Canada's Nuclear Regulator

Standards and Guidelines for Tritium in Drinking Water

Part of the Tritium Studies Project

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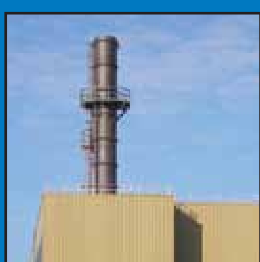
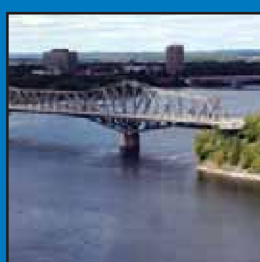

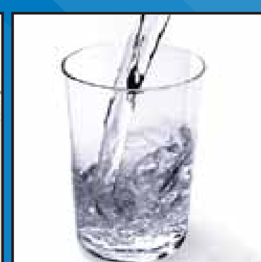

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Standards and Guidelines for Tritium in Drinking Water

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TABLE OF CONTENTS

TABLES

ACRONYMS

ACES	Advisory Committee on Environmental Standards
ACNS	Advisory Committee on Nuclear Safety
ACRP	Advisory Committee on Radiological Protection
AECB	Atomic Energy Control Board
ALARA	as low as reasonably achievable
BEIR I	Biological Effects of Ionizing Radiation
CDW	Federal-Provincial-Territorial Committee on Drinking Water
CNSC	Canadian Nuclear Safety Commission
DCF	dose conversion factor
DRL	derived release limit
EU	European Union
FAO	Food and Agriculture Organization (of the United Nations)
GL	guideline reference level
IAEA	International Atomic Energy Agency
ICRP	International Commission on Radiological Protection
JWG-6	Joint Working Group 6
MAC	maximum acceptable concentration
MCL	maximum contaminant level
MOE	Ministry of the Environment (of Ontario)
NSCA	Nuclear Safety and Control Act
OECD	Organization for Economic Cooperation and Development
OEHHA	Office of Environmental Health Hazard Assessment
PHG	public health goal
RDL	reference dose level
TID	total indicative dose
USEPA	United States Environmental Protection Agency
WHO	World Health Organisation

GLOSSARY

ALARA	Principle for radiation protection, according to which exposures are kept as low as reasonably achievable, while the social and economic factors being taken into account.
Becquerel	Unit of activity, the rate at which transformations occur in a radioactive substance. 1 Bq = 1 transformation or disintegration per second. See Table 1.
committed effective dose	Effective dose that will be accumulated over a period of time, following a single intake of radioactive material into the body. Standard periods of integration are 50 years for adults and 70 years for a lifetime exposure. Unit: Sievert, symbol Sv. See Table 1.
dose conversion factor	Converts an intake of a given radionuclide, in Becquerels, to effective dose, in Sieverts
drinking water	Water intended for human consumption.
effective dose	Measure of dose designed to reflect the amount of radiation detriment likely to result from the dose. Unit: Sievert, symbol Sv. See Table 1.
guideline reference level	Highest recommended concentration of a contaminant in drinking water guidelines. Synonyms: maximum acceptable concentration, maximum contaminant level.
maximum acceptable concentration	Highest acceptable concentration of a contaminant in the *Guidelines for Canadian Drinking Water Quality.* Synonyms: guideline reference level, maximum contaminant level.
maximum contaminant level	Highest acceptable concentration of a contaminant in the United States' National Primary Drinking Water Regulations. Synonyms: guideline reference level, maximum acceptable concentration.
radionuclide	Unstable nuclide that emits ionising radiation.

Table 1. Radiation Units

Quantity	Old unit	Symbol	SI unit	Symbol	Relationship
Activity	Curie	Ci	Becquerel	Bq	1 Ci = 3.7×10^{10} Bq
(Committed) Effective dose	rem	rem	Sievert	Sv	1 rem = 0.01 Sv

EXECUTIVE SUMMARY

In January 2007, the Canadian Nuclear Safety Commission (CNSC) Tribunal directed CNSC staff to initiate research studies on tritium releases in Canada. In response, staff initiated a "Tritium Studies" project with several information gathering and research activities extending to 2010. The objective of this major research project is to enhance the information used in the regulatory oversight of tritium processing and tritium releases in Canada. The Standards and Guidelines for Tritium in Drinking Water *report is part of this project.*

- Natural background levels of tritium can be found everywhere in the environment.
- In Canada, the control of tritium releases to the environment is important, since this element is a by-product of CANDU nuclear reactors and is used to produce gaseous tritium light sources.
- The guidelines for radionuclides in drinking water adopted by the majority of the international community are based on international radiation protection methodologies and recommendations of the International Commission on Radiological Protection (ICRP) and the World Health Organization (WHO).
- The European Union, the United States, Australia and Finland use variations of the WHO approach to arrive at differing guideline reference levels.
- In Canada, current tritium levels in drinking water are several orders of magnitude lower than the guideline reference level (GL) of 7,000 Bq/L near nuclear facilities, and similarly well below the European Union's GL of 100 Bq/L.

1. INTRODUCTION

1.1 Tritium in the Environment

Tritium is a radioactive form of hydrogen with a physical decay half-life of 12.3 years. It emits very low-energy beta radiation, which is completely absorbed by common materials such as sheets of plastic, glass or metal, and cannot penetrate the top dead layer of skin in humans. Exposure can nevertheless pose a risk if the element is ingested in drinking water or food, or inhaled or absorbed through the skin.

In Canada, the control of tritium releases to the environment is particularly important, since CANDU reactors produce significantly more tritium than most other types of reactors due to the use of heavy water (deuterium) in the moderator and heat transport system. Tritium is also used by a few industries to produce gaseous tritium light sources. Much smaller quantities are used in research applications, and as a tracer in oil and gas exploration.

Tritium also forms naturally in the upper atmosphere due to the continuous bombardment of atmospheric gases by high energy cosmic rays. When it is present either naturally or artificially, tritium may be incorporated into water, thus entering the natural hydrological cycle. Hence, natural background levels of tritium can be found everywhere in the environment, including water, soil, and vegetation.

Additional information on the presence and use of tritium in Canada can be found in a recent document produced by the Canadian Nuclear Safety Commission [CNSC, 2007a].

1.2 Regulation of Tritium Releases in Canada

Under the *Nuclear Safety and Control Act* (NSCA), the mandate of the Canadian Nuclear Safety Commission (CNSC) includes the dissemination of scientific, technical and regulatory information concerning the activities of the CNSC, and the effects on the environment and the health and safety of persons, of the development, production, possession, transport and use of nuclear substances. Under the NSCA, the CNSC regulates facilities that possess more than 1 GBq (1×10^9 Bq) of tritium.

The CNSC regulates potential releases of tritium to the environment through several licensing requirements, including absolute limits on how much tritium can be released on a license-specific basis. This is typically accomplished by imposing quantitative Derived Release Limits (DRL) on tritium entering air or water. These quantities are based on limiting releases to levels less or equal to the prescribed public dose limit of 1 mSv. Current tritium DRLs and amounts actually released relative to these absolute limits are summarized in [CNSC, 2007b].

General requirements for major nuclear facilities licensed by the CNSC include environmental protection policies, programs, and procedures that make adequate provision for protection of the environment. These are typically referred to collectively as an environmental management system, and include two key provisions for the control of releases of radioactivity to the environment: ALARA and Action Levels. ALARA is the paramount requirement for all licensed activities under the *Radiation Protection Regulations*; according to it, releases must be kept "As Low As Reasonably Achievable", social and economic factors being taken into account. Action Levels are also required, and are set such that an exceedence may indicate a loss of control. Action levels are typically set for gaseous or liquid effluent concentrations or for activity levels in the environment. Response to an action level includes a thorough investigation of the cause, remedial actions and reporting to the CNSC. In addition, licensees usually establish administrative controls set well below action levels to trigger investigations into potentially unusual operating conditions and their root causes.

The CNSC requires regular reporting of the results of monitoring of routinely-discharged radioactive effluents (including the total activity or total amount released), and, at a minimum, annual reports of environmental monitoring results. Lastly, the CNSC also requires the reporting of any release of a nuclear substance into the environment at a quantity not authorized by the NSCA, regulations or the license, or any unmeasured release.

1.3 Scope of this Document

In January 2007, the Commission tribunal directed CNSC staff to initiate research studies on tritium releases in Canada, and to study and evaluate tritium processing facilities in the world exercising best practices. In response, CNSC staff initiated a *"Tritium Studies"* project with several planned information gathering and research activities extending to 2010 (a fact sheet is available at www.nuclearsafety.gc.ca). The objective of this project is to enhance the information available to guide regulatory oversight of tritium processing and tritium releases in Canada.

This present report of drinking water standards and guidelines is a factual report, one of a series of public information documents being produced through the auspices of the *Tritium Studies* project. Its purpose is threefold:

- to summarize criteria on a national and international basis from readily-available public sources of information, along with the scientific and policy basis underlying these criteria;
- to discuss the Canadian federal drinking water guideline of 7,000 Bq/L relative to criteria or guidance from other jurisdictions; and
- to provide a perspective on the need for any revisions to the existing regulatory approach for tritium by providing representative data on the current levels of tritium in drinking water sources near major facilities releasing this radionuclide in Canada.

This compilation is reasonably comprehensive, but no attempt was made to document every possible criterion in every jurisdiction. A substantive effort was nevertheless made to obtain authoritative criteria directly from all relevant developed countries, through detailed searches of public sources of information, and through correspondence with key regulators when this information was not directly available. The focus of our effort was on countries that operate CANDU and other power reactors, countries of the European Union, and other developed countries with significant releases of tritium.

2. RADIATION PROTECTION BASIS OF DRINKING WATER GUIDELINES

In most countries, including Canada, the guidelines for radionuclides in drinking water are based on international radiation protection methodologies, including recommendations of the International Commission on Radiological Protection (ICRP) and the World Health Organization (WHO) [ICRP, 1991a; WHO, 2004]. A summary table is provided in the Appendix, along with detailed information on guidelines and standards for individual countries.

2.1 International Commission on Radiological Protection (ICRP)

Radiation protection methodologies and principles have been developed by the International Commission on Radiological Protection (ICRP). This body of international experts was established to advance the science of radiological protection for the public benefit. It examines the scientific evidence available and provides recommendations and guidance on all aspects of protection against ionising radiation. These recommendations have been followed closely in establishing the Radiation Protection Regulations under the Canadian *Nuclear Safety and Control Act.* The ICRP approach is also endorsed and used in most other countries and by international organizations, such as the World Health Organization (WHO), the International Atomic Energy Agency (IAEA) and the Nuclear Energy Agency of the Organization for Economic Cooperation and Development (OECD).

The dose limits recommended by the ICRP for occupational and public exposures are generally adopted by regulators (including the CNSC and Health Canada) for legal purposes, and must not be exceeded under normal circumstances. For members of the public, the ICRP recommends an effective dose limit of 1 mSv for any combination of external and internal doses, received or committed in one year, excluding natural background radiation and medical or therapeutic exposures. The excess lifetime risk from a single exposure to 1 mSv has been estimated to be 7.3×10^{-5} [ICRP, 1991a], or 1 in 14,000. This level of risk includes outcomes such as fatal cancer, severe hereditary effects, and non-fatal cancers weighted for severity and ease of curing. For a lifetime exposure of 1 mSv per year over 70 years, the total risk would be about 5×10^{-3} or 1 in 200 [ICRP, 1991b].

2.2 World Health Organisation (WHO)

The WHO is the directing and coordinating authority for health within the United Nations system. It is responsible for providing leadership on global health matters, shaping the health research agenda, setting norms and standards, articulating evidence-based policy options, providing technical support to countries and monitoring and assessing health trends.

In setting derived guidelines for radionuclides in drinking water, the WHO recognised that water consumption contributes only a portion of the total radiation dose, and that some radionuclides present are natural in origin and therefore cannot be excluded from consideration. Consequently, the WHO guidelines for radionuclides in drinking water have been derived based on a reference dose level (RDL) or effective dose of 0.1 mSv from one year's consumption of drinking water. This represents 10% of the dose limit for members of the public, as recommended by the ICRP [ICRP, 1991a] and as adopted in the Basic Safety Standards of the International Atomic Energy Agency [IAEA, 1996] and the CNSC's Radiation Protection Regulations. These principles have been accepted by the WHO and many of its member states, the European Commission, and the Food and Agriculture Organization of the United Nations (FAO). The RDL of 0.1 mSv represents less than 5% of the average annual dose attributable to natural background radiation (i.e., 2.4 mSv). The risk of fatal and weighted non-fatal conditions at a lifetime exposure (i.e. 70 years) of 0.1 mSv per year ($1/10^{th}$ of 1 mSv) is between 10^{-5} and 10^{-6} per year, or about 6×10^{-4} over a lifetime or 1 in 1,667 [Health Canada, 1995a].

For each radionuclide, the guideline reference level (GL, also known as the maximum acceptable concentration, MAC, or maximum contaminant level, MCL) for radionuclides in drinking water has generally been calculated using the following equation:

$$\mathbf{GL = \frac{RDL}{DCF \times q}}$$

where:

GL = guideline reference level of radionuclide in drinking water (Bq/L),
RDL = reference dose level, equal to 0.1mSv per year,
DCF = dose conversion factor for ingestion by adults (Sv/Bq),
q = annual ingested volume of drinking water.

Most national and international guidelines assume a daily water intake of 2 L, or 730 L/year, and are based on an adult dose conversion factor (DCF) provided by the ICRP [ICRP, 1996]. The DCF provides an estimate of the 50-year committed effective dose resulting from a single intake of 1 Bq of a given radionuclide.

The calculation for the GL for tritium would therefore be as follows:

$$\mathbf{GL = \frac{1 \times 10^{-4}\ Sv\ per\ year}{730\ L/year \times 1.8 \times 10^{-11}\ Sv/Bq} = 7{,}610\ Bq/L}$$

Higher DCFs for younger age groups (accounting for the higher uptake and/or metabolic rates) do not lead to significantly higher dose criteria, due to the smaller amounts of water consumed. Consequently, the GL based on adult parameters and an RDL of 0.1 mSv per year for one year's consumption of drinking water can be used for all age groups as a conservative assumption [WHO, 2004].

The guideline reference level (GL) is based on the total activity in a water sample, whether radionuclides appear singly or in combination, and includes the dose due to both natural and artificial radionuclides. Individual GLs therefore apply only in the event that a single radionuclide is found in the water supply. Where two or more radionuclides that affect the same organ or tissue are found to be present in drinking water, the total dose received from all radionuclides should not exceed the guideline reference level of 0.1 mSv per year.

In Canada and elsewhere, actual concentrations of radionuclides, particularly in surface drinking waters, are usually orders of magnitude (e.g. 100-fold) below the GL from the WHO (2004). Water supplies with levels of radioactivity up to the reference level are considered acceptable for consumption. However, the adoption of these guidelines does not imply “lack of action” until concentrations reach the GL. The treatment of water supplies for radionuclides is typically governed by the ALARA principle, i.e. keeping exposures “As Low As Reasonably Achievable”, with economic and social factors taken into consideration. Levels may be further reduced if justified. In cases where a single sample does not meet the guideline, the reference dose would be exceeded only if exposure to the same measured concentration were continued for a full year. Hence, such a sample does not in itself imply that the water is unsuitable for consumption, and should be regarded only as a level at which further investigation, including additional sampling, is needed. [WHO, 2004; Health Canada, 1995b]

3. REGULATORY APPROACHES

3.1 Application in Canada

In Canada, the quality of drinking water is primarily the responsibility of the provinces and municipalities. The Canadian *Guidelines for Canadian Drinking Water Quality* [Health Canada, 2007] combine radiological, chemical, and microbiological risk assessment and management practices within a flexible risk control strategy. The *Guidelines* have been established through the Federal-Provincial-Territorial Committee on Drinking Water (CDW), and are intended to facilitate consistency in drinking water quality across the country.

The *Guidelines* have been designed to accommodate the diverse needs of the various jurisdictions involved. Although not mandatory, the *Guidelines* may be used by the provinces and territories as a basis for setting maximum permissible levels for radionuclide, chemical, and microbiological hazards. Since water quality is essentially a provincial responsibility in Canada, the provinces may adopt the *Guidelines* in whole or in part, or may establish their own criteria.

The *Guidelines* set the GL of tritium in drinking water at 7,000 Bq/L.

3.2 Application in Canadian Provinces

Several provinces have incorporated the tritium guideline from Health Canada's *Guidelines for Canadian Drinking Water Quality* into a provincial drinking water standard; all other provinces do not have prescribed limits for tritium. Information for the provinces that have adopted this value as a standard (Alberta, Manitoba, Ontario and Quebec) is provided in the Appendix.

The Ontario Drinking Water Advisory Council is currently examining the Ontario Drinking Water Quality Standard for tritium at the request of the Ontario Minister of the Environment. In 1994, the Ontario Advisory Committee on Environmental Standards (ACES) submitted the report *"A Standard for Tritium. A Recommendation to the Minister of Environment and Energy [of Ontario]",* which recommended an interim guideline of 100 Bq/L for tritium in drinking water. Shortly thereafter, the Ontario Ministry of the Environment (MOE) issued an Interim Ontario Drinking Water Objective for tritium of 7,000 Bq/L based on internationally-recommended radiological protection approaches [MOE, 1994]. The Minister of the Environment then requested guidance from Health Canada in regards to the different approaches used within these two documents.

In response, the Joint Working Group 6 (JWG-6) was formed in January 1995, composed of representatives from the Atomic Energy Control Board's (AECB, replaced by the CNSC in 2000) Advisory Committees on Nuclear Safety (ACNS) and Radiological Protection (ACRP), the Group of Medical Advisors, and Health Canada.

The JWG-6 found that the proposed limits in the ACES report approaching the value of zero risk may not be achievable in any human endeavour. The experts further concluded that the interim risk limit of 100 Bq/L for tritium in drinking water proposed by the ACES study was inconsistent with international regulatory philosophy, which instead supported the MOE's limit of 7,000 Bq/L. The JWG-6 also studied the estimated lifetime cancer risk from continuous exposure (in drinking water) to maximum acceptable concentrations (MAC) of selected carcinogens, as derived from the Canadian Drinking Water Quality Guidelines. They noted that the risk associated with exposure to carcinogens in drinking water ranged from less than 1 to more than 800 per million, whereas the risk associated with exposure to all radioactive materials combined was 400 per million. The JWG-6 concluded that the risk-management strategy behind the 1995 guidelines provided a high degree of health protection, and the 7,000 Bq/L interim guideline for tritium was formalized as a standard in Ontario Regulation 242/07 [MOE, 2007].

3.3 Application in Other Countries

As mentioned earlier, the guidelines for radionuclides in drinking water of most of the international community are based on a single calculation incorporating international radiation protection recommendations from the ICRP and WHO:

$$\mathbf{GL} = \frac{\mathbf{RDL}}{\mathbf{DCF \times q}}$$

RDL = 0.1 mSv per year
DCF = 1.8×10^{-11} Sv/Bq
q = 730 L/year ingested water

Different guideline values among most jurisdictions (see Table 2) result from four sources of variation, described in sections 3.3.1 to 3.3.4.

Table 2. International Limits for Tritium in Drinking Water

	Power reactors		Tritium Limit
	CANDU	Total	(Bq/L)
Canada	18	18	7,000
EU	2	126	100
Finland	0	4	30,000
Australia	0	0	76,103
Russia	0	31	7,700
Switzerland	0	5	10,000
United States	0	103	740
WHO	n/a	n/a	10,000

3.3.1 Variation in RDL (or committed effective dose)

Whereas most countries implement the RDL or committed effective dose of 0.1 mSv recommended by the WHO, a few countries have chosen a different RDL, resulting in a different guideline level when used in the GL equation:

Australia: 1 mSv per year = 76,103 Bq/L [NHMRC, 2004]
Finland: 0.5 mSv per year = 30,000 Bq/L [STUK, 1993]
United States: 0.04 mSv per year = 740 Bq/L (or 2,253 Bq/L, see variation 3.3.4)

3.3.2 Variation in Rounding Out of the Final Criterion

The GL calculation above results in a value of 7,610 Bq/L. However, this value was rounded in three different ways: the WHO and Switzerland rounded the value up to 10,000 Bq/L, whereas Russia and Canada rounded it out to 7,700 and 7,000 Bq/L, respectively. [WHO, 2004; DFI, 2006; NRB-99; Health Canada, 2007]. ISTISAN (2000) reported a value 7,600 Bq/L using only two significant digits.

3.3.3 European Union Special Case

The derivation of a drinking water total indicative dose (TID) criterion (0.1 mSv/year) in the European Union's (EU) *Council Directive on the quality of water intended for human consumption 98/83/EC* [EU, 1998] is not explained in the directive or in primary documents prior to the publication of the directive. However, it follows the basic logic of the WHO as outlined in section 2.2. Derived activity concentrations were subsequently calculated after the directive was published, using parameters from the 96/29 EURATOM Directive. The corresponding criterion for an adult is 7,600 Bq/L, with a critical concentration of 6,000 Bq/L for a 1-2 year old [ISTISAN, 2000]. The inclusion of criteria for radioactivity in the directive was not part of the initial proposal of the EU Commission [EU, 1995]; these criteria were incorporated during the development of the legislation at the request of the European Parliament.

Following the *Opinion of the European Parliament* of 12 December 1996, the *Council Common Position* of 19 December 1997, and the *Decision of the European Parliament* of 13 May 1998, the EU Commission did not make the requirements for radioactivity mandatory, but only indicative. Tritium was cited as an indicator parametric value at 100 Bq/L, and the total indicative dose was cited as an indicator parametric value of 0.1 mSv/year [ISTISAN, 2000].

The 100 Bq/L parameter is effectively a screening value, providing an indication of the possible presence of other, potentially more harmful, artificial radionuclides discharged into the environment. Both the tritium concentration and the total indicative dose have a similar status, indicating a potential radiological problem when exceeded, and should not be regarded as limit values [ISTISAN, 2000].

For example, in the implementation of these principles in the United Kingdom, if the level of tritium is above 100 Bq/L, further investigation is triggered and action *may be* required [DWI, 2005]. The relevant guidance states:

"Tritium can also be an indication of contamination from artificial sources and water companies should take actions to investigate the source of any exceedence of the indicator value. If the indicator value is exceeded additional analysis should be undertaken to establish which isotopes are present and the total indicative dose calculated from the individual isotope concentrations. If the total indicative dose exceeds the indicator value of 0.10 mSv/year, appropriate medical advice should be sought. The specification for total indicative dose is expressed in terms of the dose over a year. In interpreting the results of radioactivity monitoring it is necessary to take account of the variability in activity levels over time. Some water sources are likely to show seasonal variation due to natural processes. In addition, any short term increase in radionuclides that may result from radiological incidents should be assessed against guidance for food and liquids, within guidance published by the former Department of the Environment (Civil Emergencies involving radioactive substances)."

Most EU member states have transposed the 1998 EU directive into a national law, regulation or standard, and most have followed the logic of using the 100 Bq/L value for tritium only as a screening value (see forms in Appendix).

3.3.4 United States Special Case

The United States (US) did not adopt ICRP risk coefficients and dose limit recommendations in deriving its original – and still current – drinking water standard for tritium. Instead, the United States Environmental Protection Agency (USEPA) used information from 1967 U.S. Vital Statistics, and the Biological Effects of Ionizing Radiation I report [BEIR, 1972], to set the national standard (referred to as a Maximum Contaminant Level or MCL) at 20,000 pCi/L (740 Bq/L) based on a 4 mrem (0.04 mSv) per year dose limit.

Considering the sum of the deposited fallout radioactivity and the additional amounts due to releases from other sources existing in 1967, the USEPA believed that the total dose equivalent from man-made radioactivity was not likely to result in a total body or organ dose to any individual that exceeded 4 mrem/year. Consequently, the USEPA believed that the adoption of the standard would not affect many public water systems, if any. At the same time, the Agency believed that a MCL set at this level would provide adequate public health protection.

In setting the MCLs for man-made beta and photon emitters in 1976 [USEPA, 1976], the USEPA used cancer risk estimates for the U.S. population in 1967 [see USEPA, 2000a and 2000b for a discussion of the 1991 proposed rule]. The BEIR I report indicated that the individual risk of fatal cancer from a lifetime total body dose rate of 0.04 mSv per year ranged from about 0.4 to 2×10^{-6} per year (1 in 2,500,000 to 1 in 500,000) depending on whether an absolute or relative risk model was used. Using best estimates from both models for fatal cancer, the USEPA believed that an individual risk of 0.8×10^{6} per year (1 in 1,250,000) resulting from a 0.04 mSv annual total body dose was a reasonable estimate of the annual risk from a lifetime ingestion of drinking water. Over a 70-year period, the corresponding lifetime fatal cancer risk would be 5.6×10^{-5} (1 in 17,857), with the risk from the ingestion of water containing less amounts of radioactivity being proportionately smaller [USEPA, 2000b].

Since the time the USEPA developed the 1976 standard, scientists have improved the calculation methods to equate concentrations of tritium in drinking water (pCi/L) to radiation doses in people (mrem). In 1991, the USEPA re-calculated the tritium concentration equal to a dose of 4 mrem from weighted organ-specific dose equivalent values, using weighting factors as specified by the ICRP in 1977/1979, and using metabolically-based dose calculations. With this updated method of calculation, the USEPA found that a dose of 4 mrem (0.04 mSv) per year would equal a tritium concentration of 60,900 pCi/L (2,253 Bq/L) — a threefold increase from the maximum contaminant level of 20,000 pCi/L (740 Bq/L) established in 1976. However, since the older criterion met overall risk management objectives, the USEPA kept the 1976 value of 20,000 pCi/L for tritium in its latest regulations in the final rule [USEPA, 2000a].

A search by CNSC staff of the most populated individual States indicated that most (if not all) States have adopted the USEPA MCLs for drinking water quality. However, in 2006, the Office of Environmental Health Hazard Assessment (OEHHA) in the California Environmental Protection Agency adopted a public health goal (PHG) of 400 pCi/L (14.8 Bq/L) for tritium in drinking water [OEHHA, 2006]. PHGs established by OEHHA are not regulatory, and represent only non-mandatory goals. By state and federal law, MCLs established by DHS must be at least as stringent as the federal MCL. PHGs are based solely on scientific and public health considerations, without regard to economic cost considerations or technical feasibility. While the current California maximum contaminant level (MCL) for tritium in drinking water is 20,000 pCi/L (740 Bq/L), the ongoing revision of the California drinking water standards (MCLs) will consider the above-mentioned PHG for tritium in drinking water along with economic factors and technical feasibility.

4. DIFFERENCES BETWEEN CANADIAN AND INTERNATIONAL APPROACHES

In Canada, the guideline reference level (GL), or maximum acceptable concentration (MAC), for tritium in drinking water is 7,000 Bq/L, as described in the *Guidelines for Canadian Drinking Water Quality* [Health Canada, 2007]. Of the many countries researched for the purposes of this compilation, most have based their national standard, regulation or guideline on internationally-accepted radiation protection concepts, including the ICRP's dose-risk estimations and dose conversion factors, as well as the reference dose level of 0.1 mSv per year adopted by the WHO. Together, these concepts suggest a rounded GL of 7,600 Bq/L.

There are four main exceptions or variations to this approach.

1) Rather than a mandatory parameter, the EU has elected to use a tritium guideline value of 100 Bq/L as a screening parameter for the presence of other, potentially more harmful, artificial radionuclides.
2) Whereas Australia accepts the ICRP concepts mentioned above, it differs from the WHO by adopting a reference dose level of 1 mSv per year rather than 0.1 mSv per year. The result is an Australian national guideline of 76,103 Bq/L.
3) Whereas Finland also accepts the ICRP concepts mentioned above, it differs from the WHO by adopting a reference dose level of 0.5 mSv per year rather than 0.1 mSv per year, and a drinking water intake rate of 2.2 L per day rather than 2 L. Therefore, Finland's standard for tritium in drinking water is 30,000 Bq/L.
4) The United States calculated its national MCL for tritium in drinking water in 1976 based on former radiological concepts that now differ from current ICRP and WHO opinion, and continues to retain this older criterion on a risk management basis (see section 3.3.4).

5. CURRENT TRITIUM LEVELS IN DRINKING WATER

In Canada, current tritium levels in drinking water are orders of magnitude less than the GL of 7,000 Bq/L near nuclear facilities, and similarly well below the European Union's GL of 100 Bq/L. To provide a perspective on the data available, representative data are provided in Tables 3 and 4, illustrating recent levels of tritium in drinking water near major nuclear facilities releasing this radionuclide in Canada.

Although no exhaustive search was conducted for all available international information, in developed countries with power reactors such as Belgium [AFCN, 2006], France [IRSN, 2007], Germany [BMU, 2006], and Spain [CSN, 2005], tritium levels in drinking water are also well below each country's GL of 100 Bq/L.

Table 3. Drinking Water Tritium Concentration near Nuclear Sites

Water Source	Province	Source	Distance from Site	Tritium level (Bq/L)
Kincardine	Ontario	Bruce Power[1]	15 km SSW of Bruce B	6.4
Port Elgin	Ontario	Bruce Power[1]	17 km NE of Bruce A	17.4
Southampton	Ontario	Bruce Power[1]	22 km NE of Bruce A	12.0
Local deep wells	Ontario	Bruce Power[1]	Local to Bruce	<5.9 – 19.1
Local shallow wells	Ontario	Bruce Power[1]	Local to Bruce	12.3 – 58.2
Rolphton	Ontario	Chalk River Laboratories[2]	28 km upstream of CRL	3.0
Deep River	Ontario	Chalk River Laboratories[2]	9 km upstream of CRL	3.0
Chalk River Laboratories	Ontario	Chalk River Laboratories[2]	CRL intake well	11.0
Highview	Ontario	Chalk River Laboratories[2]	8 km downstream of CRL	<15.0
Harrington Bay	Ontario	Chalk River Laboratories[2]	9 km downstream of CRL	8.0
Fort William	Ontario	Chalk River Laboratories[2]	14 km downstream of CRL	7.0
Petawawa	Ontario	Chalk River Laboratories[2]	18 km downstream of CRL	7.0
Pembroke	Ontario	Chalk River Laboratories[2]	28 km downstream of CRL	7.0
Champlain	Quebec	Hydro-Québec (Gentilly)[3]		< 18
Gentilly	Quebec	Hydro-Québec (Gentilly)[3]		< 18
Trois-Rivières	Quebec	Hydro-Québec (Gentilly)[3]		< 18
Dipper Harbour	New Brunswick	NB Power[4]	28 Ridge Rd, Dipper Harbour	15.0
Dipper Harbour	New Brunswick	NB Power[4]	22 Ridge Rd, Dipper Harbour	24.5
Dipper Harbour	New Brunswick	NB Power[4]	16 Ridge Rd, Dipper Harbour	20.0
Dipper Harbour	New Brunswick	NB Power[4]	10 Ridge Rd, Dipper Harbour	19.0
Dipper Harbour	New Brunswick	NB Power[4]	4 Ridge Rd, Dipper Harbour	18.0
Maces Bay	New Brunswick	NB Power[4]	190 Welch Cove Rd, Maces Bay	39.0
Maces Bay	New Brunswick	NB Power[4]	181 Ridge Rd, Maces Bay	32.5
Maces Bay	New Brunswick	NB Power[4]	132 Ridge Rd, Maces Bay	22.5
Maces Bay	New Brunswick	NB Power[4]	68 Ridge Rd, Maces Bay	14.0

1 *Annual Summary and Assessment of Environmental and Radiological Data for 2006.* Bruce Power. 2007.
2 *Annual Report of Radiological Environmental Monitoring in 2005 at Chalk River Laboratories.* AECL. 2006.
3 *Centrale nucléaire Gentilly-2. Résultats du programme de surveillance de l'environnement du site de Gentilly. Rapport annuel 2006.* Hydro-Québec. 2007.
4 *Point Lepreau Generating Station. Environmental Monitoring Radiation Data.* NB Power. 2007.

Water Source	Province	Source	Distance from Site	Tritium level (Bq/L)
Bowmanville	Ontario	Ontario Power Generation[5]	7 km ENE of Darlington	6.0
Newcastle	Ontario	Ontario Power Generation[5]	13 km E of Darlington	5.8
Oshawa	Ontario	Ontario Power Generation[5]	8 km W of Darlington	7.1
Local water wells	Ontario	Ontario Power Generation[5]	Local to Darlington	<1.9 – 21.6
Ajax	Ontario	Ontario Power Generation[5]	5 km ENE of Pickering	6.1
Scarborough Horgan	Ontario	Ontario Power Generation[5]	11 km SW of Pickering	5.1
Toronto Harris	Ontario	Ontario Power Generation[5]	22 km WSW of Pickering	5.1
Whitby	Ontario	Ontario Power Generation[5]	12 km ENE of Pickering	6.4
Local water wells (range)	Ontario	Ontario Power Generation[5]	Local to Pickering	<1.9 – 114.7

5 *2006 Results of Radiological Environmental Monitoring Programs.* Ontario Power Generation Inc. 2007.

Table 4. Drinking Water Tritium Concentration in Background Locations

Water Source	Province	Source	Tritium level (Bq/L)
Bancroft	Ontario	Bruce Power[1]	<3.7
Bancroft	Ontario	Ontario Power Generation[5]	<1.9
Belleville	Ontario	Bruce Power[1]	4.2
Belleville	Ontario	Ontario Power Generation[5]	2.6
Brockville	Ontario	Bruce Power[1]	4.6
Brockville	Ontario	Ontario Power Generation[5]	3.9
Burlington	Ontario	Bruce Power[1]	6.0
Burlington	Ontario	Ontario Power Generation[5]	3.3
Coburg	Ontario	Bruce Power[1]	5.3
Coburg	Ontario	Ontario Power Generation[5]	4.8
Drummondville	Quebec	Hydro-Québec (Gentilly)[3]	< 18
Goderich	Ontario	Bruce Power[1]	5.2
Goderich	Ontario	Ontario Power Generation[5]	4.5
Kingston	Ontario	Bruce Power[1]	4.6
Kingston	Ontario	Ontario Power Generation[5]	3.6
London	Ontario	Bruce Power[1]	3.7
London	Ontario	Ontario Power Generation[5]	2.5
Niagara Falls	Ontario	Bruce Power[1]	4.1
Niagara Falls	Ontario	Ontario Power Generation[5]	2.7
North Bay	Ontario	Bruce Power[1]	<3.7
North Bay	Ontario	Ontario Power Generation[5]	<1.9
Orangeville	Ontario	Bruce Power[1]	<3.7
Orangeville	Ontario	Ontario Power Generation[5]	<1.9
Parry Sound	Ontario	Bruce Power[1]	<3.7
Parry Sound	Ontario	Ontario Power Generation[5]	2.0
Sarnia	Ontario	Bruce Power[1]	4.0
Sarnia	Ontario	Ontario Power Generation[5]	4.0
St. Catharines	Ontario	Bruce Power[1]	3.7
St. Catharines	Ontario	Ontario Power Generation[5]	2.9
Sudbury	Ontario	Bruce Power[1]	5.8
Sudbury	Ontario	Ontario Power Generation[5]	2.9
Thunder Bay	Ontario	Bruce Power[1]	<3.7
Thunder Bay	Ontario	Ontario Power Generation[5]	<1.9
Windsor	Ontario	Bruce Power[1]	5.2
Windsor	Ontario	Ontario Power Generation[5]	4.6

1 *Annual Summary and Assessment of Environmental and Radiological Data for 2006.* Bruce Power. 2007.

3 *Centrale nucléaire Gentilly-2. Résultats du programme de surveillance de l'environnement du site de Gentilly. Rapport annuel 2006.* Hydro-Québec. 2007.

5 *2006 Results of Radiological Environmental Monitoring Programs.* Ontario Power Generation Inc. 2007.

APPENDIX

COMPILATION OF TRITIUM GUIDELINES AND STANDARDS

Introduction

The following appendix includes a summary table along with forms containing information on the standards or guidelines for tritium in drinking water currently observed by a number of countries (including CANDU owner countries, the members of the G8, representative State members of the EU, and other significant countries) international organisations and Canadian provinces (in alphabetical order). All government and organisation websites were thoroughly searched for relevant legal and regulatory documents. Some information was supplemented by personal communication with relevant officials, where it was feasible. Additional information may be available, but was not obtainable within reasonable effort.

This database is not exhaustive, however it can be considered to be reasonably complete in regards to the major emitters of tritium in the world. The occasional blank spaces in the forms indicate that the relevant information was not accessible.

TABLE A1. SUMMARY TABLE OF INTERNATIONAL LIMITS FOR TRITIUM IN DRINKING WATER

		Power reactors*		Information Obtained	Tritium Limit (Bq/L)
		CANDU	Total		
CANDU OWNERS	Canada	18	18	yes	7,000
	- Alberta	0	0	yes	7,000
	- Manitoba	0	0	yes	7,000
	- N. Brunswick	1	1	yes	none
	- Ontario	16	16	yes	7,000
	- Quebec	1	1	yes	7,000
	India	15	17	no	n/a
	Republic of Korea	4	20	partly	none
	Romania	2	2	yes	100
	China	2	10	yes	none
	Argentina	1	12	partly	none
	Pakistan	1	2	no	n/a
EU	Total	2	126	yes	100
	Belgium	0	7	yes	100
	Finland	0	4	yes	30,000
	France	0	59	yes	100
	Germany	0	17	yes	100
	Italy	0	0	yes	100
	Northern Ireland	0	0	yes	100
	Scotland	0	2	yes	100
	Spain	0	8	yes	100
	Sweden	0	10	yes	100
	United Kingdom	0	19	yes	100
OTHER	Australia	0	0	yes	76,103
	Japan	0	53	partly	none
	Norway	0	0	yes	100
	Russia	0	31	partly	7,700
	Switzerland	0	5	yes	10,000
	United States	0	103	yes	740
	- California	0	4	yes	740
	WHO	n/a	n/a	yes	10,000

** Sources:*
World Nuclear Association reactor database http://www.world-nuclear.org/reference/reactorsdb_index.php
CANDU Owners Group website http://www.candu.org

Jurisdiction	ALBERTA
Tritium limit in drinking water	7,000 Bq/L
Committed effective dose	0.1 mSv/year
Additional considerations	The sum of the committed effective doses from all radionuclides is not to exceed 0.1 mSv/year.
Exact / Rounded	Rounded down to the nearest 1,000
Scope	Provincial
Policy point of origin	Guidelines for Canadian Drinking Water Quality
Legal standard / Guideline	☒ standard ☐ guideline
Year of adoption	2003
Technical / legal reference(s)	Potable Water Regulation, Alta. Reg. 277/2003 http://www.canlii.org/ab/laws/regu/2003r.277/20070717/whole.html Standards and Guidelines for Municipal Waterworks, Wastewater and Storm Drainage Systems http://environment.gov.ab.ca/info/posting.asp?assetid=6979&categoryid=5
Enforcement	Alberta Environment is responsible for enforcement, as per the regulation and standards mentioned above
Consequences of exceeding limit	
Target population : All ages and sexes Urban Rural	 ☐ yes ☒ no : adult dose conversion factor ☒ yes ☐ no ☒ yes ☐ no
Applicability	
Technical basis for calculation: Drinking water intake rate Dose conversion factor Committed effective dose Comment	 2 L/day (730 L/year) 1.8×10^{-11} Sv/Bq 0.1 mSv/year $\text{MAC (Bq/L)} = \frac{1 \times 10^{-4} \text{ (Sv/year)}}{730 \text{ (L/year)} \times \text{DCF } (1.8 \times 10^{-11} \text{ Sv/Bq})}$ Calculation = 7,610 Bq/L, rounded down to 7,000

Jurisdiction	ALBERTA
Safety factor	A recommended reference dose level (RDL) of the committed effective dose, equal to 0.1 mSv from 1 year's consumption of drinking water (from the possible total radioactive contamination of the annual drinking water consumption). This comprises 10% of the intervention exemption level recommended by the ICRP for dominant commodities (e.g., food and drinking-water) for prolonged exposure situations, which is most relevant to long-term consumption of drinking water by the public (ICRP, 2000). The RDL of 0.1 mSv is also equal to 10% of the dose limit for members of the population, recommended by both the ICRP (1991) and the International Basic Safety Standards (IAEA, 1996).
Context : CANDU reactors Total power reactors Research centres Tritium light manufacturing	 0 0 0 0
General comments	When two or more radionuclides are found in drinking water, the following relationship should be satisfied: $\frac{C_1}{MAC_1} + \frac{C_2}{MAC_2} + \ldots \frac{C_i}{MAC_i} \leq 1$ where C_i and MAC_i are the observed and maximum acceptable concentrations, respectively, for each contributing radionuclide.

Jurisdiction	ARGENTINA
Tritium limit in drinking water	No guideline or standard Reference value of 10,000 Bq/L from the WHO, used on a case-by-case basis
Committed effective dose	0.1 mSv/year
Additional considerations	
Exact / Rounded	
Scope	
Policy point of origin	
Legal standard / Guideline	Argentine Food Code (Law 18.284) http://www.anmat.gov.ar/codigoa/caa1.htm Standards do not include radioactivity
Year of adoption	
Technical / legal reference(s)	Personal communication with the Nuclear Regulatory Authority Argentina (July 31, 2007)
Enforcement	
Consequences of exceeding limit	
Target population : All ages and sexes Urban Rural	
Applicability	
Technical basis for calculation: Drinking water intake rate Dose conversion factor Committed effective dose Comment	 2 L/day (730 L/year) 1.8×10^{-11} Sv/Bq 0.1 mSv/year Level (Bq/L) = $\frac{1 \times 10^{-4} \text{ (Sv/year)}}{730 \text{ (L/year)} \times \text{DCF } (1.8 \times 10^{-11} \text{ Sv/Bq})}$ Calculation = 7,610 Bq/L, rounded up to 10,000

Jurisdiction	ARGENTINA
Safety factor	
Context : CANDU reactors Total power reactors Research centres Tritium light manufacturing	 1 2 0 0
General comments	

Jurisdiction	AUSTRALIA
Tritium limit in drinking water	1 mSv/year (76,103 Bq/L)
Committed effective dose	1 mSv/year
Additional considerations	
Exact / Rounded	Exact
Scope	National
Policy point of origin	ICRP 1991; 2000
Legal standard / Guideline	☐ standard ☒ guideline
Year of adoption	2003
Technical / legal reference(s)	Australian Drinking Water Guidelines 6 http://www.nhmrc.gov.au/publications/synopses/_files/adwg_11_06.pdf
Enforcement	Enforced at the State and Terrritorial level
Consequences of exceeding limit	*Summary of operational responses:* **Dose level Response (mSv per year)** < 0.5 1. Continue routine monitoring. 0.5-1 1. Consult with relevant health authority. 2. Review frequency of ongoing sampling. 3. Evaluate operational options to reduce exposure. >1-10 1. Consult with relevant health authorities. 2. Assess in detail possible remedial actions, taking into account potential health impacts and cost effectiveness of actions. 3. Implement appropriate remedial action on the basis of the cost-benefit evaluation. > 10 1. Water not suitable for consumption on the basis of radioactivity levels. 2. Consult with relevant health authorities. 3. Immediate intervention is expected and remedial action must be taken to reduce doses to below the guideline value of 1.0 mSv.

Jurisdiction	AUSTRALIA
Target population : All ages and sexes Urban Rural	 ☐ yes ☒ no : reference man = 70 kg ☒ yes ☐ no ☒ yes ☐ no
Applicability	Drinking water is defined as water intended primarily for human consumption, either directly, as supplied from the tap, or indirectly, in beverages, ice or foods prepared with water. Drinking water is also used for other domestic purposes such as bathing and showering. With the exception of bottled or packaged water, the ADWG apply to any water intended for drinking irrespective of the source (municipal supplies, rainwater tanks, bores etc) or where it is consumed (the home, restaurants, camping areas, shops etc). This Guideline deals only with situations where the radionuclide concentrations arise either from natural sources, or, more rarely, as the result of past practices (such as abandoned mining operations). It specifically does not apply to situations where the radionuclides arise from current practices under regulatory control, such as an operating uranium mine. Therefore, the guideline should not be used to support an increase in the radionuclide concentrations of drinking water as a result of an operation, on the grounds that the overall dose levels remain below 1 mSv per year.
Technical basis for calculation: Drinking water intake rate Dose conversion factor Committed effective dose Comment	 2 L/day (730 L/year) 1.8×10^{-11} Sv/Bq 1 mSv/year Annual dose (mSv/year) = DCF × water consumption × radionuclide concentration (mSv/Bq) × (litres/year) × (Bq/L)

Jurisdiction	AUSTRALIA
Safety factor	The ICRP recommended that, for commodities that are essential for normal living and are amenable to intervention, an individual dose of approximately 1 mSv per year is an acceptable intervention exemption level (ICRP 2000). This is consistent with the recommendation of the NHMRC (1995) of a public exposure limit for practices of 1 mSv per year from all sources. Furthermore, Lokan (1998) concluded that a value of 1 mSv per year might be appropriate as a default action level above which some corrective action will be necessary. Based on the above, it is recommended that a guideline dose of 1 mSv per year should be applied for radioactivity in drinking water.
Context : CANDU reactors Total power reactors Research centres Tritium light manufacturing	 0 0 2 0
General comments	The total estimated dose per year from all radionuclides in drinking water, excluding the dose from potassium-40, should not exceed 1.0 mSv. The ICRP (1991) estimates the lifetime risk of a fatal cancer resulting from exposure to radiation to be 5×10^{-2} per Sv of radiation dose, that is, five additional fatal cancers for every 100 people exposed per year. Based on this estimate, a dose of 1 mSv per year gives an annual risk of 5×10^{-5}, that is, about five additional fatal cancers per 100,000 people exposed per year.

Jurisdiction	BELGIUM
Tritium limit in drinking water	100 Bq/L
Committed effective dose	0.1 mSv/year
Additional considerations	Total indicative dose from radionuclides not to exceed 0.1 mSv/year
Exact / Rounded	Exact
Scope	National
Policy point of origin	EU Directive 98/83/EC
Legal standard / Guideline	☐ standard ☒ guideline
Year of adoption	1998
Technical / legal reference(s)	« Surveillance radiologique de la Belgique – Rapport de synthèse 2005 » http://fanc.fgov.be/download/Rapport%20SRT%202005%20FR.pdf
Enforcement	None. EU Directive 98/83/EC not yet transposed into law.
Consequences of exceeding limit	n/a
Target population : All ages and sexes Urban Rural	 ☐ yes ☒ no : Adult dose conversion factor, applies to adults and children over 10 years old ☒ yes ☐ no ☒ yes ☐ no
Applicability	As defined in the EU Directive 98/83/EC: <u>‘water intended for human consumption’ shall mean:</u> (a) all water either in its original state or after treatment, intended for drinking, cooking, food preparation or other domestic purposes, regardless of its origin and whether it is supplied from a distribution network, from a tanker, or in bottles or containers;

Jurisdiction	BELGIUM
	(b) all water used in any food-production undertaking for the manufacture, processing, preservation or marketing of products or substances intended for human consumption unless the competent national authorities are satisfied that the quality of the water cannot affect the wholesomeness of the foodstuff in its finished form; <u>Exclusion:</u> (a) natural mineral waters recognised as such by the competent national authorities, in accordance with Council Directive 80/777/EEC of 15 July 1980 on the approximation of the laws of the Member States relating to the exploitation and marketing of natural mineral waters (1); (b) waters which are medicinal products within the meaning of Council Directive 65/65/EEC of 26 January 1965 on the approximation of provisions laid down by law, regulation or administrative action relating to medicinal products (2).
Technical basis for calculation: Drinking water intake rate Dose conversion factor Committed effective dose Comment	 2 L/day (730 L/year) 1.8×10^{-11} Sv/Bq 0.1 mSv/year Level (Bq/L) = $\frac{1 \times 10^{-4} \text{ (Sv/year)}}{730 \text{ (L/year)} \times \text{DCF } (1.8 \times 10^{-11} \text{ Sv/Bq})}$ Calculation = 7,610 Bq/L. Adoption of 100 Bq/L indicator parameter according to Council Directive 98/83/EC.
Safety factor	Maximum dose (0.1 mSv/y) is 10% of the dose limit for members of the population (see WHO form for details).
Context : CANDU reactors Total power reactors Research centres Tritium light manufacturing	 0 7 5 0
General comments	See WHO comments.

Jurisdiction	CALIFORNIA
Tritium limit in drinking water	740 Bq/L* (20,000 pCi/L)
Committed effective dose	4 mrem/year (0.04 mSv/year)
Additional considerations	If two or more radionuclides are present, the sum of their annual dose equivalent to the total body or to any organ shall not exceed 4 millirem/year.
Exact / Rounded	Exact
Scope	State
Policy point of origin	US National Primary Drinking Water Regulations
Legal standard / Guideline	☒ standard ☐ guideline
Year of adoption	2002 (updated 2007)
Technical / legal reference(s)	California Regulations Related to Drinking Water, CCR Title 22, Div. 4, Chap 15, Article 5 http://weblinks.westlaw.com/Find/Default.wl?DB=CA%2DADAC%2DTOC%3BRVADCCATOC&DocName=22CAADCS64443&FindType=W&AP=&fn=_top&rs=WEBL7.07&vr=2.0&spa=CCR-1000&trailtype=26
Enforcement	
Consequences of exceeding limit	
Target population : All ages and sexes Urban Rural	 ☐ yes ☒ no : adult ☒ yes ☐ no ☒ yes ☐ no
Applicability	
Technical basis for calculation: Drinking water intake rate Dose conversion factor Committed effective dose Comment	 2 L/day (730 L/year) 4 mrem/year (0.04 mSv/year)

** Level currently under revision*

Jurisdiction	CALIFORNIA
Safety factor	
Context : CANDU reactors Total power reactors Research centres Tritium light manufacturing	 0 4 0 0
General comments	The current California maximum contaminant level (MCL) for tritium in drinking water is 20,000 pCi/L (740 Bq/L). The Office of Environmental Health Hazard Assessment in the California Environmental Protection Agency adopted a public health goal (PHG) of 400 pCi/L (14.8 Bq/L) for tritium in drinking water. PHGs established by OEHHA are not regulatory in nature and represent only non-mandatory goals. By state and federal law, MCLs established by DHS must be at least as stringent as the federal MCL, if one exists. PHGs are based solely on scientific and public health considerations, without regard to economic cost considerations or technical feasibility. The ongoing revision of the California drinking water standards (MCLs) will consider the PHG for tritium in drinking water along with pertinent economic factors and technical feasibility.

Jurisdiction	CANADA
Tritium limit in drinking water	7,000 Bq/L*
Committed effective dose	0.1 mSv/year
Additional considerations	The sum of the committed effective doses from all radionuclides is not to exceed 0.1 mSv/year.
Exact / Rounded	Rounded down to the nearest 1,000
Scope	National
Policy point of origin	ICRP
Legal standard / Guideline	☐ standard ☒ guideline
Year of adoption	1995
Technical / legal reference(s)	Page 6 – Guidelines for Canadian Drinking Water Quality: – Summary Table
Enforcement	None (guideline only, except in Ontario)
Consequences of exceeding limit	None
Target population : All ages and sexes Urban Rural	 ☐ yes ☒ no : adult dose conversion factor ☒ yes ☐ no ☒ yes ☐ no
Applicability	
Technical basis for calculation: Drinking water intake rate Dose conversion factor Committed effective dose Comment	 2 L/day (730 L/year) 1.8×10^{-11} Sv/Bq 0.1 mSv/year $\text{MAC (Bq/L)} = \frac{1 \times 10^{-4}\ \text{(Sv/year)}}{730\ \text{(L/year)} \times \text{DCF}\ (1.8 \times 10^{-11}\ \text{Sv/Bq})}$ Calculation = 7,610 Bq/L, rounded down to 7,000

** Level currently under revision*

Jurisdiction	CANADA
Safety factor	A recommended reference dose level (RDL) of the committed effective dose, equal to 0.1 mSv from 1 year's consumption of drinking water (from the possible total radioactive contamination of the annual drinking water consumption). This comprises 10% of the intervention exemption level recommended by the ICRP for dominant commodities (e.g., food and drinking-water) for prolonged exposure situations, which is most relevant to long-term consumption of drinking water by the public (ICRP, 2000). The RDL of 0.1 mSv is also equal to 10% of the dose limit for members of the population, recommended by both the ICRP (1991) and the International Basic Safety Standards (IAEA, 1996).
Context : CANDU reactors Total power reactors Research centres Tritium light manufacturing Tritium removal facility	 17 17 1 2* 1
General comments	When two or more radionuclides are found in drinking water, the following relationship should be satisfied: $\frac{C_1}{MAC_1} + \frac{C_2}{MAC_2} + \ldots \frac{C_i}{MAC_i} \leq 1$ where C_i and MAC_i are the observed and maximum acceptable concentrations, respectively, for each contributing radionuclide.

** 1 operating facility in September 2007*

Jurisdiction	CHINA
Tritium limit in drinking water	No specific guideline or standard. WHO guidelines used in environmental samples.
Committed effective dose	
Additional considerations	
Exact / Rounded	
Scope	
Policy point of origin	
Legal standard / Guideline	Standards for drinking water quality (GB 5749-2006) Limited concentrations of radionuclides in foods (GB 14482-94) Standards do not include radioactivity
Year of adoption	
Technical / legal reference(s)	Personal communication with the National Institute for Radiological Protection (September 30, 2007)
Enforcement	
Consequences of exceeding limit	
Target population : All ages and sexes Urban Rural	
Applicability	
Technical basis for calculation: Drinking water intake rate Dose conversion factor Committed effective dose Comment	

Jurisdiction	CHINA
Safety factor	
Context : CANDU reactors Total power reactors Research centres Tritium light manufacturing	 2 10 0 0
General comments	

Jurisdiction	EUROPEAN UNION (EU)
Tritium limit in drinking water	100 Bq/L
Committed effective dose	0.1 mSv/year
Additional considerations	Total indicative dose from radionuclides not to exceed 0.1 mSv/year
Exact / Rounded	Exact
Scope	International
Policy point of origin	WHO 2004
Legal standard / Guideline	☐ standard ☒ guideline
Year of adoption	1998
Technical / legal reference(s)	Council Directive 98/83/EC http://eur-lex.europa.eu/LexUriServ/site/en/oj/1998/l_330/l_33019981205en00320054.pdf
Enforcement	Each Member State must transpose Directive 98/83/EC into national law. Each Member State is responsible for enforcement of its national water laws or guidelines. Monitoring for tritium is not required if justifiable.
Consequences of exceeding limit	None at EU level unless risk to public health in several EU Member States.
Target population : All ages and sexes Urban Rural	 ☐ yes ☒ no : Adult dose conversion factor ☒ yes ☐ no ☒ yes ☐ no
Applicability	<u>'water intended for human consumption' shall mean:</u> (a) all water either in its original state or after treatment, intended for drinking, cooking, food preparation or other domestic purposes, regardless of its origin and whether it is supplied from a distribution network, from a tanker, or in bottles or containers;

Jurisdiction	EUROPEAN UNION (EU)
	(b) all water used in any food-production undertaking for the manufacture, processing, preservation or marketing of products or substances intended for human consumption unless the competent national authorities are satisfied that the quality of the water cannot affect the wholesomeness of the foodstuff in its finished form; Exclusion: (a) natural mineral waters recognised as such by the competent national authorities, in accordance with Council Directive 80/777/EEC of 15 July 1980 on the approximation of the laws of the Member States relating to the exploitation and marketing of natural mineral waters (1); (b) waters which are medicinal products within the meaning of Council Directive 65/65/EEC of 26 January 1965 on the approximation of provisions laid down by law, regulation or administrative action relating to medicinal products (2). Possible exclusion (each member State must decide whether to exclude or not): "Water intended for human consumption from an individual supply providing less than 10 m³ a day as an average or serving fewer than 50 persons, unless the water is supplied as part of a commercial or public activity."
Technical basis for calculation: Drinking water intake rate Dose conversion factor Committed effective dose Comment	 2 L/day (730 L/year) 1.8×10^{-11} Sv/Bq 0.1 mSv/year $\text{Level (Bq/L)} = \frac{1 \times 10^{-4}\ \text{(Sv/year)}}{730\ \text{(L/year)} \times \text{DCF}\ (1.8 \times 10^{-11}\ \text{Sv/Bq})}$ Calculation = 7,610 Bq/L. Adoption of 100 Bq/L indicator parameter according to Council Directive 98/83/EC. [see also ISTISAN, 2000]
Safety factor	Maximum dose (0.1 mSv/y) is 10% of the dose limit for members of the population (see WHO form for details)
Context : CANDU reactors Total power reactors Research centres Tritium light manufacturing	 2 133 0 0
General comments	See WHO/EU for detailed comments.

Jurisdiction	FINLAND
Tritium limit in drinking water	30,000 Bq/L
Committed effective dose	0.5 mSv/year
Additional considerations	Total indicative dose from radionuclides not to exceed 0.5 mSv/year
Exact / Rounded	Rounded to the nearest 1,000
Scope	National
Policy point of origin	National
Legal standard / Guideline	☒ standard ☐ guideline
Year of adoption	1993
Technical / legal reference(s)	Radioactivity of Household Water (ST 12.3), STUK
Enforcement	
Consequences of exceeding limit	
Target population : All ages and sexes Urban Rural	 ☐ yes ☒ no : Adult dose conversion factor ☐ yes ☐ no ☐ yes ☐ no
Applicability	Household water comprises water used for drinking, water used in the production of beverages, and water used in preparing or producing foods industrially.
Technical basis for calculation: Drinking water intake rate Dose conversion factor Committed effective dose Comment	 2.2 L/day (803 L/year) 1.8×10^{-11} Sv/Bq 0.5 mSv/year Level (Bq/L) = $\frac{5 \times 10^{-4} \text{ (Sv/year)}}{803 \text{ (L/year)} \times \text{DCF } (1.8 \times 10^{-11} \text{ Sv/Bq})}$ Calculation = 34,592 Bq/L, rounded down to 30,000

Jurisdiction	FINLAND
Safety factor	
Context : CANDU reactors Total power reactors Research centres Tritium light manufacturing	 0 4 0 0
General comments	Although Finland is a member of the EU, it has not yet implemented Council Directive 98/83/EC

Jurisdiction	FRANCE
Tritium limit in drinking water	100 Bq/L
Committed effective dose	0.1 mSv/year
Additional considerations	Total indicative dose from radionuclides not to exceed 0.1 mSv/year
Exact / Rounded	Exact
Scope	National
Policy point of origin	EU Directive 98/83/EC
Legal standard / Guideline	☒ standard ☐ guideline
Year of adoption	2001
Technical / legal reference(s)	Decree No. 2001-1220 relative to water intended for human consumption, excluding mineral water http://www.car-analyse.com/hydro/d011220.htm
Enforcement	Transposition of EU Directive 98/83/EC into national law
Consequences of exceeding limit	Test for presence of other artificial radionuclides
Target population : All ages and sexes Urban Rural	 ☐ yes ☒ no : Adult dose conversion factor ☒ yes ☐ no ☒ yes ☐ no
Applicability	Decree applies to: (a) all water either in its original state or after treatment, intended for drinking, cooking, food preparation or other domestic purposes, regardless of its origin and whether it is supplied from a distribution network, from a tanker, or in bottles or containers; (b) all water used in any food-production undertaking for the manufacture, processing, preservation or marketing of products or substances intended for human consumption unless the competent national authorities are satisfied that the quality of the water cannot affect the wholesomeness of the foodstuff in its finished form, including water-based food ice.

Jurisdiction	FRANCE
Technical basis for calculation: Drinking water intake rate Dose conversion factor Committed effective dose Comment	 2 L/day (730 L/year) 1.8×10^{-11} Sv/Bq 0.1 mSv/year $\text{Level (Bq/L)} = \frac{1 \times 10^{-4} \text{ (Sv/year)}}{730 \text{ (L/year)} \times \text{DCF } (1.8 \times 10^{-11} \text{ Sv/Bq})}$ Calculation = 7,610 Bq/L. Adoption of 100 Bq/L indicator parameter according to Council Directive 98/83/EC.
Safety factor	Maximum dose (0.1 mSv/y) is 10% of the dose limit for members of the population (see WHO form for details).
Context : CANDU reactors Total power reactors Research centres Tritium light manufacturing	 0 59 ITER fusion project 0
General comments	See WHO comments.

Jurisdiction	GERMANY
Tritium limit in drinking water	100 Bq/L
Committed effective dose	0.1 mSv/year
Additional considerations	Total indicative dose from radionuclides not to exceed 0.1 mSv/year
Exact / Rounded	Exact
Scope	National
Policy point of origin	EU Directive 98/83/EC
Legal standard / Guideline	☒ standard ☐ guideline
Year of adoption	2001
Technical / legal reference(s)	Drinking Water Regulation (TrinkwV-2001) [in German] http://bundesrecht.juris.de/trinkwv_2001/index.html
Enforcement	Transposition of EU Directive 98/83/EC into national law
Consequences of exceeding limit	Fines and penalties if contamination is high or low and not quickly remediated.
Target population : All ages and sexes Urban Rural	 ☐ yes ☒ no : Adult dose conversion factor ☒ yes ☐ no ☒ yes ☐ no
Applicability	Applies to: (a) all water either in its original state or after treatment, intended for drinking, cooking, food preparation or other domestic purposes, including the cleaning of items that may come into contact with foodstuffs or the human body.

Jurisdiction	GERMANY
Technical basis for calculation: Drinking water intake rate Dose conversion factor Committed effective dose Comment	 2 L/day (730 L/year) 1.8×10^{-11} Sv/Bq 0.1 mSv/year Level (Bq/L) = $\frac{1 \times 10^{-4} \text{ (Sv/year)}}{730 \text{ (L/year)} \times \text{DCF } (1.8 \times 10^{-11} \text{ Sv/Bq})}$ Calculation = 7,610 Bq/L. Adoption of 100 Bq/L indicator parameter according to Council Directive 98/83/EC.
Safety factor	Maximum dose (0.1 mSv/y) is 10% of the dose limit for members of the population (see WHO form for details).
Context : CANDU reactors Total power reactors Research centres Tritium light manufacturing	 0 17 7 0
General comments	See WHO comments.

Jurisdiction	ITALY
Tritium limit in drinking water	100 Bq/L
Committed effective dose	0.1 mSv/year
Additional considerations	Total indicative dose from radionuclides not to exceed 0.1 mSv/year
Exact / Rounded	Exact
Scope	National
Policy point of origin	EU Directive 98/83/EC
Legal standard / Guideline	☒ standard ☐ guideline
Year of adoption	2001
Technical / legal reference(s)	Legislative Decree 2 February 2001, no. 31 "Application of Directive 98/83/EC Relative to the Quality of Water Destined for Human Consumption." [in Italian] http://www.parlamento.it/leggi/deleghe/01031dl.htm
Enforcement	Transposition of Directive 98/83/EC into national law
Consequences of exceeding limit	
Target population : All ages and sexes Urban Rural	 ☐ yes ☒ no : Adult dose conversion factor ☒ yes ☐ no ☒ yes ☐ no
Applicability	As defined in the EU Directive 98/83/EC: <u>'water intended for human consumption' shall mean:</u> (a) all water either in its original state or after treatment, intended for drinking, cooking, food preparation or other domestic purposes, regardless of its origin and whether it is supplied from a distribution network, from a tanker, or in bottlesor containers;

Jurisdiction	ITALY
	(b) all water used in any food-production undertaking for the manufacture, processing, preservation or marketing of products or substances intended for human consumption unless the competent national authorities are satisfied that the quality of the water cannot affect the wholesomeness of the foodstuff in its finished form; Exclusion: (a) natural and medicinal mineral waters
Technical basis for calculation: Drinking water intake rate Dose conversion factor Committed effective dose Comment	 2 L/day (730 L/year) 1.8×10^{-11} Sv/Bq 0.1 mSv/year $\text{Level (Bq/L)} = \frac{1 \times 10^{-4}\ \text{(Sv/year)}}{730\ \text{(L/year)} \times \text{DCF}\ (1.8 \times 10^{-11}\ \text{Sv/Bq})}$ Calculation = 7,610 Bq/L. Adoption of 100 Bq/L indicator parameter according to Council Directive 98/83/EC.
Safety factor	Maximum dose (0.1 mSv/y) is 10% of the dose limit for members of the population (see WHO form for details).
Context : CANDU reactors Total power reactors Research centres Tritium light manufacturing	 0 0 0 0
General comments	See WHO comments.

Jurisdiction	JAPAN
Tritium limit in drinking water	No guideline or standard
Committed effective dose	
Additional considerations	
Exact / Rounded	
Scope	
Policy point of origin	
Legal standard / Guideline	Water quality standards do not include radioactivity. http://www.jwwa.or.jp/english/water_en/water-e07.html
Year of adoption	
Technical / legal reference(s)	Personal communication with the Office of Radiation Regulation, Science and Technology Policy Bureau; Ministry of Education, Culture, Sports, Science and Technology. (July 31, 2007)
Enforcement	
Consequences of exceeding limit	
Target population : All ages and sexes Urban Rural	
Applicability	
Technical basis for calculation: Drinking water intake rate Dose conversion factor Committed effective dose Comment	

Jurisdiction	JAPAN
Safety factor	
Context : CANDU reactors Total power reactors Research centres Tritium light manufacturing	 0 53 0 0
General comments	

Jurisdiction	MANITOBA
Tritium limit in drinking water	7,000 Bq/L
Committed effective dose	0.1 mSv/year
Additional considerations	The sum of the committed effective doses from all radionuclides is not to exceed 0.1 mSv/year.
Exact / Rounded	Rounded down to the nearest 1,000
Scope	Provincial
Policy point of origin	Guidelines for Canadian Drinking Water Quality
Legal standard / Guideline	☒ standard ☐ guideline
Year of adoption	2002
Technical / legal reference(s)	Drinking Water Safety Act Drinking Water Safety Regulation Drinking Water Quality Standards Regulation http://www.gov.mb.ca/waterstewardship/odw/reg-info/acts-regs/index.html
Enforcement	Manitoba Office of Drinking Water, as per the act, regulation and standards mentioned above
Consequences of exceeding limit	
Target population : All ages and sexes Urban Rural	 ☐ yes ☒ no : adult dose conversion factor ☒ yes ☐ no ☒ yes ☐ no
Applicability	
Technical basis for calculation: Drinking water intake rate Dose conversion factor Committed effective dose Comment	 2 L/day (730 L/year) 1.8×10^{-11} Sv/Bq 0.1 mSv/year $\text{MAC (Bq/L)} = \frac{1 \times 10^{-4} \text{ (Sv/year)}}{730 \text{ (L/year)} \times \text{DCF } (1.8 \times 10^{-11} \text{ Sv/Bq})}$ Calculation = 7,610 Bq/L, rounded down to 7,000

Jurisdiction	MANITOBA
Safety factor	A recommended reference dose level (RDL) of the committed effective dose, equal to 0.1 mSv from 1 year's consumption of drinking water (from the possible total radioactive contamination of the annual drinking water consumption). This comprises 10% of the intervention exemption level recommended by the ICRP for dominant commodities (e.g., food and drinking-water) for prolonged exposure situations, which is most relevant to long-term consumption of drinking water by the public (ICRP, 2000). The RDL of 0.1 mSv is also equal to 10% of the dose limit for members of the population, recommended by both the ICRP (1991) and the International Basic Safety Standards (IAEA, 1996).
Context : CANDU reactors Total power reactors Research centres Tritium light manufacturing	 0 0 0 0
General comments	When two or more radionuclides are found in drinking water, the following relationship should be satisfied: $\frac{C_1}{MAC_1} + \frac{C_2}{MAC_2} + \ldots \frac{C_i}{MAC_i} \leq 1$ where C_i and MAC_i are the observed and maximum acceptable concentrations, respectively, for each contributing radionuclide.

Jurisdiction	NEW BRUNSWICK
Tritium limit in drinking water	none
Committed effective dose	
Additional considerations	
Exact / Rounded	
Scope	Provincial
Policy point of origin	
Legal standard / Guideline	☐ standard ☒ guideline
Year of adoption	1993
Technical / legal reference(s)	New Brunswick Potable Water Regulation 93-203 http://www.gnb.ca/0062/regs/93-203.htm
Enforcement	
Consequences of exceeding limit	
Target population : All ages and sexes Urban Rural	 ☐ yes ☐ no : ☐ yes ☐ no ☐ yes ☐ no
Applicability	
Technical basis for calculation: Drinking water intake rate Dose conversion factor Committed effective dose Comment	
Safety factor	
Context : CANDU reactors Total power reactors Research centres Tritium light manufacturing	 1 1 0 0
General comments	

Jurisdiction	NORTHERN IRELAND
Tritium limit in drinking water	100 Bq/L
Committed effective dose	0.1 mSv/year
Additional considerations	Total indicative dose from radionuclides not to exceed 0.1 mSv/year
Exact / Rounded	Exact
Scope	Regional
Policy point of origin	EU Directive 98/83/EC
Legal standard / Guideline	☒ standard ☐ guideline
Year of adoption	2001
Technical / legal reference(s)	Statutory Rule 2007 No. 147 "The Water Supply (Water Quality) Regulations (Northern Ireland) 2007" http://www.opsi.gov.uk/sr/sr2007/20070147.htm#sch2
Enforcement	
Consequences of exceeding limit	
Target population : All ages and sexes Urban Rural	 ☐ yes ☒ no : Adult dose conversion factor ☒ yes ☐ no ☒ yes ☐ no
Applicability	Applies to water supplied: (a) for such domestic purposes as consist in or include, cooking, drinking, food preparation or washing; or (b) to premises in which food is produced, wholesomeness of the foodstuff in its finished form.

Jurisdiction	NORTHERN IRELAND
Technical basis for calculation: Drinking water intake rate Dose conversion factor Committed effective dose Comment	 2 L/day (730 L/year) 1.8×10^{-11} Sv/Bq 0.1 mSv/year Level (Bq/L) = $\frac{1 \times 10^{-4} \text{ (Sv/year)}}{730 \text{ (L/year)} \times \text{DCF } (1.8 \times 10^{-11} \text{ Sv/Bq})}$ Calculation = 7,610 Bq/L. Adoption of 100 Bq/L indicator parameter according to Council Directive 98/83/EC.
Safety factor	Maximum dose (0.1 mSv/y) is 10% of the dose limit for members of the population (see WHO form for details).
Context : CANDU reactors Total power reactors Research centres Tritium light manufacturing	 0 0 0 0
General comments	See WHO comments.

Jurisdiction	NORWAY
Tritium limit in drinking water	100 Bq/L
Committed effective dose	0.1 mSv/year
Additional considerations	Total indicative dose from radionuclides not to exceed 0.1 mSv/year
Exact / Rounded	Exact
Scope	National
Policy point of origin	EU Directive 98/83/EC
Legal standard / Guideline	☒ standard ☐ guideline
Year of adoption	2001
Technical / legal reference(s)	Drinking Water Regulations FOR 2001-12-04 nr 1372 [In Norwegian] http://www.lovdata.no/cgi-wift/ldles?doc=/sf/sf/sf-20011204-1372.html
Enforcement	Transposition of EU Directive 98/83/EC into national law
Consequences of exceeding limit	As per Food Law (LOV 2003-12-19-124); investigation required
Target population : All ages and sexes Urban Rural	 ☐ yes ☒ no : Adult dose conversion factor ☒ yes ☐ no ☒ yes ☐ no
Applicability	<u>“drinking water” definition:</u> (a) all water either in its original state or after treatment, intended for drinking, cooking, food preparation or other domestic purposes, regardless of its origin and whether it is supplied from a distribution network, from a tanker, or in bottles or containers; (b) all water used in any food-production undertaking for the manufacture, processing, preservation or marketing of products or substances intended for human consumption unless the competent national authorities are satisfied that the quality of the water cannot affect the wholesomeness of the foodstuff in its finished form.

Jurisdiction	NORWAY
Technical basis for calculation:	
Drinking water intake rate	2 L/day (730 L/year)
Dose conversion factor	1.8×10^{-11} Sv/Bq
Committed effective dose	0.1 mSv/year
	MAC (Bq/L) = $\frac{1 \times 10^{-4} \text{ (Sv/year)}}{730 \text{ (L/year)} \times \text{DCF } (1.8 \times 10^{-11} \text{ Sv/Bq})}$
Comment	Calculation = 7,610 Bq/L. Adoption of 100 Bq/L indicator parameter according to Council Directive 98/83/EC.
Safety factor	Maximum dose (0.1 mSv/y) is 10% of the dose limit for members of the population (see WHO form for details).
Context :	
CANDU reactors	0
Total power reactors	0
Research centres	1 (Halden Reactor Project)
Tritium light manufacturing	0
General comments	See WHO comments.

Jurisdiction	ONTARIO
Tritium limit in drinking water	7,000 Bq/L
Committed effective dose	0.1 mSv/year
Additional considerations	The sum of the committed effective doses from all radionuclides is not to exceed 0.1 mSv/year.
Exact / Rounded	Rounded down to the nearest 1,000
Scope	Provincial
Policy point of origin	Guidelines for Canadian Drinking Water Quality
Legal standard / Guideline	☒ standard ☐ guideline
Year of adoption	2002
Technical / legal reference(s)	Ontario Safe Drinking Water Act, 2002 http://www.search.e-laws.gov.on.ca/en/isysquery/84f3bc08-caf6-4104-8bc7-ca6d6bddd3eb/4/frame/?search=browseStatutes&context= Ontario Drinking water Quality Standards (O. Reg. 169/03 and 242/07) http://www.canlii.org/on/laws/regu/2003r.169/20070717/whole.html Ontario Drinking Water Systems Regulation (O. Reg. 170/03) http://www.canlii.org/on/laws/regu/2003r.170/20070717/whole.html
Enforcement	Ontario Ministry of the Environment, as per the regulation and standards mentioned above
Consequences of exceeding limit	
Target population : All ages and sexes Urban Rural	 ☐ yes ☒ no : adult dose conversion factor ☒ yes ☐ no ☒ yes ☐ no
Applicability	

Jurisdiction	**ONTARIO**
Technical basis for calculation:	
Drinking water intake rate	2 L/day (730 L/year)
Dose conversion factor	1.8×10^{-11} Sv/Bq
Committed effective dose	0.1 mSv/year
	$\text{MAC (Bq/L)} = \dfrac{1 \times 10^{-4} \text{ (Sv/year)}}{730 \text{ (L/year)} \times \text{DCF } (1.8 \times 10^{-11} \text{ Sv/Bq})}$
Comment	Calculation = 7,610 Bq/L, rounded down to 7,000
Safety factor	A recommended reference dose level (RDL) of the committed effective dose, equal to 0.1 mSv from 1 year's consumption of drinking water (from the possible total radioactive contamination of the annual drinking water consumption). This comprises 10% of the intervention exemption level recommended by the ICRP for dominant commodities (e.g., food and drinking-water) for prolonged exposure situations, which is most relevant to long-term consumption of drinking water by the public (ICRP, 2000). The RDL of 0.1 mSv is also equal to 10% of the dose limit for members of the population, recommended by both the ICRP (1991) and the International Basic Safety Standards (IAEA, 1996).
Context :	
CANDU reactors	16
Total power reactors	0
Research centres	4
Tritium light manufacturing	2*
Tritium removal facility	1
General comments	When two or more radionuclides are found in drinking water, the following relationship should be satisfied: $\dfrac{C_1}{MAC_1} + \dfrac{C_2}{MAC_2} + \ldots \dfrac{C_i}{MAC_i} \leq 1$ where C_i and MAC_i are the observed and maximum acceptable concentrations, respectively, for each contributing radionuclide.

** 1 operating facility in September 2007*

Jurisdiction	QUEBEC
Tritium limit in drinking water	7,000 Bq/L
Committed effective dose	0.1 mSv/year
Additional considerations	The sum of the committed effective doses from all radionuclides is not to exceed 0.1 mSv/year.
Exact / Rounded	Rounded down to the nearest 1,000
Scope	Provincial
Policy point of origin	Guidelines for Canadian Drinking Water Quality
Legal standard / Guideline	☒ standard ☐ guideline
Year of adoption	2003
Technical / legal reference(s)	Regulation Respecting the Quality of Drinking Water (Q-2, r.18.1.1) http://www.canlii.org/qc/laws/regu/q-2r.18.1.1/20070717/whole.html
Enforcement	The Ministère du Développement durable, de l'Environnement et des Parcs is responsible for enforcement, as per the regulation mentioned above.
Consequences of exceeding limit	
Target population : All ages and sexes Urban Rural	 ☐ yes ☒ no : adult dose conversion factor ☒ yes ☐ no ☒ yes ☐ no
Applicability	
Technical basis for calculation: Drinking water intake rate Dose conversion factor Committed effective dose Comment	 2 L/day (730 L/year) 1.8×10^{-11} Sv/Bq 0.1 mSv/year $\text{MAC (Bq/L)} = \frac{1 \times 10^{-4} \text{ (Sv/year)}}{730 \text{ (L/year)} \times \text{DCF } (1.8 \times 10^{-11} \text{ Sv/Bq})}$ Calculation = 7,610 Bq/L, rounded down to 7,000

Jurisdiction	QUEBEC
Safety factor	A recommended reference dose level (RDL) of the committed effective dose, equal to 0.1 mSv from 1 year's consumption of drinking water (from the possible total radioactive contamination of the annual drinking water consumption). This comprises 10% of the intervention exemption level recommended by the ICRP for dominant commodities (e.g., food and drinking-water) for prolonged exposure situations, which is most relevant to long-term consumption of drinking water by the public (ICRP, 2000). The RDL of 0.1 mSv is also equal to 10% of the dose limit for members of the population, recommended by both the ICRP (1991) and the International Basic Safety Standards (IAEA, 1996).
Context : CANDU reactors Total power reactors Research centres Tritium light manufacturing	 1 0 0 0
General comments	When two or more radionuclides are found in drinking water, the following relationship should be satisfied: $\frac{C_1}{MAC_1} + \frac{C_2}{MAC_2} + \ldots \frac{C_i}{MAC_i} \leq 1$ where C_i and MAC_i are the observed and maximum acceptable concentrations, respectively, for each contributing radionuclide.

Jurisdiction	REPUBLIC OF KOREA
Tritium limit in drinking water	No guideline or standard
Committed effective dose	
Additional considerations	
Exact / Rounded	
Scope	
Policy point of origin	
Legal standard / Guideline	
Year of adoption	
Technical / legal reference(s)	Personal communication with the Korea Institute of Nuclear Safety (KINS) (26 July, 2007)
Enforcement	
Consequences of exceeding limit	
Target population : All ages and sexes Urban Rural	
Applicability	
Technical basis for calculation: Drinking water intake rate Dose conversion factor Committed effective dose Comment	
Safety factor	
Context : CANDU reactors Total power reactors Research centres Tritium light manufacturing	 4 20 0 0
General comments	

Jurisdiction	ROMANIA
Tritium limit in drinking water	100 Bq/L
Committed effective dose	0.1 mSv/year
Additional considerations	Total indicative dose from radionuclides not to exceed 0.1 mSv/year
Exact / Rounded	Exact
Scope	National
Policy point of origin	EU Directive 98/83/EC
Legal standard / Guideline	☒ standard ☐ guideline
Year of adoption	2002
Technical / legal reference(s)	Water Law No. 458/2002 “Concerning the Quality of Potable Water” [in Romanian] http://www.phg.ro/showlege.php?id=1900
Enforcement	Transposition of EU Directive 98/83/EC into national law. Amendment 311/2004 (to law 458/2002). The Ministry of Health supervises and controls the monitoring of water quality.
Consequences of exceeding limit	
Target population : All ages and sexes Urban Rural	 ☐ yes ☒ no : Adult dose conversion factor ☒ yes ☐ no ☒ yes ☐ no
Applicability	As defined in the EU Directive 98/83/EC: <u>‘water intended for human consumption’ shall mean:</u> (a) all water either in its original state or after treatment, intended for drinking, cooking, food preparation or other domestic purposes, regardless of its origin and whether it is supplied from a distribution network, from a tanker, or in bottles or containers;

Jurisdiction	ROMANIA
	(b) all water used in any food-production undertaking for the manufacture, processing, preservation or marketing of products or substances intended for human consumption unless the competent national authorities are satisfied that the quality of the water cannot affect the wholesomeness of the foodstuff in its finished form; Exclusion: (a) natural mineral waters recognised as such by the competent national authorities, in accordance with Council Directive 80/777/EEC of 15 July 1980 on the approximation of the laws of the Member States relating to the exploitation and marketing of natural mineral waters (1); (b) waters which are medicinal products within the meaning of Council Directive 65/65/EEC of 26 January 1965 on the approximation of provisions laid down by law, regulation or administrative action relating to medicinal products (2).
Technical basis for calculation: Drinking water intake rate Dose conversion factor Committed effective dose Comment	 730 L/year 1.8×10^{-11} Sv/Bq 0.1 mSv/year $\text{Level (Bq/L)} = \frac{1 \times 10^{-4} \text{ (Sv/year)}}{730 \text{ (L/year)} \times \text{DCF } (1.8 \times 10^{-11} \text{ Sv/Bq})}$ Calculation = 7,610 Bq/L. Adoption of 100 Bq/L indicator parameter according to Council Directive 98/83/EC.
Safety factor	Maximum dose (0.1 mSv/y) is 10% of the dose limit for members of the population (see WHO form for details).
Context : CANDU reactors Total power reactors Research centres Tritium light manufacturing	 2 2 1 0
General comments	See WHO comments.

Jurisdiction	**RUSSIA**
Tritium limit in drinking water	7,700 Bq/L
Committed effective dose	0.1 mSv/year
Additional considerations	
Exact / Rounded	Rounded to the nearest 100
Scope	National
Policy point of origin	Assumed ICRP
Legal standard / Guideline	☒ standard ☐ guideline
Year of adoption	1999
Technical / legal reference(s)	Radiation Safety Norms (NRB-99)
Enforcement	
Consequences of exceeding limit	
Target population : All ages and sexes Urban Rural	 ☐ yes ☒ no : Value identified for “critical receptor” of child 1-2 years ☐ yes ☐ no ☐ yes ☐ no
Applicability	
Technical basis for calculation: Drinking water intake rate Dose conversion factor Committed effective dose Comment	 730 L/year 1.8×10^{-11} Sv/Bq 0.1 mSv/year Level (Bq/L) = $\frac{1 \times 10^{-4} \text{ (Sv/year)}}{730 \text{ (L/year)} \times \text{DCF } (1.8 \times 10^{-11} \text{ Sv/Bq})}$ Calculation = 7,610 Bq/L, rounded to 7,700 Bq/L

Jurisdiction	RUSSIA
Safety factor	Maximum dose (0.1 mSv/y) is 10% of the dose limit for members of the population.
Context : CANDU reactors Total power reactors Research centres Tritium light manufacturing	 0 31 0 0
General comments	See WHO comments.

Jurisdiction	SCOTLAND
Tritium limit in drinking water	100 Bq/L
Committed effective dose	0.1 mSv/year
Additional considerations	Total indicative dose from radionuclides not to exceed 0.1 mSv/year
Exact / Rounded	Exact
Scope	Regional
Policy point of origin	EU Directive 98/83/EC
Legal standard / Guideline	☒ standard ☐ guideline
Year of adoption	2001
Technical / legal reference(s)	2001 No. 207 The Water Supply (Water Quality) (Scotland) Regulations 2001 http://www.opsi.gov.uk/legislation/scotland/ssi2001/ssi_20010207_en.pdf
Enforcement	
Consequences of exceeding limit	
Target population : All ages and sexes Urban Rural	 ☐ yes ☒ no : Adult dose conversion factor ☐ yes ☐ no ☐ yes ☐ no
Applicability	Applies to water supplied: (a) for such domestic purposes as consist in or include, cooking, drinking, food preparation or washing; or (b) for any of those domestic purposes to premises in which food is produced.

Jurisdiction	SCOTLAND
Technical basis for calculation: Drinking water intake rate Dose conversion factor Committed effective dose Comment	 2 L/day (730 L/year) 1.8×10^{-11} Sv/Bq 0.1 mSv/year Level (Bq/L) = $\frac{1 \times 10^{-4} \text{ (Sv/year)}}{730 \text{ (L/year)} \times \text{DCF } (1.8 \times 10^{-11} \text{ Sv/Bq})}$ Calculation = 7,610 Bq/L. Adoption of 100 Bq/L indicator parameter according to Council Directive 98/83/EC.
Safety factor	Maximum dose (0.1 mSv/y) is 10% of the dose limit for members of the population (see WHO form for details).
Context : CANDU reactors Total power reactors Research centres Tritium light manufacturing	 0 2 0 0
General comments	See WHO comments.

Jurisdiction	SPAIN
Tritium limit in drinking water	100 Bq/L
Committed effective dose	0.1 mSv/year
Additional considerations	Total indicative dose from radionuclides not to exceed 0.1 mSv/year
Exact / Rounded	Exact
Scope	National
Policy point of origin	EU Directive 98/83/EC
Legal standard / Guideline	☒ standard ☐ guideline
Year of adoption	2003
Technical / legal reference(s)	"Royal Decree 140/2003, by Which are Established the Sanitary Criteria of the Quality of Water for Human Consumption." [in Spanish] http://www.msc.es/ciudadanos/saludAmbLaboral/docs/rd_140_2003.pdf
Enforcement	Transposition of EU Directive 98/83/EC into national law. Non-conforming water quality results reported to the Sistema de Información Nacional de Agua de Consumo.
Consequences of exceeding limit	Depending on severity, possible stop to activities and water distribution and/or public warning. Sanctions (according to law 14/1986) if corrective measures not implemented quickly and completely.
Target population : All ages and sexes Urban Rural	 ☐ yes ☒ no : Adult dose conversion factor ☒ yes ☐ no ☒ yes ☐ no
Applicability	Applies to: (a) all water either in its original state or after treatment, intended for drinking, cooking, food preparation or other domestic purposes, regardless of its origin and whether it is supplied from a distribution network, from a tanker, or in bottles or containers;

Jurisdiction	SPAIN
	(b) all water used in any food-production undertaking for the manufacture, processing, preservation or marketing of products or substances intended for human consumption unless the competent national authorities are satisfied that the quality of the water cannot affect the wholesomeness of the foodstuff in its finished form; <u>Exclusions:</u> (a) natural mineral waters recognised as such by the competent national authorities, in accordance with Council Directive 80/777/EEC of 15 July 1980 on the approximation of the laws of the Member States relating to the exploitation and marketing of natural mineral waters (1); (b) waters and mineral waters which are medicinal products within the meaning of laws 22/1976, 743/1928, and 25/1990. (c) water intended for human consumption from an individual supply providing less than 10 m³ a day as an average, or serving fewer than 50 persons, unless the water is supplied as part of a commercial or public activity.
Technical basis for calculation: Drinking water intake rate Dose conversion factor Committed effective dose Comment	 2 L/day (730 L/year) 1.8×10^{-11} Sv/Bq 0.1 mSv/year Level (Bq/L) = $\frac{1 \times 10^{-4} \text{ (Sv/year)}}{730 \text{ (L/year)} \times \text{DCF } (1.8 \times 10^{-11} \text{ Sv/Bq})}$ Calculation = 7,610 Bq/L. Adoption of 100 Bq/L indicator parameter according to Council Directive 98/83/EC.
Safety factor	Maximum dose (0.1 mSv/y) is 10% of the dose limit for members of the population (see WHO form for details).
Context : CANDU reactors Total power reactors Research centres Tritium light manufacturing	 0 8 1 0
General comments	See WHO comments.

Jurisdiction	SWEDEN
Tritium limit in drinking water	100 Bq/L
Committed effective dose	0.1 mSv/year
Additional considerations	Total indicative dose from radionuclides not to exceed 0.1 mSv/year
Exact / Rounded	Exact
Scope	National
Policy point of origin	EU Directive 98/83/EC
Legal standard / Guideline	☒ standard ☐ guideline
Year of adoption	2001
Technical / legal reference(s)	"The National Food Administration's Drinking Water Regulations (SLVFS 2001:30)" [in Swedish] http://www.slv.se/upload/dokument/Lagstiftning/2000-2005/2001_30.pdf
Enforcement	Transposition of EU Directive 98/83/EC into national law.
Consequences of exceeding limit	As per Food Act (SFS 2006:804)
Target population : All ages and sexes Urban Rural	 ☐ yes ☒ no : Adult dose conversion factor ☒ yes ☐ no ☒ yes ☐ no
Applicability	As defined in the EU Directive 98/83/EC: 'water intended for human consumption' shall mean: (a) all water either in its original state or after treatment, intended for drinking, cooking, food preparation or other domestic purposes, regardless of its origin and whether it is supplied from a distribution network, from a tanker, or in bottles or containers;

Jurisdiction	SWEDEN
	(b) all water used in any food-production undertaking for the manufacture, processing, preservation or marketing of products or substances intended for human consumption unless the competent national authorities are satisfied that the quality of the water cannot affect the wholesomeness of the foodstuff in its finished form.
Technical basis for calculation:	
Drinking water intake rate	2 L/day (730 L/year)
Dose conversion factor	1.8×10^{-11} Sv/Bq
Committed effective dose	0.1 mSv/year Level (Bq/L) = $\frac{1 \times 10^{-4} \text{ (Sv/year)}}{730 \text{ (L/year)} \times \text{DCF } (1.8 \times 10^{-11} \text{ Sv/Bq})}$
Comment	Calculation = 7,610 Bq/L. Adoption of 100 Bq/L indicator parameter according to Council Directive 98/83/EC.
Safety factor	Maximum dose (0.1 mSv/y) is 10% of the dose limit for members of the population (see WHO form for details).
Context :	
CANDU reactors	0
Total power reactors	10
Research centres	1
Tritium light manufacturing	0
General comments	See WHO comments.

Jurisdiction	SWITZERLAND
Tritium limit in drinking water	10,000 Bq/L
Committed effective dose	0.1 mSv/year
Additional considerations	
Exact / Rounded	Rounded up to the next 1000
Scope	National
Policy point of origin	National
Legal standard / Guideline	☒ standard ☐ guideline
Year of adoption	2006 (1995 originally)
Technical / legal reference(s)	Ordonnance du DFI sur les substances étrangères et les composants dans les denrées alimentaires (817.021.23) http://www.admin.ch/ch/f/rs/8/817.021.23.fr.pdf
Enforcement	
Consequences of exceeding limit	Tolerance value set at 1,000 Bq/L. Above tolerance value, water is designated to be "of lesser value". Above limit of 10,000 Bq/L, water is declared unfit for human consumption.
Target population : All ages and sexes Urban Rural	 ☐ yes ☐ no ☒ yes ☐ no ☒ yes ☐ no
Applicability	"Drinking water" means water, either in its original state or after treatment, intended for drinking, cooking, food preparation or for cleaning of objects coming into contact with foodstuffs.
Technical basis for calculation: Drinking water intake rate Dose conversion factor Committed effective dose Comment	 600 L/year (0.6 m^3 / year) 1.8×10^{-11} Sv/Bq 0.1 mSv/year Level (Bq/L) = $\frac{1 \times 10^{-4} \text{ (Sv/year)}}{730 \text{ (L/year)} \times \text{DCF } (1.8 \times 10^{-11} \text{ Sv/Bq})}$ Calculation = 9,259.3 Bq/L, rounded up to 10,000

Jurisdiction	SWITZERLAND
Safety factor	Maximum dose (0.1 mSv/y) is 10% of the dose limit for members of the population (see WHO form for details).
Context : CANDU reactors Total power reactors Research centres Tritium light manufacturing	 0 5 1 1
General comments	See WHO comments.

Jurisdiction	UNITED KINGDOM (England and Wales)
Tritium limit in drinking water	100 Bq/L
Committed effective dose	0.1 mSv/year
Additional considerations	Total indicative dose from radionuclides not to exceed 0.1 mSv/year
Exact / Rounded	Exact
Scope	National
Policy point of origin	EU Directive 98/83/EC
Legal standard / Guideline	☒ standard ☐ guideline
Year of adoption	2000; 2001
Technical / legal reference(s)	2000 No. 3184 WATER, ENGLAND AND WALES The Water Supply (Water Quality) Regulations 2000 http://www.dwi.gov.uk/regs/si3184/3184.htm
Enforcement	Drinking Water Inspectorate
Consequences of exceeding limit	If the indicator value is exceeded, additional analysis should be undertaken to establish which isotopes are present and the total indicative dose calculated from the individual isotope concentrations. If the total indicative dose exceeds the indicator value of 0.10 mSv/year, appropriate medical advice should be sought.
Target population : All ages and sexes Urban Rural	 ☐ yes ☒ no : Adult dose conversion factor ☐ yes ☐ no ☐ yes ☐ no
Applicability	Applies to water supplied: (a) for such domestic purposes as consist in or include, cooking, drinking, food preparation or washing; or (b) for any of those domestic purposes, to premises in which food is produced.

Jurisdiction	UNITED KINGDOM (England and Wales)
Technical basis for calculation: Drinking water intake rate Dose conversion factor Committed effective dose Comment	 2L/day (730 L/year) 1.8×10^{-11} Sv/Bq 0.1 mSv/year Level (Bq/L) = $\frac{1 \times 10^{-4} \text{ (Sv/year)}}{730 \text{ (L/year)} \times \text{DCF } (1.8 \times 10^{-11} \text{ Sv/Bq})}$ Calculation = 7,610 Bq/L. Adoption of 100 Bq/L indicator parameter according to Council Directive 98/83/EC.
Safety factor	Maximum dose (0.1 mSv/y) is 10% of the dose limit for members of the population (see WHO form for details).
Context : CANDU reactors Total power reactors Research centres Tritium light manufacturing	 0 19 1 0
General comments	See WHO comments.

Jurisdiction	UNITED STATES
Tritium limit in drinking water	740 Bq/L* (20,000 pCi/L)
Committed effective dose	4 mrem/year (0.04 mSv/year)
Additional considerations	If two or more radionuclides are present, the sum of their annual dose equivalent to the total body or to any organ shall not exceed 4 millirem/year.
Exact / Rounded	Exact
Scope	National
Policy point of origin	National
Legal standard / Guideline	☒ standard ☐ guideline
Year of adoption	1976 (retained in 2003, although updated calculations would have resulted in a new standard of 2,253 Bq/L))
Technical / legal reference(s)	Title 40, Volume 19, Part 141—National Primary Drinking Water Regulations http://a257.g.akamaitech.net/7/257/2422/14mar20010800/edocket.access.gpo.gov/cfr_2002/julqtr/40cfr141.16.htm
Enforcement	USEPA Civil Enforcement program
Consequences of exceeding limit	EPA may issue administrative orders, take legal actions, or fine utilities for violation of the standards. Under Section 1414(b) of the SDWA, an imposed penalty not to exceed $25,000 per day; under Section 1414(g)(3) of the SDWA, an administrative order can result in a $5,000 maximum penalty assessed; up to $25,000 per violation per day; under Section 1431(b), the statutory maximum is $5,000 per violation per day of an emergency order; under Section 1432(c), tampering with a public water system carries a maximum civil penalty of $50,000; a maximum civil penalty of $20,000 can be imposed for an attempt or threat to tamper with a public water system; and under Section 1445(c), the statutory maximum penalty is $25,000 in a civil judical action for failing or refusing to keep appropriate records, make reports, etc.

Jurisdiction	UNITED STATES
Target population : All ages and sexes Urban Rural	 ☐ yes ☒ no : Adult ☐ yes ☐ no ☐ yes ☐ no
Applicability	
Technical basis for calculation: Drinking water intake rate Dose conversion factor Committed effective dose Comment	 2L/day (730 L/year) 4 mrem/year (0.04 mSv/year)
Safety factor	
Context : CANDU reactors Total power reactors Research centres Tritium light manufacturing	 0 103 0 0
General comments	Except for the radionuclides listed in Table A, the concentration of man-made radionuclides causing 4 mrem total body or organ dose equivalents shall be calculated on the basis of a 2 liter per day drinking water intake using the 168 hour data listed in "Maximum Permissible Body Burdens and Maximum Permissible Concentration of Radionuclides in Air or Water for Occupational Exposure," NBS Handbook 69 as amended August 1963, U.S. Department of Commerce. Table A--Average Annual Concentrations Assumed to Produce a Total Body or Organ Dose of 4 mrem/yr --- Radionuclide Critical organ pCi per liter --- Tritium Total body 20,000

** Level currently under revision*

Jurisdiction	WORLD HEALTH ORGANISATION (WHO)
Tritium limit in drinking water	10,000 Bq/L
Committed effective dose	0.1 mSv/year
Additional considerations	Total indicative dose from radionuclides not to exceed 0.1 mSv/year
Exact / Rounded	Other (Rounded by averaging the log scale values)
Scope	International
Policy point of origin	n/a
Legal standard / Guideline	☐ standard ☒ guideline
Year of adoption	2004
Technical / legal reference(s)	Guidelines for Drinking water Quality. Vol. 1 : 3rd ed. http://www.who.int/water_sanitation_health/dwq/GDWQ2004web.pdf
Enforcement	n/a
Consequences of exceeding limit	n/a
Target population : All ages and sexes Urban Rural	 ☐ yes ☒ no : Adult dose conversion factor ☒ yes ☐ no ☒ yes ☐ no
Applicability	
Technical basis for calculation: Drinking water intake rate Dose conversion factor Committed effective dose Comment	 2L/day (730 L/year) 1.8×10^{-11} Sv/Bq 0.1 mSv/year Level (Bq/L) = $\frac{1 \times 10^{-4} \text{ (Sv/year)}}{730 \text{ (L/year)} \times \text{DCF } (1.8 \times 10^{-11} \text{ Sv/Bq})}$ Calculation = 7,610 Bq/L, rounded up to 10,000

Jurisdiction	WORLD HEALTH ORGANISATION (WHO)
Safety factor	A recommended reference dose level (RDL) of the committed effective dose, equal to 0.1 mSv from 1 year's consumption of drinking water (from the possible total radioactive contamination of the annual drinking water consumption). This comprises 10% of the intervention exemption level recommended by the ICRP for dominant commodities (e.g., food and drinking-water) for prolonged exposure situations, which is most relevant to long-term consumption of drinking water by the public (ICRP, 2000). The RDL of 0.1 mSv is also equal to 10% of the dose limit for members of the population, recommended by both the ICRP (1991) and the International Basic Safety Standards (IAEA, 1996).
Context : CANDU reactors Total power reactors Research centres Tritium light manufacturing	 n/a n/a n/a n/a
General comments	The dose coefficient for adults was provided by the ICRP. The nominal probability coefficient for radiation-induced stochastic health effects, which include fatal cancer, non-fatal cancer and severe hereditary effects for the whole population, is 7.3×10^{-2}/Sv (ICRP, 1991). Multiplying this by an RDL equal to 0.1 mSv annual exposure via drinking water gives an estimated lifetime risk of stochastic health effects of 10^{-5}, which can be considered small in comparison with other health risks. This risk level is comparable to the reference level of risk used elsewhere in these Guidelines. Background radiation exposures vary widely across various regions of the Earth, but the average is about 2.4 mSv/year, with the highest local levels being up to 10 times higher without any apparent health consequences; 0.1 mSv therefore represents a small addition to background levels. Despite the uncertainties in the determination of risk from radiation exposure at low levels, radiation risks are probably well below those due to microbes and some chemicals in drinking-water.

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