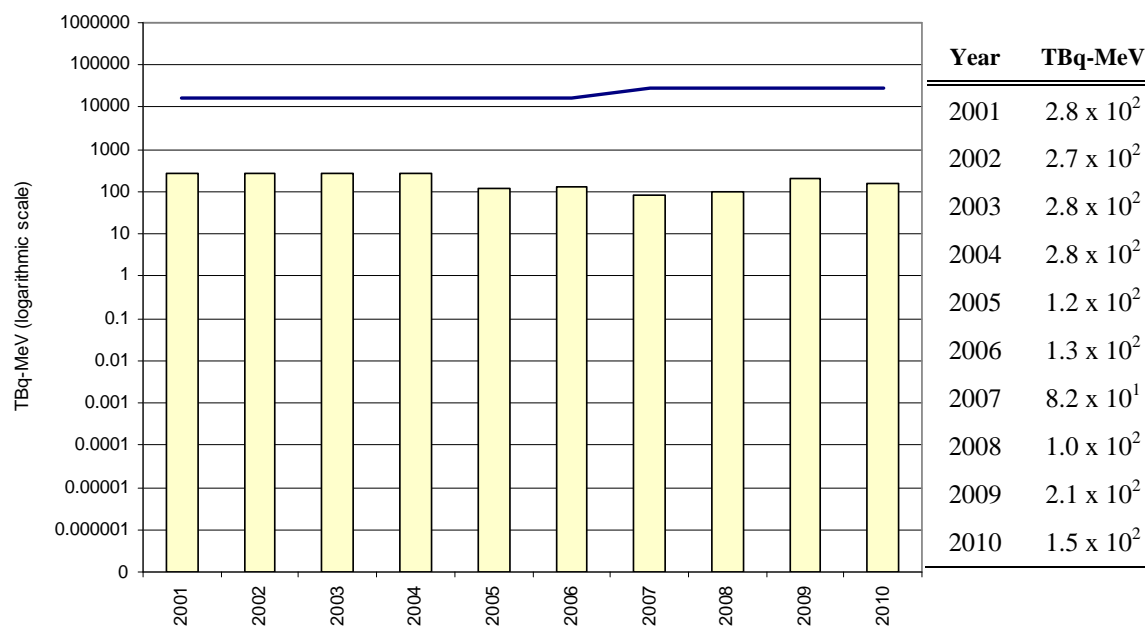


**Figure 5.1: Tritium oxide in gaseous effluent from the Pickering A Nuclear Generating Station (2001–10)**



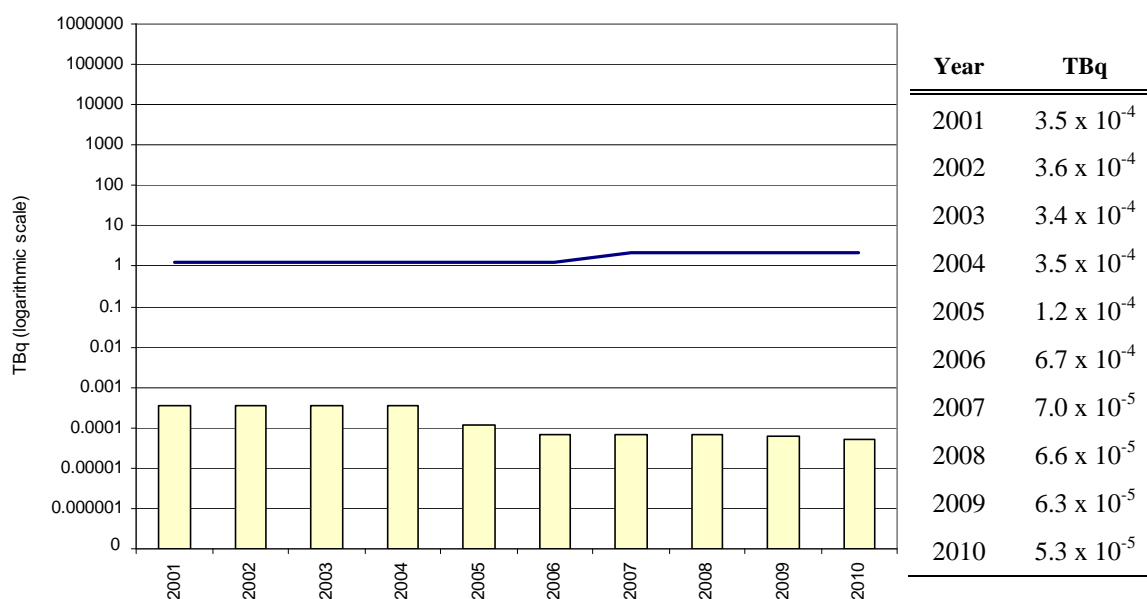
DRL from 2001 to 2006: 2.2 TBq; DRL since 2007: 9.7 TBq

**Figure 5.2: Iodine-131 in gaseous effluent from the Pickering A Nuclear Generating Station (2001–10)**



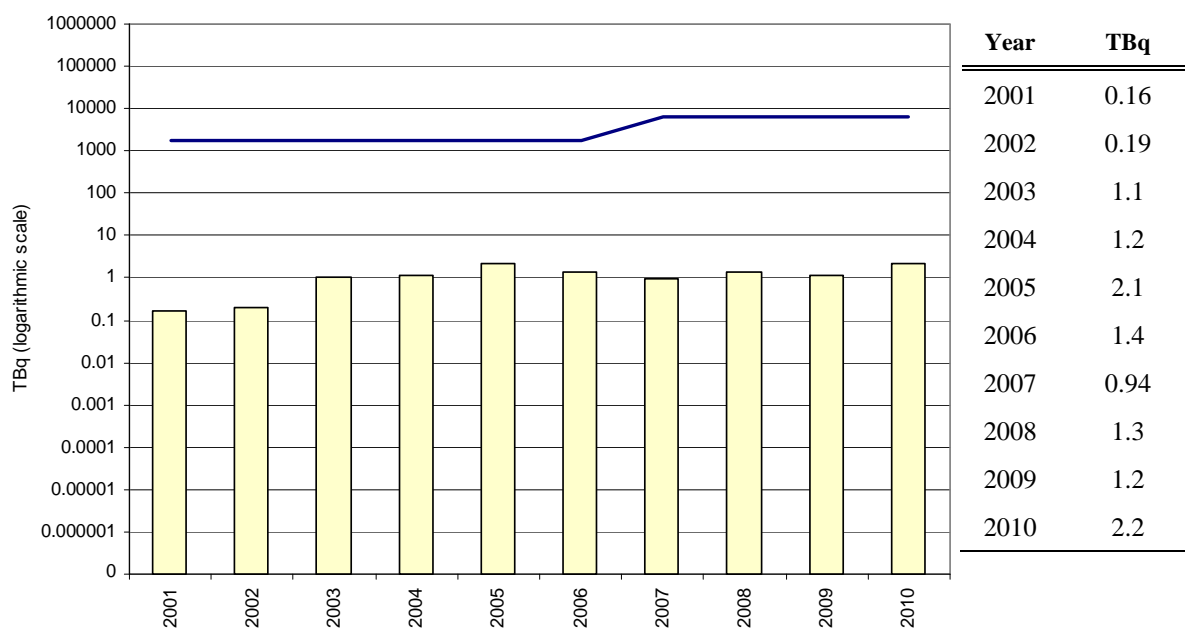
DRL from 2001 to 2006:  $1.7 \times 10^4$  TBq-MeV; DRL since 2007:  $2.9 \times 10^4$  TBq-MeV

**Figure 5.3: Noble gas in gaseous effluent from the Pickering A Nuclear Generating Station (2001–10)**



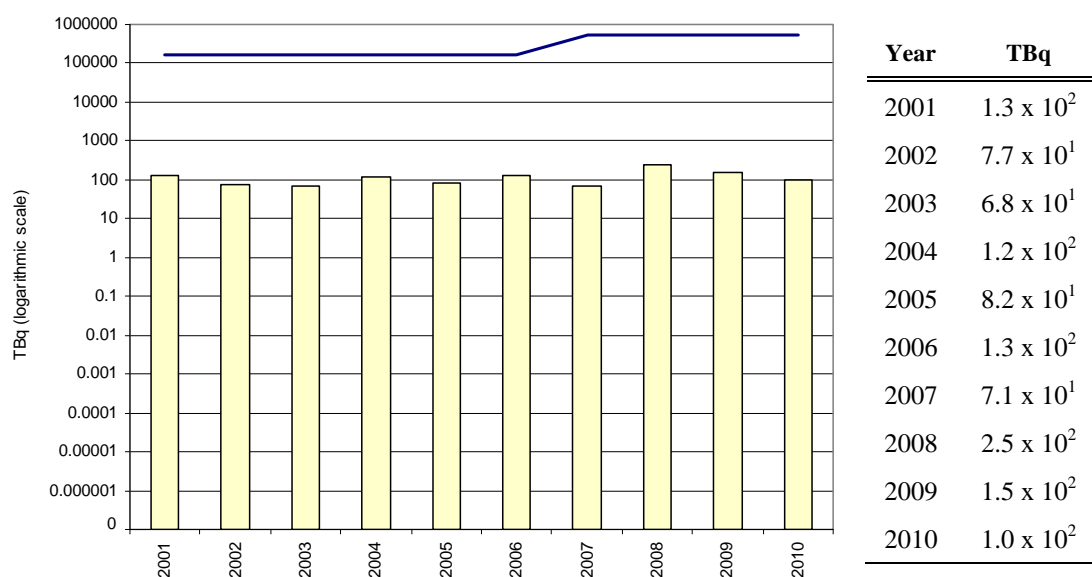
DRL from 2001 to 2006: 1.2 TBq; DRL since 2007: 2.1 TBq

**Figure 5.4: Radioactive particulate in gaseous effluent from the Pickering A Nuclear Generating Station (2001–10)**



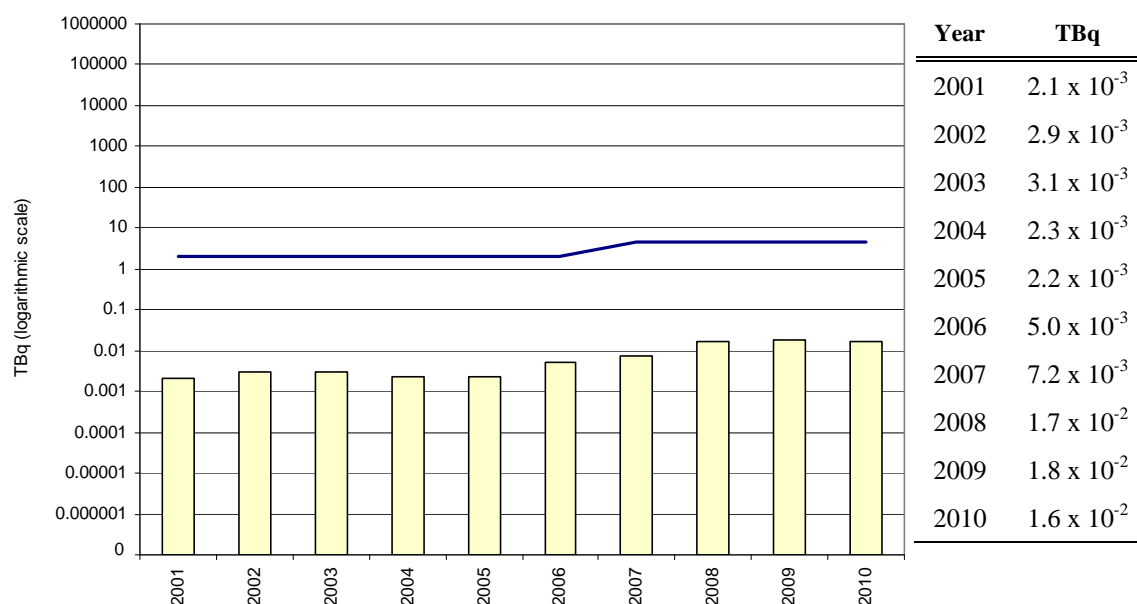
DRL from 2001 to 2006:  $1.8 \times 10^3$  TBq; DRL since 2007:  $6.3 \times 10^3$  TBq

**Figure 5.5: Carbon-14 in gaseous effluent from the Pickering A Nuclear Generating Station (2001–10)**



DRL from 2001 to 2006:  $1.7 \times 10^5$  TBq; DRL since 2007:  $5.1 \times 10^5$  TBq

**Figure 5.6: Tritium oxide in liquid effluent from the Pickering A Nuclear Generating Station (2001–10)**



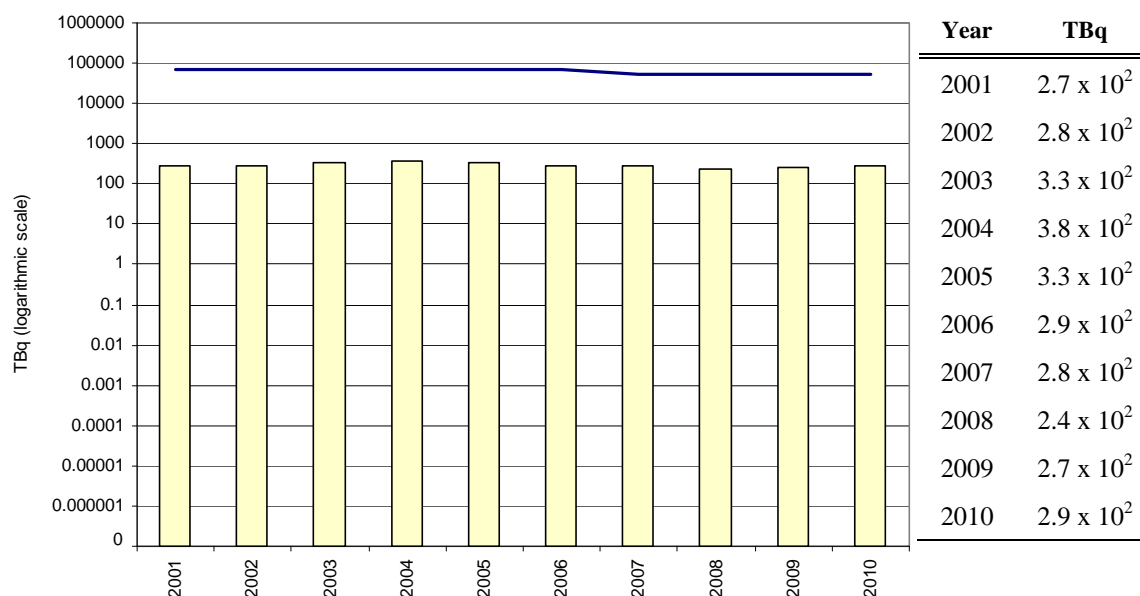
DRL from 2001 to 2006: 2.0 TBq; DRL since 2007: 4.7 TBq

**Figure 5.7: Gross beta-gamma activity in liquid effluent from the Pickering A Nuclear Generating Station (2001–10)**

## Pickering B Nuclear Generating Station

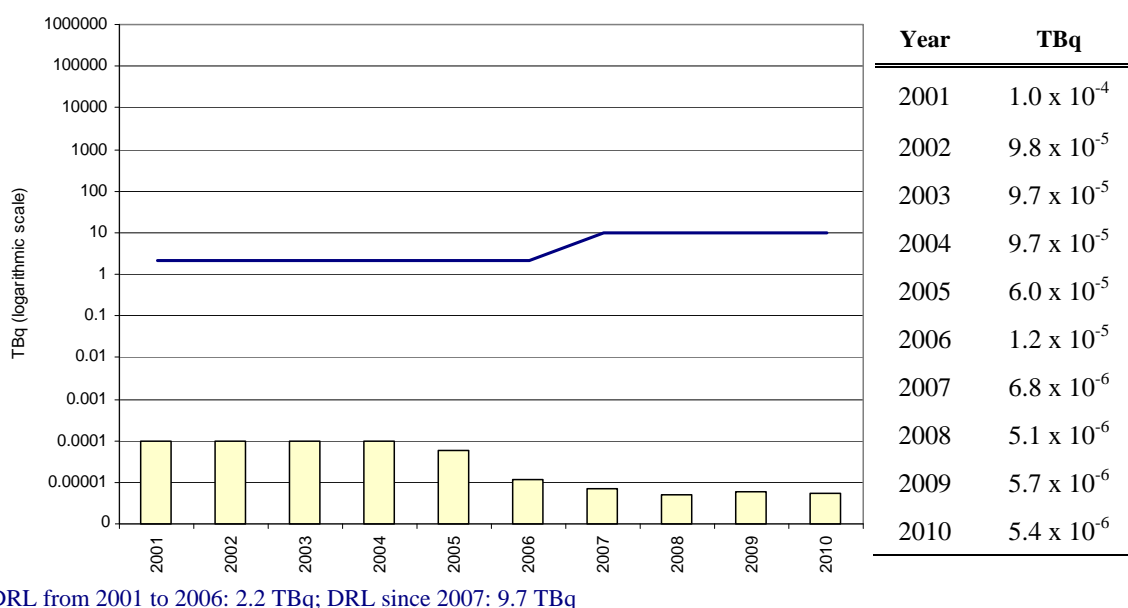
The Pickering B Nuclear Generating Station consists of four nuclear reactors (units 5 to 8), which began operation in 1982. It is located on the shore of Lake Ontario, near the town of Pickering, Ontario.

Data for radioactive gaseous and liquid effluents released between 2001 and 2010 from the Pickering B Nuclear Generating Station are presented in the graphs below. 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). 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).

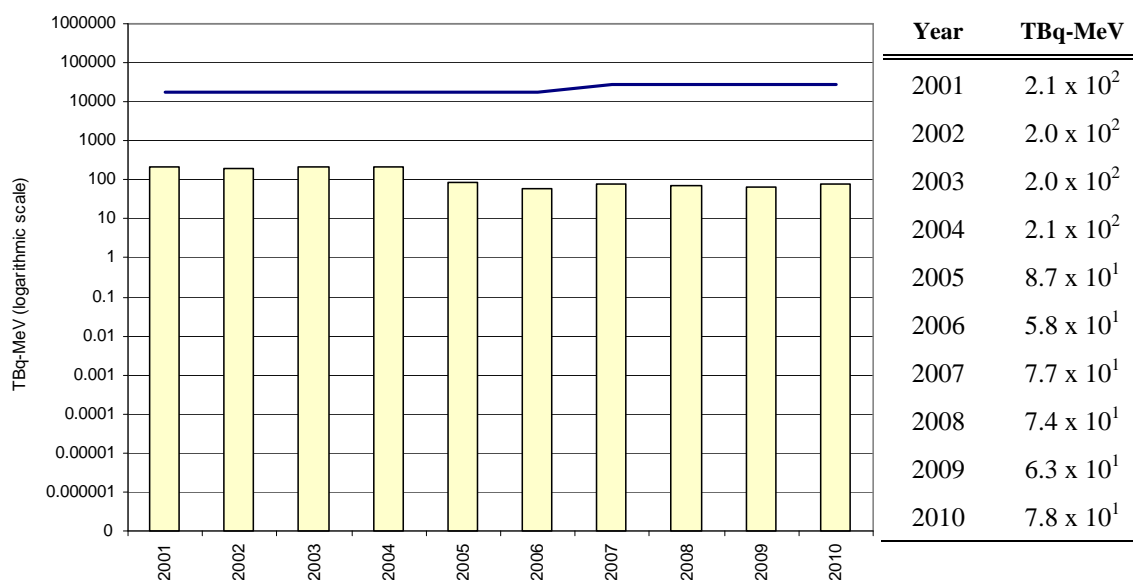


DRL from 2001 to 2006:  $7.0 \times 10^4$  TBq; DRL since 2007:  $5.5 \times 10^4$  TBq

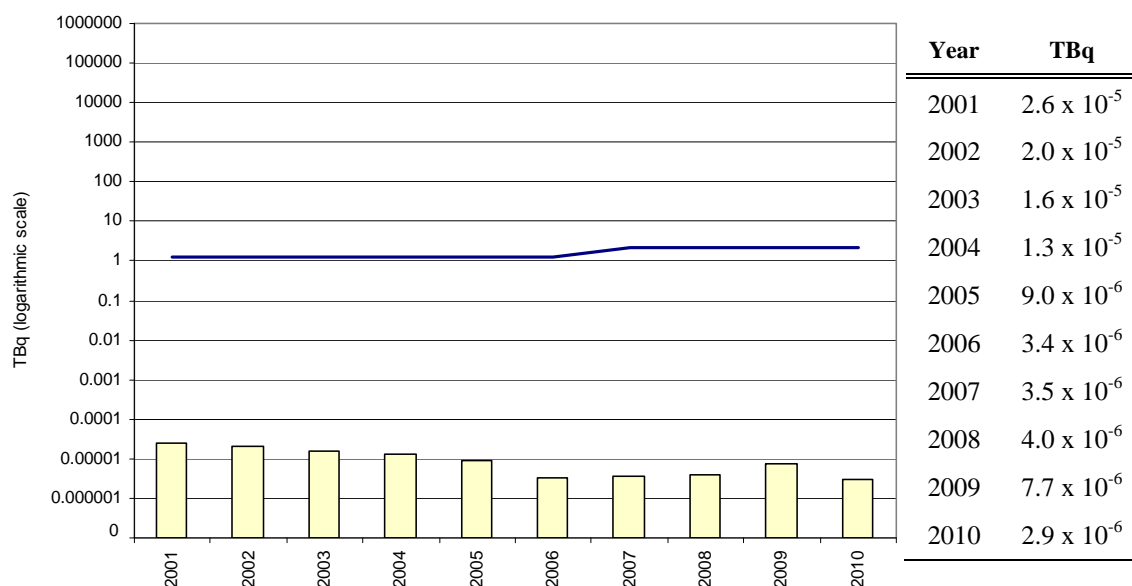
**Figure 6.1: Tritium oxide in gaseous effluent from the Pickering B Nuclear Generating Station (2001–10)**



**Figure 6.2: Iodine-131 in gaseous effluent from the Pickering B Nuclear Generating Station (2001–10)**

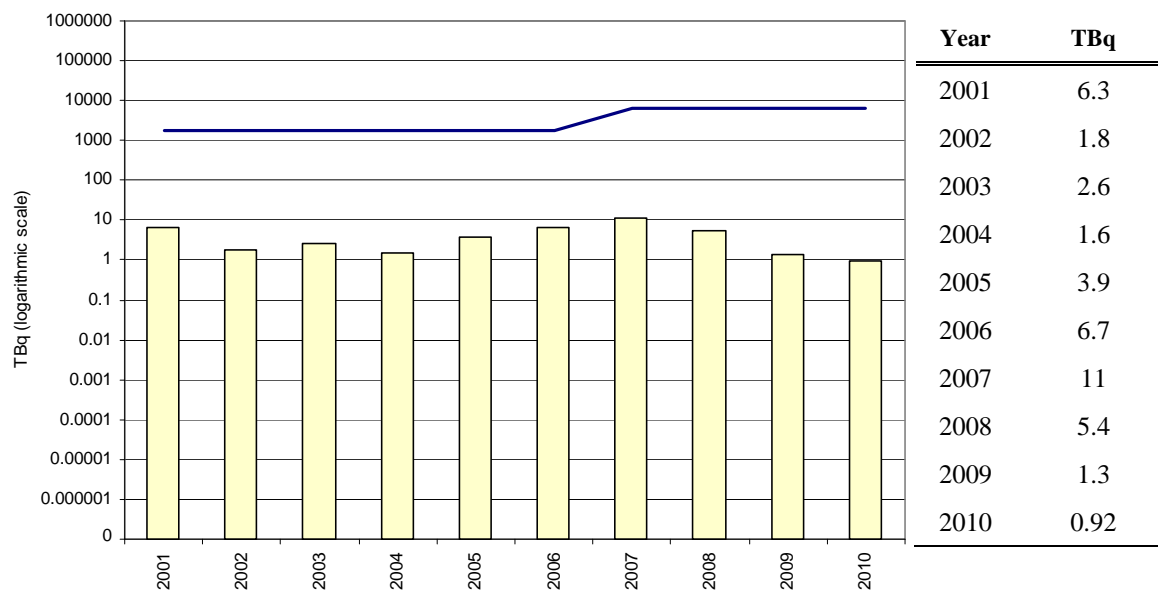


**Figure 6.3: Noble gas in gaseous effluent from the Pickering B Nuclear Generating Station (2001–10)**



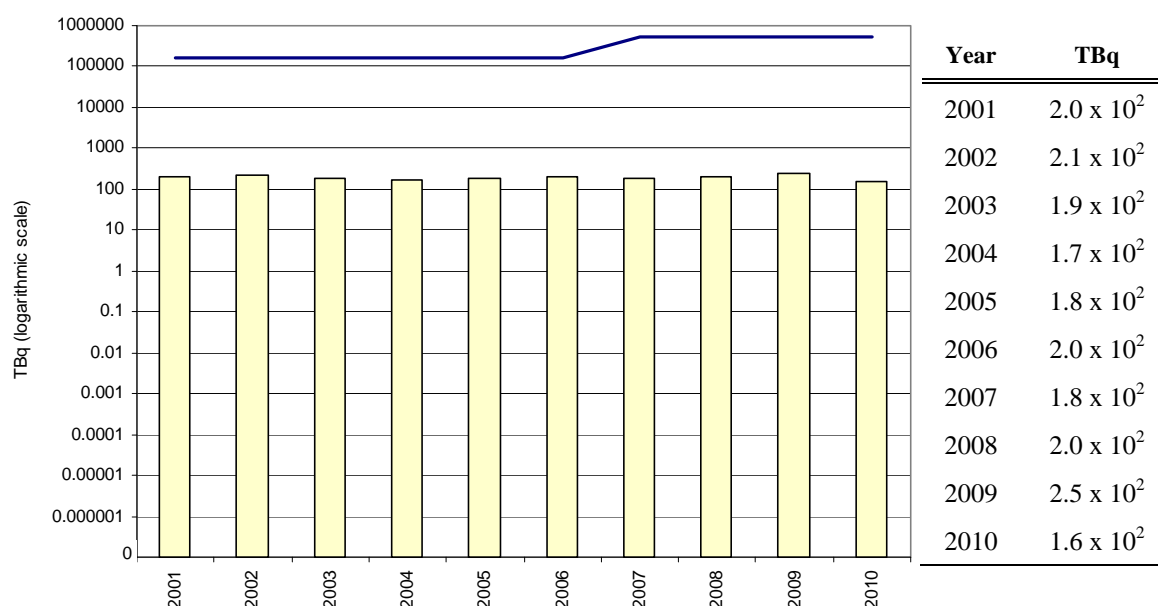
DRL from 2001 to 2006: 1.2 TBq; DRL since 2007: 2.1 TBq

**Figure 6.4: Radioactive particulate in gaseous effluent from the Pickering B Nuclear Generating Station (2001–10)**



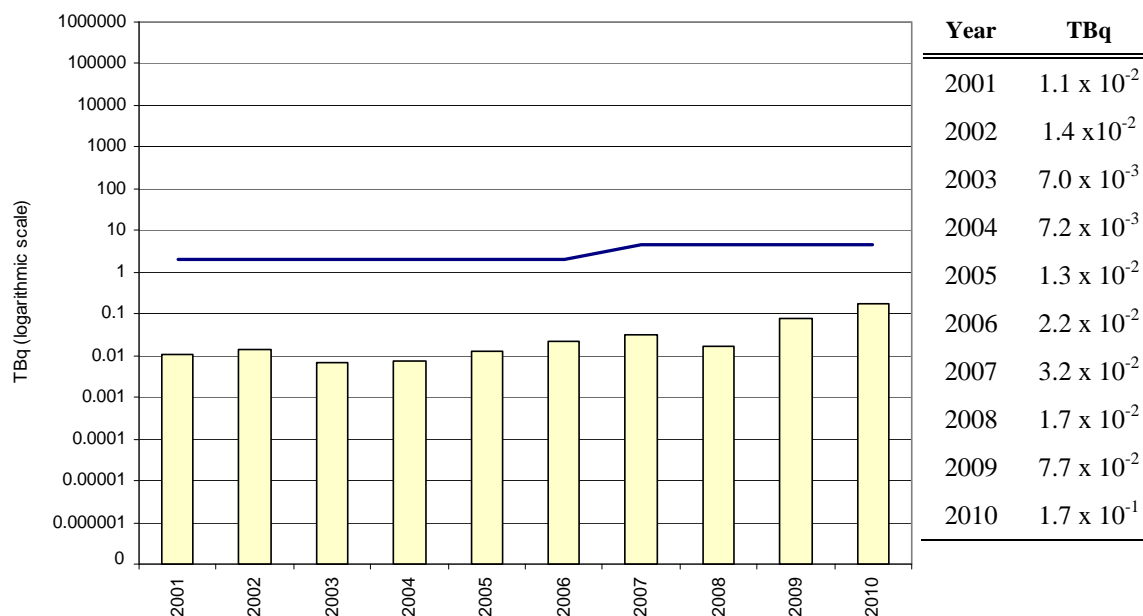
DRL from 2001 to 2006:  $1.8 \times 10^3$  TBq; DRL since 2007:  $6.3 \times 10^3$  TBq

**Figure 6.5: Carbon-14 in gaseous effluent from the Pickering-B Nuclear Generating Station (2001–10)**



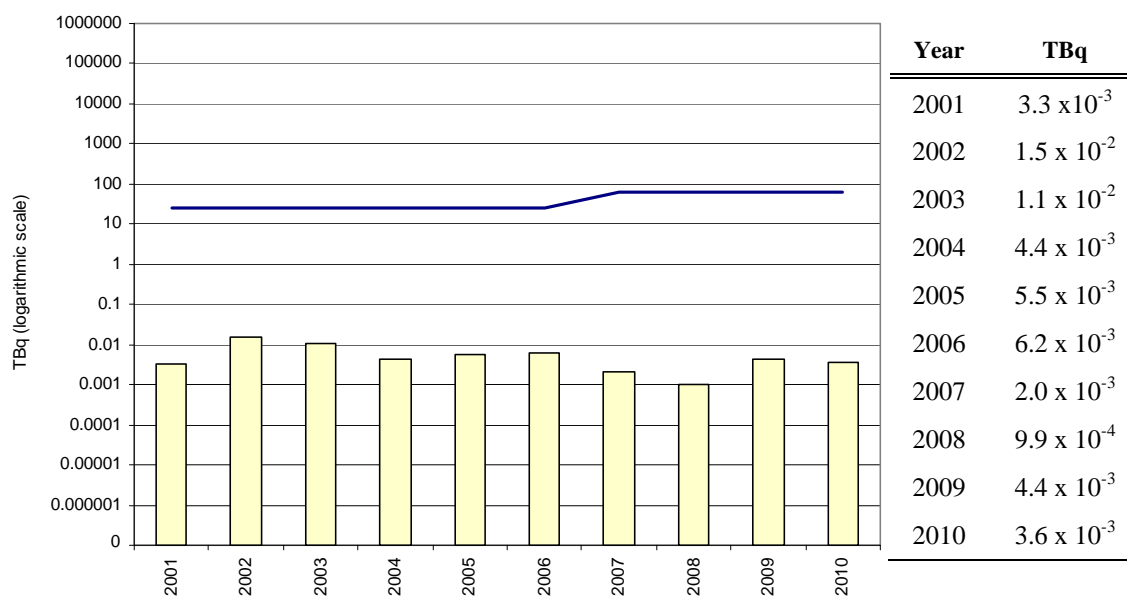
DRL from 2001 to 2006:  $1.7 \times 10^5$  TBq; DRL since 2007:  $5.1 \times 10^5$  TBq

**Figure 6.6: Tritium oxide in liquid effluent from the Pickering B Nuclear Generating Station (2001–10)**



DRL from 2001 to 2006: 2.0 TBq; DRL since 2007: 4.7 TBq

**Figure 6.7: Gross beta-gamma activity in liquid effluent from the Pickering B Nuclear Generating Station (2001–10)**



DRL from 2001 to 2006:  $2.6 \times 10^1$  TBq; DRL since 2007:  $6.4 \times 10^1$  TBq

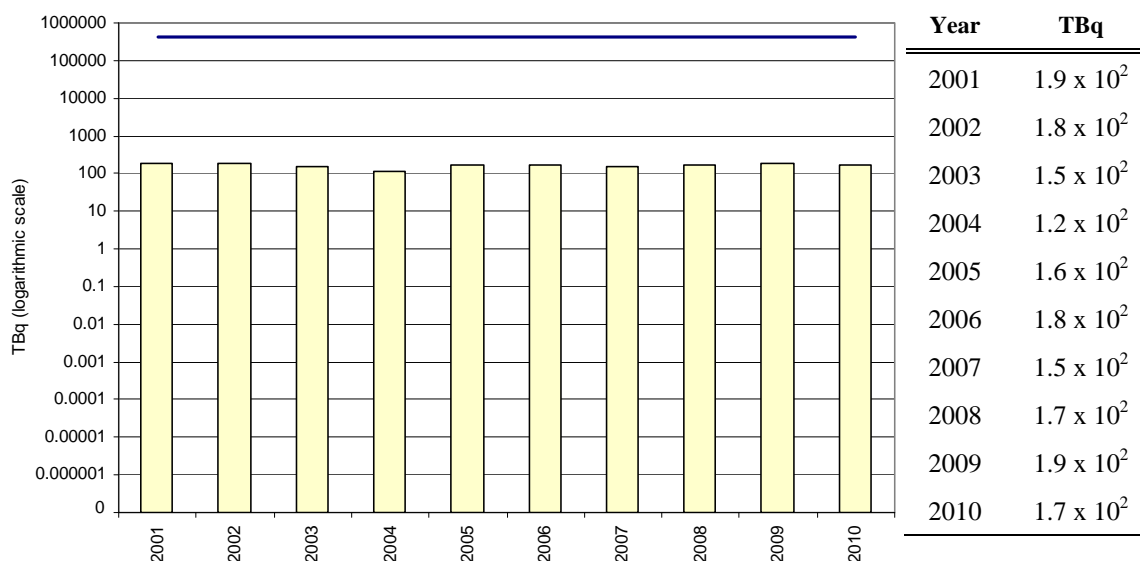
**Figure 6.8: Carbon-14 in liquid effluent from both Pickering A and Pickering B Nuclear Generating Stations (2001–10)**

## Quebec

### Gentilly-2 Nuclear Generating Station

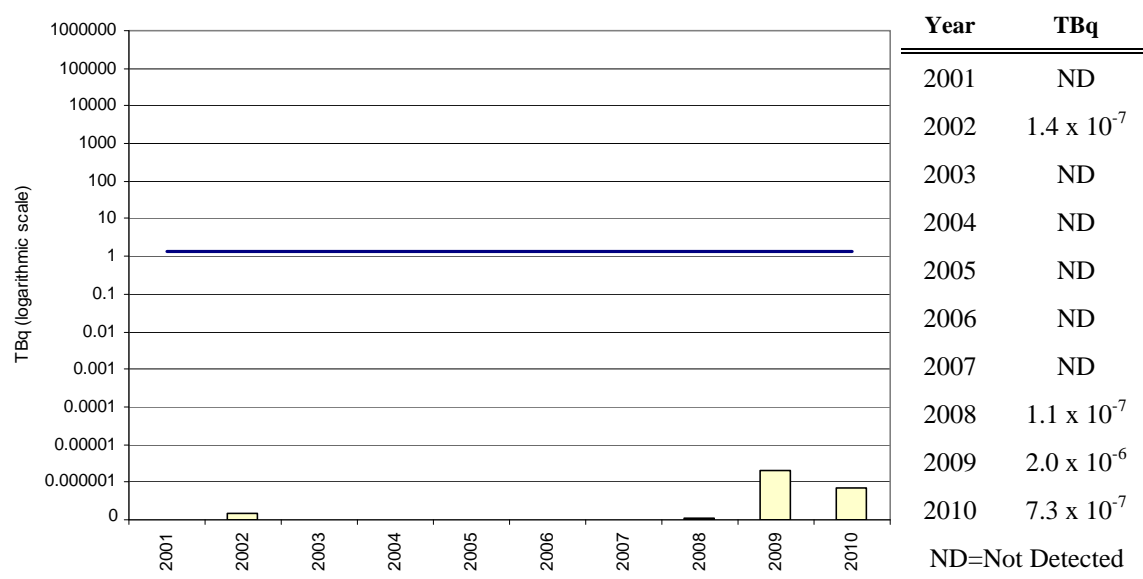
The Gentilly-2 Nuclear Generating Station consists of one nuclear reactor which became operational in 1982. It is located in on the Saint Lawrence River, near the city of Bécancour, Quebec.

Data for radioactive gaseous and liquid effluents released between 2001 and 2010 from the Gentilly-2 Nuclear Generating Station are presented in the graphs below. 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 particulate (Figure 7.4) and carbon-14 (Figure 7.5). 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).



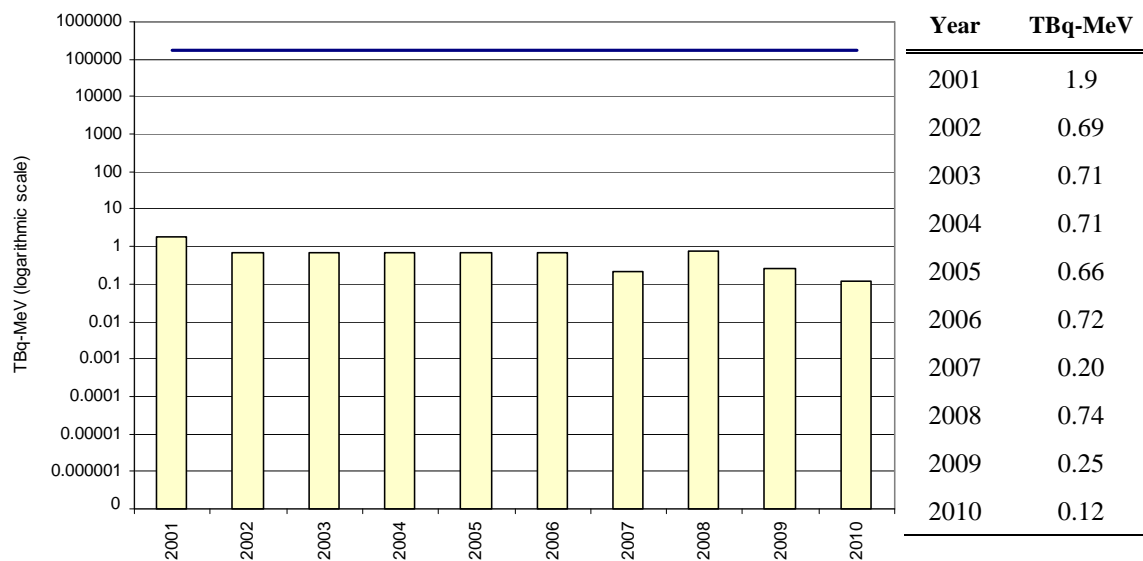
DRL since 1992:  $4.4 \times 10^5$  TBq

**Figure 7.1: Tritium oxide in gaseous effluent from the Gentilly-2 Nuclear Generating Station (2001–10)**



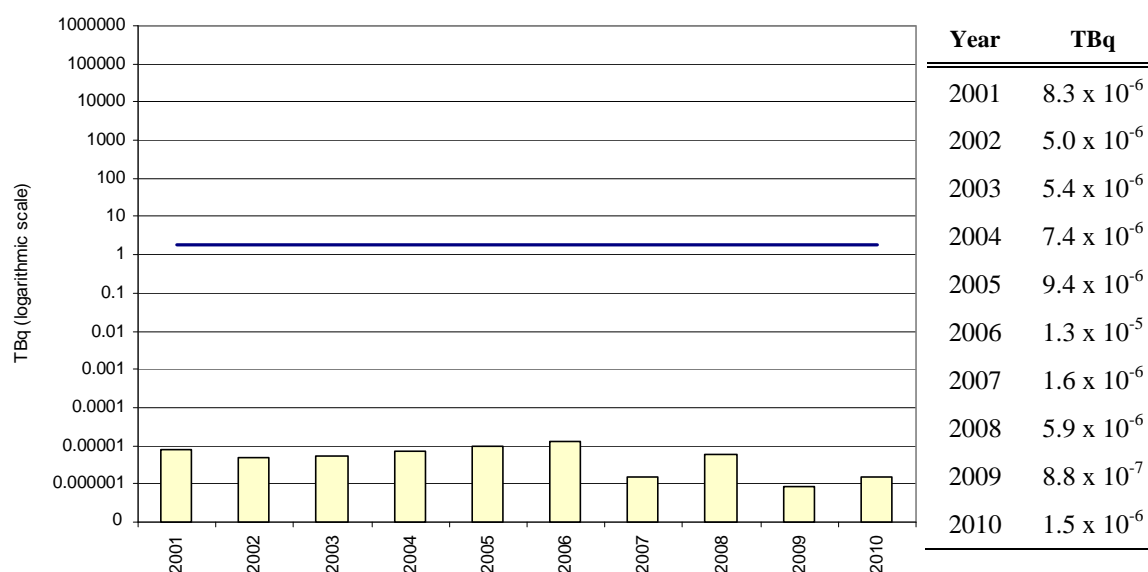
DRL since 1992: 1.3 TBq

**Figure 7.2: Iodine-131 in gaseous effluent from the Gentilly-2 Nuclear Generating Station (2001–10)**



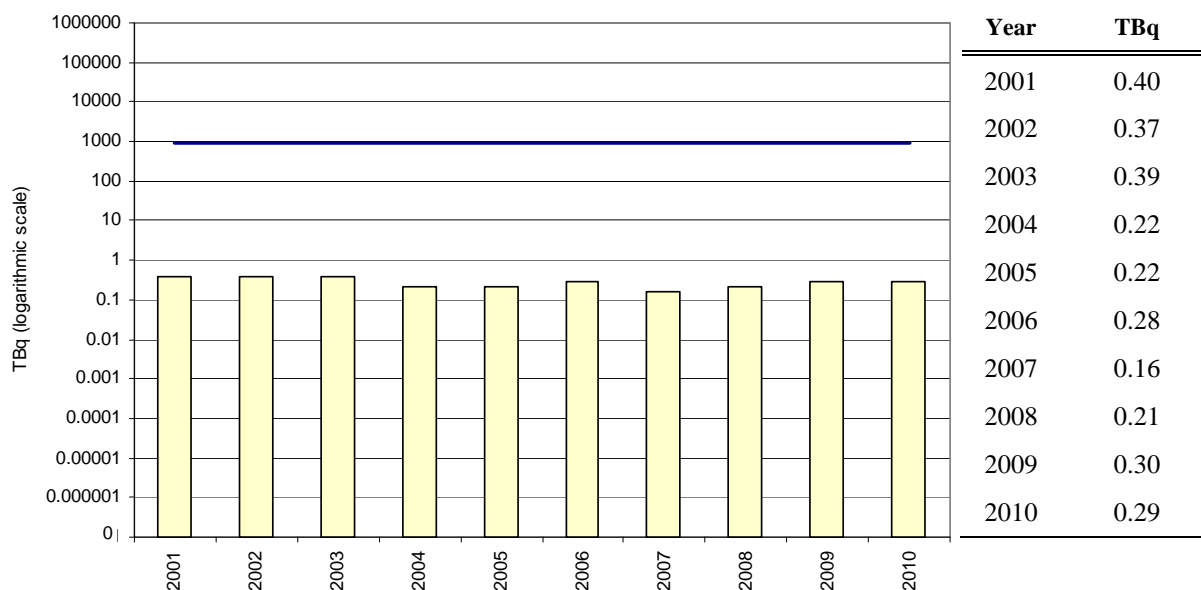
DRL since 1992:  $1.7 \times 10^5$  TBq-MeV

**Figure 7.3: Noble gas in gaseous effluent from the Gentilly-2 Nuclear Generating Station (2001–10)**



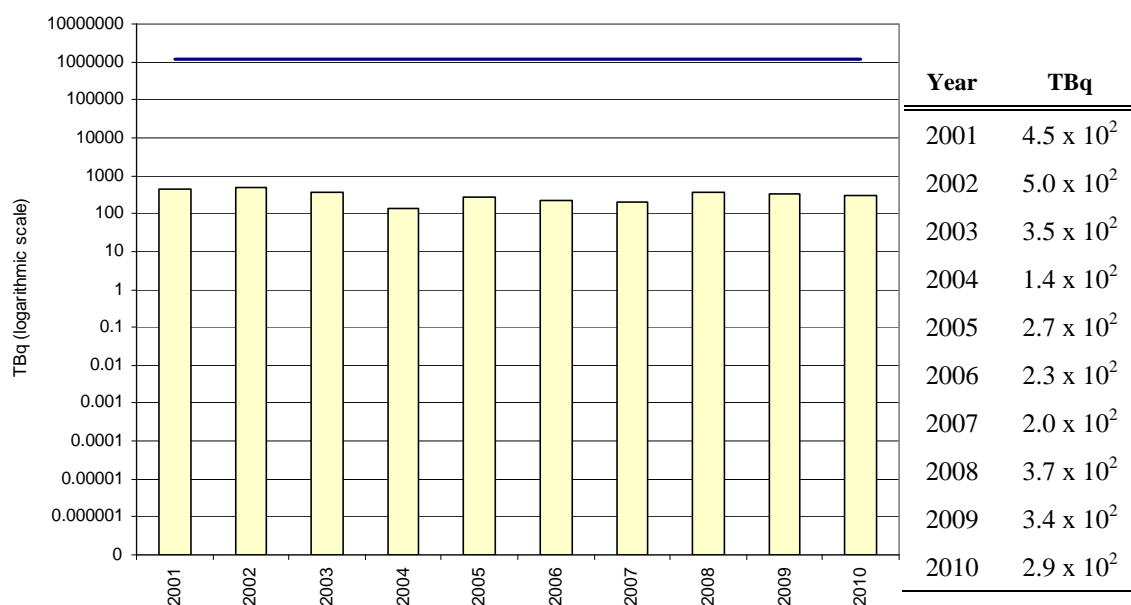
DRL since 1992: 1.9 TBq

**Figure 7.4: Radioactive particulate in gaseous effluent from the Gentilly-2 Nuclear Generating Station (2001–10)**



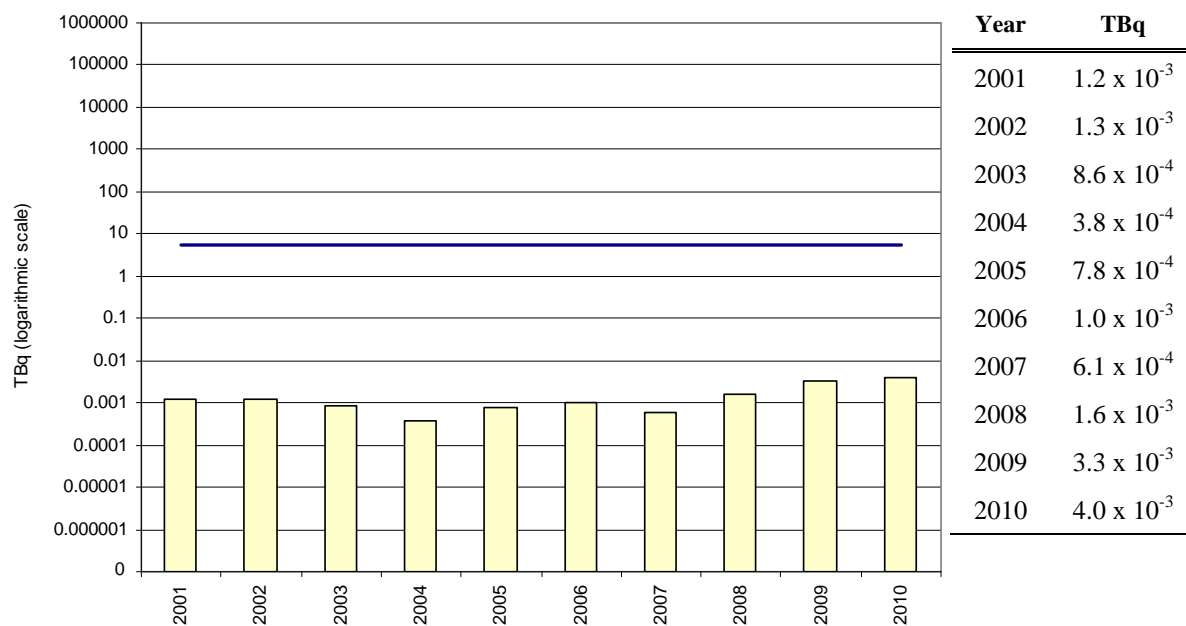
DRL from 1992 to 2003:  $9.1 \times 10^2$ , DRL since 2003:  $8.8 \times 10^2$  TBq

**Figure 7.5: Carbon-14 in gaseous effluent from the Gentilly-2 Nuclear Generating Station (2001–10)**



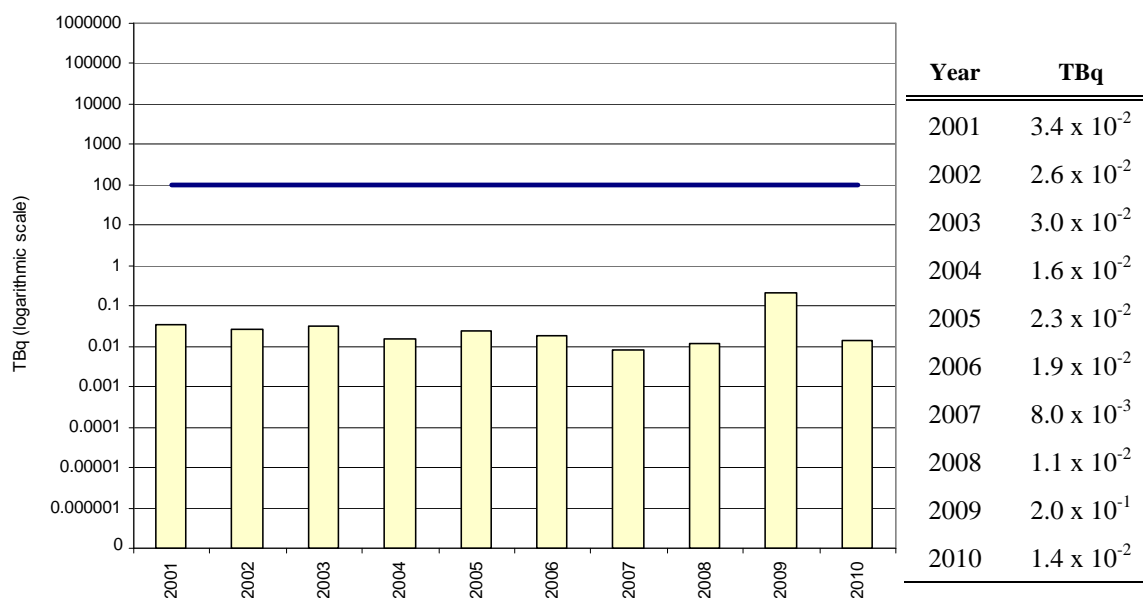
DRL since 1992:  $1.2 \times 10^6$  TBq

**Figure 7.6: Tritium oxide in liquid effluent from the Gentilly-2 Nuclear Generating Station (2001–10)**



DRL since 1992: 5.3 TBq

**Figure 7.7: Gross beta-gamma activity in liquid effluent from the Gentilly-2 Nuclear Generating Station (2001–10)**



DRL since 1992:  $1.0 \times 10^2$  TBq

**Figure 7.8: Carbon-14 in liquid effluent from the Gentilly-2 Nuclear Generating Station (2001–10)**

## Glossary

**Action Level:** A specific quantity of radionuclide (released as effluent) that, if reached, may indicate a loss of control of part of a licensee's environmental protection program and trigger a requirement for specific action to be taken.

**Becquerel (Bq):** The unit under the SI system used to measure the quantity of radiation emitted by an isotope of an element. It is equivalent to 1 disintegration per second, or  $2.7 \times 10^{-11}$  curies.

**Derived Release Limit (DRL):** A limit on the release of a radioactive substance from a licensed nuclear facility. Compliance with this threshold gives reasonable assurance that the regulatory public dose limit will not be exceeded.

**Dose Limit:** A maximum allowable radiation dose, as specified in the CNSC *Radiation Protection Regulations*, which is in place to minimize the risk of adverse health effects due to radiation exposure.

**Iodine-131 (I-131):** One of several radioisotopes of iodine. It is produced during the normal operation of a nuclear reactor.

**Carbon-14:** A radioactive isotope of carbon that is produced during normal operation of a CANDU nuclear reactor.

**Gross Beta-Gamma:** A measurement of all beta and gamma activity present, regardless of their specific radionuclide source. Gross measurements are used as a method to screen samples for relative levels of radioactivity.

**Ionizing Radiation:** Any atomic or subatomic particle or electromagnetic wave with sufficient energy to produce ions (atoms that 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 separating each value from the reference point are proportional to their exponents, rather than their linear relationship. The presentation of data on a logarithmic scale is helpful when the data covers a large range of values.

**Noble Gases:** The chemically inert gases (xenon, argon, krypton, neon and helium). Radioisotopes of the noble gases are created during the operation of a nuclear reactor.

**Radionuclide:** A material with an unstable atomic nucleus that spontaneously decays or disintegrates, producing radiation.

**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.

**Representative Person:** An individual who receives a radiation dose and is representative of the more highly exposed individuals in the population. While the concept of the representative person is the same for all nuclear power plants stations in Canada, the description of the representative person for each station is unique for each facility and is based on analysis of site-specific radionuclide releases and exposure pathways.

**Sievert (Sv):** The SI unit of dose, corresponding to the rem ( $1 \text{ Sv} = 100 \text{ rem}$ ). It is the product of absorbed dose in grays and the radiation weighting factor.

**Tritium:** A radioactive form of hydrogen that has an atomic mass number of three. Tritium is produced during the normal operation of CANDU reactors. Elemental tritium refers to the form HT, and tritium oxide refers to the form HTO.