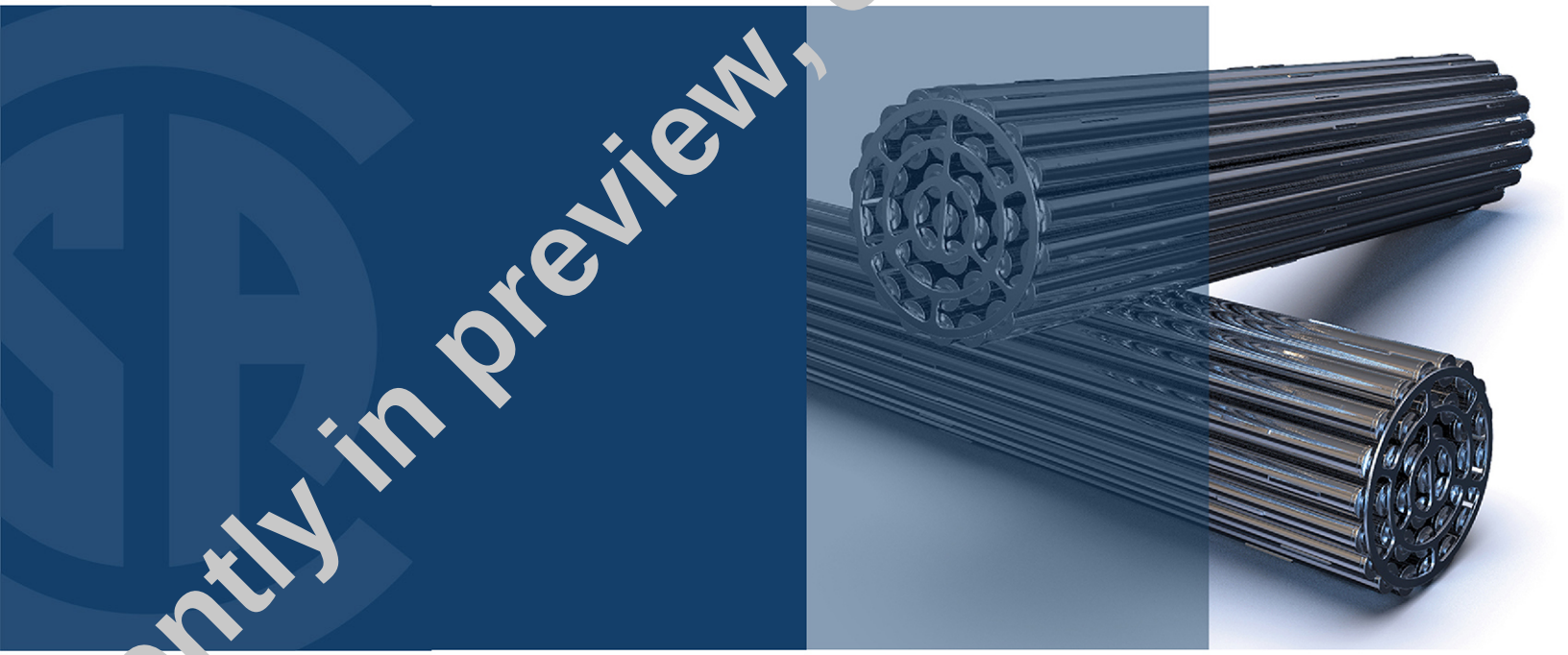
CSA N288.1:20

Guidelines for modelling radionuclide environmental transport, fate, and exposure associated with the normal operation of nuclear facilities



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Guidelines for modelling radionuclide environmental transport, fate, and exposure associated with the normal operation of nuclear facilities

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Contents

Technical Committee on Environmental Management for Nuclear Facilities *6*

Subcommittee on Guidelines for Calculating Derived Release Limits for Radioactive Material in Airborne and Liquid Effluents for Normal Operation of Nuclear Facilities *9*

Preface *11*

0 Introduction *13*
0.1 Application of the Guidelines *13*
0.1.1 General *13*
0.1.2 Derived release limit (DRL) *13*
0.1.3 Dose to public *13*
0.1.4 Environmental risk assessment (ERA) *14*
0.1.5 Radionuclide relative contributions to dose *14*
0.2 History of the Guidelines *14*

1 Scope *15*
1.1 Facilities *15*
1.2 Release paths *15*
1.3 Release duration *15*
1.4 Contaminants *16*
1.5 Receptors *16*
1.6 Downwind distance of validity *16*
1.7 Site specificity *16*
1.8 Level of complexity *16*
1.8.1 Simpler approaches *16*
1.8.2 Default transfer parameters *16*
1.9 Terminology *17*

2 Reference publications *17*

3 Definitions and abbreviations *29*
3.1 Definitions *29*
3.2 Abbreviations *31*

4 Basic concepts *33*
4.1 Dose limits *33*
4.2 Representative person concept *34*
4.2.1 Grouping members of the public *34*
4.2.2 Age classes *34*
4.2.3 Multiple representative persons *34*
4.2.4 Indigenous and other representative persons *35*
4.2.5 Homogeneity and group size *35*
4.2.6 Averaging across distinct practices *35*
4.2.7 Data for the representative person *36*
4.2.8 Nuclear facility workers *36*
4.2.9 Conservative dose estimates for the representative person *36*

4.3 Selection of radionuclides *36*

5 Environmental transfer model *45*
5.1 General concepts *45*
5.2 Calculation of derived release limits (DRLs) *51*
5.2.1 General *51*
5.2.2 DRLs for releases to air *52*
5.2.3 DRLs for releases to surface water *52*
5.2.4 Dose per unit release *52*
5.2.5 Dose per unit release to air *52*
5.2.6 Dose per unit release to surface water *52*
5.2.7 Stochastic and deterministic effects and limits *53*
5.2.8 General procedure for DRL calculation *53*

6 Transfer parameters for airborne releases *54*
6.1 Atmospheric dispersion (P_{01}) *54*
6.1.1 Air concentrations *54*
6.1.2 Effective release height *55*
6.1.3 Vertical dispersion and building wake effects *59*
6.1.4 Meteorological data *61*
6.1.5 Decay and ingrowth *63*
6.1.6 Tritium transformation from HT to HTO *64*
6.2 Air immersion ($P(e)_{19}$) *66*
6.2.1 Semi-infinite cloud model *66*
6.2.2 Finite cloud model *67*
6.2.3 Dose coefficients *68*
6.2.4 Occupancy factors *69*
6.2.5 Building shielding factors *69*
6.2.6 Noble gases *69*
6.2.7 Radionuclides limited by dose to skin *70*
6.2.8 Default values of $P(e)_{19}$ *71*
6.3 Radionuclide concentration in soil due to atmospheric deposition (P_{13}) *71*
6.3.1 Soil compartment *71*
6.3.2 Soil model *72*
6.3.3 Deposition velocity *73*
6.3.4 Erosion losses *75*
6.3.5 Volatilization losses *76*
6.3.6 Losses due to leaching *76*
6.3.7 Losses due to crop removal *77*
6.4 Deposition on crops, forage, and wild plants (P_{14}) *78*
6.4.1 Deposition model *78*
6.4.2 Values of f_{int} *78*
6.4.3 Values of tf *78*
6.4.4 Values of λ_p *79*
6.4.5 Values of t_e *79*
6.4.6 Tritiated water *79*
6.4.7 Elemental tritium *79*
6.4.8 Organically bound tritium *80*
6.4.9 Carbon-14 (C-14) *81*

6.5 Transfer from soil to groundwater wells ($P_{3area2w}$) *82*
6.5.1 Conceptual well model *82*
6.5.2 Groundwater travel time *82*
6.5.3 Transfer to well water *84*
6.5.4 Tritiated water *85*
6.5.5 C-14 *86*
6.6 Transfer from soil to inland pond ($P_{3area2p}$) *86*
6.6.1 Pond model *86*
6.6.2 Parameter values for the pond model *87*
6.7 Transfer from atmosphere to inland pond (P_{12p}) *90*
6.7.1 Pond model *90*
6.7.2 Parameter values *90*
6.7.3 Tritiated water *90*
6.7.4 C-14 *90*
6.8 Plant uptake from soil (P_{3mass4}) *91*
6.9 Transfer from ponds and wells to animal and plant produce (P_{2p5} and P_{2w5}, P_{2p6} and P_{2p7}) *92*
6.9.1 Radionuclides other than tritium and noble gases *92*
6.9.2 Tritiated water *93*
6.9.3 Organically-bound tritium *94*
6.9.4 P_{2p6} and P_{2p7} for tritium and C-14 *95*
6.9.5 Noble gases *95*
6.10 Transfer from plants and invertebrates to animal produce (P_{45}, P_{65}, P_{75}) *95*
6.10.1 Radionuclides other than tritium, C-14, and noble gases *95*
6.10.2 Tritiated water *96*
6.10.3 Organically-bound tritium *97*
6.10.4 C-14 and noble gases *98*
6.10.5 Transfer to honey ($P_{45\text{-honey}}$) *99*
6.11 Transfer from soil and sediment to animal produce (P_{3mass5}, P_{85}) *100*
6.11.1 Radionuclides other than tritium, C-14, and noble gases *100*
6.11.2 Tritium, C-14, and noble gases *100*
6.12 Transfer from air to animal produce (P_{15}) *101*
6.12.1 Radionuclides other than tritium, C-14, and noble gases *101*
6.12.2 Tritium *101*
6.12.3 C-14 and noble gases *102*
6.13 Transfer from air to humans ($P(i)_{19}$) *102*
6.14 External dose from ground deposits ($P(e)_{3area9}$) *103*
6.15 Internal dose from ingestion ($P(i)_{29}$, $P(i)_{3mass9}$, P_{49}, and P_{59}) *104*
6.15.1 Human dietary intakes *104*
6.15.2 Soil intake *105*
6.15.3 Drinking water intake rates *105*
6.15.4 Ingestion dose *106*
6.16 Dose from water immersion ($P(e)_{2w9}$) *107*
6.16.1 External dose *107*
6.16.2 Internal dose from tritium *108*

7 Transfer parameters for releases to surface water *109*
7.1 Aquatic dispersion (P_{02}) *109*
7.1.1 Liquid emissions *109*
7.1.2 Radionuclide concentrations in receiving waters *109*

7.1.3 Discharges to coastal waters *110*
7.1.4 Discharges to rivers *112*
7.2 Contamination of soil by irrigation (P_{23}) *114*
7.2.1 Irrigation *114*
7.2.2 Transfer from irrigation water to soil *115*
7.2.3 Parameter values for the irrigation model *115*
7.2.4 Re-suspension of soil (P_{3area1}) *116*
7.2.5 Volatilization from irrigated soil (P_{3mass1}) *116*
7.3 Direct contamination of crops by spray irrigation (P_{24}) *118*
7.3.1 Radionuclides other than tritium, C-14, and noble gases *118*
7.3.2 Tritiated water (HTO) *118*
7.3.3 Organically bound tritium (OBT) *119*
7.3.4 C-14 *119*
7.4 Transfer from surface water to animal produce (P_{25}) *120*
7.5 Internal dose from drinking water ($P(i)_{29}$) *120*
7.6 Dose from water immersion ($P(e)_{29}$) *120*
7.6.1 External dose *120*
7.6.2 Internal dose from tritium *121*
7.7 Transfer to aquatic animals (P_{26}) and plants (P_{27}) *122*
7.7.1 Bioaccumulation factors *122*
7.7.2 Fresh water *122*
7.7.3 Sea water *123*
7.7.4 Tritium *123*
7.7.5 C-14 *125*
7.8 Transfer to sediment (P_{28}) *126*
7.9 Transfer from aquatic biota and sediment to animal produce *127*
7.9.1 Transfer from aquatic animals (P_{65}) and plants (P_{75}) to animal produce *127*
7.9.2 Transfer from sediment to animal produce (P_{85}) *127*
7.10 External dose from contaminated shoreline ($P(e)_{89}$) *128*
7.11 Internal dose from incidental ingestion of contaminated sediments ($P(i)_{89}$) *128*
7.12 Internal dose from intake of aquatic foods and irrigated crops *129*

8 Application guides *130*
8.1 Source averaging times for monitoring *130*
8.1.1 Airborne releases *130*
8.1.2 Liquid releases *131*
8.2 Release duration *131*
8.2.1 General considerations *131*
8.2.2 Intermittent releases *131*
8.2.3 Airborne releases *131*
8.2.4 Liquid releases *132*
8.2.5 Alternative approaches *133*
8.3 Additivity effects from different radionuclides, pathways, and sources *133*
8.4 Practical monitoring considerations *134*

Annex A — Default values of transfer parameters *136*
Annex B — Sample calculations *337*
Annex C — Dose coefficients *353*
Annex D — Selection of limiting radionuclides for mixed effluents *380*

Annex E — Half-lives and decay constants for the radionuclides considered in these Guidelines *382*
Annex F — Hydrologic and aquatic transport models *386*
Annex G — Parameter values for terrestrial pathways models *393*
Annex H — The finite cloud model for air immersion dose *412*
Annex I — Equations for transfer factors for progeny in decay chains *466*

Preface

This is the fourth edition of CSA N288.1, *Guidelines for modelling radionuclide environmental transport, fate and exposure associated with the normal operation of nuclear facilities*. It supersedes the previous editions published in 2014, 2008, and 1987 under the title, *Guidelines for calculating derived release limits for radioactive material in airborne and liquid effluents for normal operation of nuclear facilities*.

Major changes to this edition include

a) updated the structure of these Guidelines for increased consistency within the CSA N288 series;
b) removed administrative language from the Guidelines;
c) provided additional clarification in areas identified by users;
d) identified stable carbon data for aquatic plants and invertebrates;
e) improved consistency of language throughout the Guidelines; and
f) updated the guidance on transfer factors.

The COG background document (Hart, 2013) was revised in concert with the fourth edition; the updated version is referred to hereafter as the COG *Derived Release Limits Guidance* or CDG (Hart, 2019).

Users of these Guidelines are reminded that the site selection, design, manufacture, construction, installation, commissioning, operation, and decommissioning of nuclear facilities in Canada are subject to the *Nuclear Safety and Control Act* and its *Regulations*.

The CSA N-Series Standards provide an interlinked set of requirements for the management of nuclear facilities and activities. CSA N286 provides overall direction to management to develop and implement sound management practices and controls, while the other CSA Group nuclear Standards provide technical requirements and guidance that support the management system. These Guidelines work in harmony with CSA N286 and do not duplicate the generic requirements of CSA N286; however, they may provide more specific direction for those requirements.

These Guidelines were prepared by the Subcommittee on Guidelines for Calculating Derived Release Limits for Radioactive Material in Airborne and Liquid Effluents for Normal Operation of Nuclear Facilities, under the jurisdiction of the Technical Committee on Environmental Management and the Nuclear Strategic Steering Committee, and have been formally approved by the Technical Committee.

Notes:

1) *Use of the singular does not exclude the plural (and vice versa) when the sense allows.*
2) *Although the intended primary application of this Guideline is stated in its Scope, it is important to note that it remains the responsibility of the users of the Guideline to judge its suitability for their particular purpose.*
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   c) *wording of the proposed change; and*
   d) *rationale for the change.*

CSA N288.1:20
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0 Introduction

0.1 Application of the Guidelines

0.1.1 General

CSA N288.1 provides guidance for developing a radionuclide transport and exposure pathways model (referred to as "the model") which can be used in multiple applications including

a) to calculate derived release limits for radionuclides corresponding to the regulatory annual dose limit for a member of the public;
b) to calculate public dose based on radionuclide in effluent and/or environmental monitoring data; and
c) to support environmental risk assessment for human health and ecological risk.

Note: *Environmental risk assessments (ERAs) are addressed in CSA N288.6.*

The Guidelines consist of an array of mathematical equations that describe the transfer of radioactive materials through the environment from either a point of release to a receptor or from an intermediate compartment to the receptor. It incorporates numerous transport and exposure pathways, which can lead to internal and/or external exposure resulting in a dose.

0.1.2 Derived release limit (DRL)

In the past, the Guidelines have most commonly been applied for the development of exposure-based radionuclide release rates, known as derived release limits or DRLs. The DRL for a given radionuclide is the release rate that would cause an individual of the most highly exposed group to receive a committed dose equal to the the annual public dose limit due to release of the radionuclide to air or surface water during normal operation of a nuclear facility over the period of a calendar year. The DRL is derived using mathematical equations that describe the transfer of radioactive materials through the environment to humans. It takes into account all exposure pathways, including external exposure from immersion in contaminated air and water, external exposure to contaminated substrate (sediment, soil, beach sand), and internal exposure from inhalation and ingestion of radioactivity.

Note: *For purposes of standardization, a DRL is based on 1 mSv/year, the dose limit for members of the public (see Clause 4.1). A facility's release limit approved by the authority having jurisdiction (AHJ), might be the DRL or a fraction of the DRL.*

0.1.3 Dose to public

These Guidelines can be applied to calculate the dose to a member of the public based on radionuclide release rates from a facility, which can be corroborated with radiological measurements in the environment where available.

0.1.4 Environmental risk assessment (ERA)

While these Guidelines focus on the calculation of dose to the public, they can also support the calculation of absorbed dose to non-human biota through the modelling of activity levels in environmental media and associated food webs. As for public dose, this modelling can be further corroborated with environmental measurements.

Note: *An understanding of the fate and transport of contaminants in the environment is necessary for performing ERAs. The requirements for ERAs are addressed in CSA N288.6.*

0.1.5 Radionuclide relative contributions to dose

When applied for either DRLs or for dose calculations, the model can provide information on the relative contribution to dose for each radionuclide and/or exposure pathway.

0.2 History of the Guidelines

In 1987, CSA Group published CSA N288.1 to provide guidelines and a methodology for calculating DRLs for routine releases of radionuclides to air and surface water from nuclear facilities. Since 1987, significant scientific advances were made in dosimetry and in the understanding of radionuclide behaviour in the environment; thus, there was a general consensus in the Canadian nuclear industry that the models and data in CSA N288.1 needed to be updated. Revision began in 2000 with the development of a derived release limits guidance document prepared for Ontario Power Generation (OPG). This document was specifically designed to calculate DRLs at CANDU® nuclear power generation facilities in southern Ontario (i.e., the Bruce, Pickering, and Darlington stations).

In 2006, the document was extended by the CANDU Owners Group (COG) to cover all CANDU facilities in Canada, including the power generation stations at Gentilly (G-2) and Point Lepreau and the research laboratories at Chalk River (CRL). This extended document (Hart, 2008) formed the basis for the second edition of these Guidelines and included background material deemed too detailed for inclusion in the Guidelines itself. Most of the models and parameter values in the first edition of the Guidelines were updated and new exposure pathways were added in producing the second edition, which was issued in 2008. Following publication, users of the Guidelines identified a number of minor errors, which were corrected in an amendment issued in July 2011.

It was not possible during the development of the second edition to implement all of the changes that were deemed desirable. These changes were set aside so that the second edition could be published in a timely fashion. Work on these changes continued through a number of research projects funded by COG. The findings of these projects form the basis for most of the improvements to the third edition, published in 2014. The COG background document (Hart, 2008) was revised in concert with the third edition (Hart, 2013).

Major updates to the third edition included the following:

a) updated energy expenditures and dietary intake rates for humans;
b) updated half-lives, gamma energies, and photon yields for all radionuclides;
c) updated values for many parameters based largely on a new International Atomic Energy Agency handbook of parameter values for environmental transfers of radionuclides (IAEA, 2010);
d) improved direction on when the Guidelines can be used to calculate DRLs for intermittent releases;
e) updated wind direction and precipitation data for use in the wet deposition model;
f) introduction of a model for wild waterfowl as an additional source of human exposure through ingestion;
g) extension of the carbon-14 (C-14) specific activity model to cover plant to animal transfer;
h) an improved specific activity model for tritium in animals, including an update and extension of the water intake source fractions for fresh and dry feed; and

i) provision of equations for explicit accounting of decay and progeny ingrowth in all physical media, as an alternative to the use of progeny-inclusive dose coefficients.

Note: *CANDU (CANada Deuterium Uranium) is a registered trademark of Atomic Energy of Canada Limited (AECL).*

1 Scope

1.1 Facilities

These Guidelines and the CDG are intended to apply to CANDU nuclear power stations in Canada. However, the radionuclides and environmental pathways addressed make these Guidelines applicable to releases from many other nuclear facilities, including research reactors, radioisotope processing facilities, waste processing facilities such as incinerators, and power reactors other than those of CANDU design, subject to the limitations detailed in Clauses 1.2 to 1.8. Application to other types of facilities such as fuel fabrication plants and refineries is limited by the radionuclides considered here (see Clause 4.3). These Guidelines may be adapted to cover part of the needs of such facilities, but additional models or methodologies might be necessary for other parts. However, neither the radionuclides nor the models included in these Guidelines are complete enough to cover releases from sources such as uranium mines and mills, or permanent geologic disposal facilities. In addition, the pathways are incomplete for any facilities where extensive modelling of groundwater pathways is required.

1.2 Release paths

These Guidelines cover releases to the atmosphere and to surface water (both fresh and marine). They do not address releases to groundwater, although transfers from other media to groundwater wells and ponds are considered. Direct gamma irradiation from radioactivity inside the facility is not modelled because it does not involve a release.

1.3 Release duration

The methods specified in these Guidelines are designed for routine, continuous, low-level emissions. They also apply to periodic, short-term releases (see Clause 8.2), provided that

a) the releases are controlled and associated with normal operations;
b) the release rate is roughly the same from event to event;
c) for atmospheric releases, the total release duration exceeds approximately 1000 h in the year; for aquatic releases, at least one or two releases occur in each month of the year; and
d) the releases occur randomly over time.

Where the requirement of Item d) is not met but the releases are known to occur at a particular time of day or year, these Guidelines apply only if the air (water) concentrations are calculated using the meteorological (hydrological) data in effect for that time.

Notes:

1) *Where non-random releases are calculated using time-appropriate data, it might be possible to relax the conditions on the release frequencies.*
2) *Releases that do not meet these conditions can use another model, such as that specified in CSA N288.2 for atmospheric releases.*
3) *For some facilities, intermittent releases occur predictably as spikes on a continuous base release. Such releases can be considered part of routine emissions and included in the DRL without special treatment if the total activity released in intermittent form is less than approximately 30% of the total release from the facility. The 30% cut-off is considered a small fraction of the overall uncertainty of the DRL estimates.*