GENERIC CRITERIA AND OPERATIONAL INTERVENTION LEVELS FOR NUCLEAR EMERGENCY PLANNING AND RESPONSE

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» **NOTE TO READERS**

THE FIRST OCCURRENCES IN THE TEXT OF TERMS THAT ARE LISTED IN THE GLOSSARY ARE FORMATTED IN BOLD. TITLES OF ACTS, PLANS AND SUPPORTING DOCUMENTS ARE FORMATTED IN ITALICS. A LIST OF ACRONYMS AND A GLOSSARY OF TERMS USED IN THIS DOCUMENT ARE PROVIDED IN APPENDIX A AND APPENDIX B, RESPECTIVELY.

1 INTRODUCTION

The primary purpose of this document is to recommend dosimetric and operational quantities, in terms of **generic criteria** and **Operational Intervention Levels** (OIL), to assist emergency response authorities when developing **protection strategies** for nuclear emergencies.

Generic criteria and OILs are tools to support planning and implementation. Generic criteria are expressed as dose levels over a specified time interval which, when exceeded, signal that **protective actions** and associated response actions, such as notification, are warranted. OILs are used post-release to prompt the implementation of protective actions based on monitoring results.

The generic criteria and OILs recommended in this document support the International Atomic Energy Agency (IAEA) requirement to develop protection strategies for nuclear emergencies that are justified and optimized on the basis of identified hazards and potential consequences (Requirement 5, IAEA 2015a).

The requirement for protection strategies is also reflected in CSA N1600-16, *General requirements for nuclear emergency management programs*, published by the Canadian Standards Association (CSA 2016). Generic criteria and OILs support the requirements related to protective actions,[1] including the need for organizations to identify and apply decision-making criteria when delineating **emergency planning zones** and establishing other planning arrangements.

This document was developed in accordance with Health Canada's responsibilities under the Federal Nuclear Emergency Plan (FNEP, HC 2014a), which defines Nuclear Emergency Functions (NEF) specifically related to **nuclear emergency** preparedness and response. Responsibility for each NEF is assigned to primary or supporting federal department(s) or agency(s). Health Canada has the primary responsibility for NEF 5.1: Provide recommendations for protective actions in areas of federal jurisdiction or as requested by a province and NEF 6.1: Provide radiological protection advice, assistance and equipment for first responders and federal emergency workers, including provision of emergency dosimetry services. Health Canada also has a supporting role for NEF 5.2: Implementing protective actions under federal jurisdiction and NEF 5.3: Contributing to the assessment of actual or potential impacts of protective actions.

This document replaces two previous Health Canada documents: *Canadian Guidelines for Intervention During a Nuclear Emergency* (HC 2003) and *Canadian Guidelines for the Restriction of Radioactively Contaminated Food and Water Following a Nuclear Emergency* (HC 2000). It has been updated with considerations of international recommendations for nuclear emergencies current at the time of this publication. An overview of these international recommendations can be found in Appendix D.

This document is not intended to supersede existing criteria in provincial or territorial plans, but rather to serve as guidance when these plans are reviewed or modified. Provinces and territories are encouraged to adopt the generic criteria and OILs presented in this document as significant benefits related to decision-making and public confidence can be achieved by the adoption of consistent national criteria.

[1] Note that the term "protective actions," as used in this document, includes ingestion controls. See also Table 1.

1.1 Scope

This document supports Health Canada's responsibilities under the FNEP and, therefore, supports planning to protect the public from many types of scenarios involving uncontrolled sources of radioactivity. The FNEP outlines five categories of nuclear emergencies, depending on the scope of impacts in Canada and the scale of the federal response that is required.

The five categories are (HC 2014a):

- Category A: An emergency at a nuclear power plant in Canada;
- Category B: An emergency at a nuclear power plant in the United States or Mexico;
- Category C: An emergency involving a nuclear-powered vessel in Canada;
- Category D: Other serious nuclear emergencies or potential threats in North America that require a multi-departmental response; and
- Category E: A nuclear emergency outside of North America.[2]

The generic criteria recommended in this document are applicable to all five nuclear emergency categories, as are OILs 3_γ–6. However, the default values for OILs 1_γ and 2_γ were derived specifically for an emergency involving a severe release of **radioactive material** from a nuclear reactor or its spent fuel (IAEA 2017). These OILs may not be appropriate for emergencies involving other sources of radioactivity and may need to be recalculated before being applied to Category D emergencies as well as some scenarios in Category E. Due to the wide range of possible scenarios for non-reactor emergencies, this document does not provide a detailed approach to such calculations, although some considerations are discussed briefly in Appendix E.

Note that the values in this document for food controls apply only to consumption of domestic products after domestic contamination events. The international food standard *Codex Alimentarius* (Codex 2010) should guide decisions about importing and exporting potentially contaminated food.

This document does not cover all aspects of planning during nuclear emergency preparedness or decision-making during nuclear emergency response. The generic criteria and OILs provided in this document are only part of the larger protection strategy that authorities should develop in order to achieve the response objectives. Other components include, but are not limited to (IAEA 2015a)

- decision-making triggers based on other observable indicators, such as plant conditions (for reactor facilities);
- plans and arrangements to ensure that protective actions, when warranted, can be implemented, adjusted, and rescinded safely and effectively; and
- plans and arrangements to mitigate non-radiological consequences.

More comprehensive guidance on nuclear emergency planning can be found in the references included at the end of this document. Health Canada's Radiation Protection Bureau can also assist; contact us at hc.rpb-brp.sc@canada.ca.

1.2 Dose-related terminology

For the purposes of talking about radiation protection, international organizations have adopted a vocabulary for different kinds of dose and dose quantities. These have been designed by the International Commission on Radiological Protection (ICRP) and the International Commission on Radiation Units & Measurements (ICRU) to precisely communicate information required to interpret dose values in a given context. A brief overview of the terms used in this document is provided below; more complete definitions are provided in the glossary (Appendix B).

[2] In the case of events abroad, the criteria in this document will be considered when providing advice to Canadians in affected areas in light of protective actions taken by the relevant local authorities and the recommendations of the international community.

Protection quantities relate radiation exposure to the risk of impacts on human health. The following protection quantities are used in this document:

- **equivalent dose**, when the exposure and the risk relates to a specific organ or tissue; and
- **effective dose**, when the exposure and risk relates to the whole body.

Most of the generic criteria are expressed as effective dose (E) and equivalent dose to the fetus (H_{fetus}); the exception is **Iodine Thyroid Blocking** (ITB), which is expressed as equivalent dose to the thyroid ($H_{thyroid}$). The units in this document are millisieverts (mSv).

To relate measurements from instruments to protection quantities, the following operational dose quantities are used:

- **ambient dose equivalent**, for environmental monitoring; and
- **personal dose equivalent**, for individual monitoring.

The generic criterion for **off-site emergency workers** is personal dose equivalent ($H_p(10)$) and the units are mSv. OILs 1–4 are expressed as ambient dose equivalent ($H^*(10)$) rates with units microsieverts per hour (μSv/h).

When using protection quantities for exposure planning and decision-making, the following terms are used (based on ICRP 2009):

- **projected dose** is the effective or equivalent dose that would be expected to be received if protective actions were not taken;
- **averted dose** is the effective or equivalent dose that can be avoided by the implementation of protective actions; and
- **residual dose** is the effective dose that is expected to be received as a result of the decisions made regarding protective actions In other words, the residual dose is the projected dose minus the averted dose. The timeframe used to calculate residual dose from the emergency should correspond to the period for which the reference level applies.

2 KEY CONCEPTS FOR CONSIDERING RADIOLOGICAL RISK IN NUCLEAR EMERGENCY PLANNING AND RESPONSE

The practical goals of the response to a nuclear emergency include (modified from IAEA 2015a):

- ensuring that an adequate capability is in place to respond to an emergency;
- regaining control of the situation and mitigating radiological consequences;
- protecting human health, property and the environment;
- mitigating non-radiological consequences;
- keeping the public informed and maintaining their trust; and
- preparing for the resumption of normal societal and economic activity.

ICRP and IAEA state, and Health Canada agrees, that radiological risk must be considered appropriately in order to achieve these goals (e.g., ICRP 2007; ICRP 2009; IAEA 2015a). Fundamentally, this means that the level of protection from radiation exposure should be the best possible under the prevailing circumstances, such that the benefits resulting from the reduced exposure outweigh the detriment caused by taking the action. If radiation levels are high enough to cause **severe deterministic injuries**, actions to reduce exposures are definitely warranted. However, when radiation levels are lower, authorities should consider all significant risks, radiological and non-radiological, in order to optimally protect the public and workers under their jurisdiction. As recent history has shown, decisions based entirely on avoiding dose may cause significantly more harm than good (e.g., SHAMISEN 2017).

At the same time, doses should be kept as low as reasonably achievable. In order to help bound what is "reasonable" and keep the risks of radiation exposure in perspective, ICRP and IAEA recommend that authorities determine, in advance, criteria and operational quantities to guide decisions about implementing protective actions. These include:

- an initial reference level;
- generic criteria; and
- OILs.

These parameters are only some of the inputs that authorities will require in order to develop and implement effective protection strategies, which are the key to optimizing exposure during an emergency. The concept of a protection strategy is briefly described below, followed by explanations of the afore-mentioned parameters.

2.1 Protection Strategy

A protection strategy describes what needs to be done and how it will get done in order to achieve the goals of a nuclear emergency response, in consideration of all of the risks, constraints, and other factors that will need to be managed—not just the radiological ones. IAEA states the following about protection strategies (IAEA 2015a, para 4.29):

> *Each protective action, in the context of the protection strategy, and the protection strategy itself shall be demonstrated to be justified (i.e. to do more good than harm), with account taken not only of those detriments that are associated with radiation exposure but also of those detriments associated with the impacts of actions taken on public health, the economy, society and the environment.*
>
> (*Examples of such [health] impacts include possible deaths among patients evacuated without the necessary medical care and possible reduced life expectancy due to resettlement.*)

According to the IAEA (2015b), protection strategies should be developed at the preparedness stage and involve all relevant response organizations, as well as other interested parties. Arrangements should cover the period from when the emergency is declared until it is terminated and, for large-scale events, may continue through the transition to recovery and beyond.

2.2 Reference Level

The reference level is the level of residual dose above which it is generally judged to be inappropriate to plan to allow exposures to occur. For comparison against the reference level, residual dose should be calculated as the effective dose (or the equivalent dose to the fetus) remaining after the implementation of an optimised protection strategy, considering all exposure pathways (ICRP 2007).[3]

It is prudent to set the reference level for an emergency situation higher than for more controlled exposure situations because there are risks associated with taking protective actions and these may be higher than the incremental risk associated with a higher residual dose.

For off-site nuclear emergency planning, a reference level should be established and then protection strategies developed in order to keep total doses to all affected people below it. During an emergency, the reference level is a tool to help gauge the effectiveness of the protection measures being implemented and signal the need to make adjustments. If it appears that residual dose to some groups of people could exceed the reference level, authorities should take additional actions to reduce exposure.

ICRP 109 (2009) recommends setting reference levels for emergencies between 20 and 100 mSv, acute or annual dose, depending on the type of emergency. Severe deterministic injuries do not occur at these levels and there is no epidemiological evidence to suggest increased risk of other **tissue reactions** or **stochastic effects**, like cancer, at doses below about 100 mSv (ICRP 2007) The values for generic criteria and OILs presented in this document are appropriate for emergencies where authorities have established a reference level towards the upper end of this range, based on annual effective dose, in order to be inclusive of all categories of emergency addressed by the FNEP, including severe accidents.

2.3 Generic criteria

Generic criteria are triggers within protection strategies that help authorities identify when, where, and to what extent arrangements for protective actions should be planned (in advance of an emergency) and implemented (during an emergency). They are determined during the planning stage, when planners have time to think through all possible contributors to dose and the incidental impacts of taking action to limit them. Once established, generic criteria facilitate decision-making: if the level for an action is exceeded, implementation of that action should be considered a priority as it will almost definitely do more good than harm.

In advance of an emergency, generic criteria are used to characterize the extent to which arrangements for protective actions might be required. For example, by comparing projected doses from postulated accident scenarios to the generic criteria for **stable iodine thyroid blocking** (ITB), **evacuation, temporary relocation** and **ingestion controls**, emergency planners can better understand the likelihood that these protective actions will be required. This supports the delineation of emergency planning zones and the corresponding arrangements within them.

During the early stages of an emergency, after urgent protective actions have been implemented but before measurements are available, generic criteria for exposure control can be compared to projected dose in order to confirm, for example, that the pre-determined arrangements to protect populations are sufficient for the scenario that is unfolding.

Throughout the emergency, generic criteria for medical management and for off-site emergency workers are used to identify situations where intervention is required to manage or mitigate risks to individuals.

It is recognized that, even with thoughtful planning, authorities may require flexibility in order to manage the risks posed by unforeseen hazards in an emergency. In these cases, generic criteria may need to be revised so that protection can be optimized in a different way in order to respond to the specific demands of an emergency.[4] The changes, along with the reasons for the change, should be communicated to the public quickly and transparently.

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[3] ICRP (2009) states that reference levels in terms of equivalent dose to specific organs may be considered for some exposure scenarios, notably irradiation of the thyroid by radioiodine. Given Canadian practice to ensure the availability of iodine thyroid blocking agents for emergency scenarios involving radioiodine, Health Canada has determined that a separate reference level is not necessary.

[4] Changing generic criteria during an emergency should be avoided if possible as it can create confusion for both responders and members of the public.

The generic criteria recommended by Health Canada should keep total residual doses for all affected populations and individuals well below the upper limit of the reference level for the emergency (100 mSv).

More information about how generic criteria are used before and during an emergency, as well as the default values recommended by Health Canada, is provided in Section 5.

2.4 OILs

OILs are values that support decision-making by quickly relating discrete measurements of contamination to generic criteria, thereby identifying the need for or confirming the adequacy of protective actions. Exceeding an OIL triggers the requirement to implement the corresponding protective action within a pre-determined timeframe.

OILs are derived from generic criteria and so are calculated to keep total residual doses for all affected populations and individuals well below the upper limit of the reference level (100 mSv), when implemented within the recommended timeframes. Information on how OILs are calculated can be found in Appendices E and F.

Information on how OILs are used during an emergency as well as default values recommended by Health Canada is provided in Section 6.

2.5 Functions of protective actions

For ease of reference in this document, Health Canada occasionally refers to groups of protective actions by their function in a protection strategy. These groupings are explained in Table 1.

TABLE 1. Protective actions, grouped by function and response objectives. More information on the protective actions is provided in Section 7.

FUNCTION	RESPONSE OBJECTIVE	PROTECTIVE ACTIONS
Exposure Control	• To preclude severe deterministic injuries • To reduce the risk of stochastic effects to populations living in contaminated or potentially contaminated areas	• Stable iodine thyroid blocking • Evacuation • **Sheltering** • Temporary relocation
Ingestion Control	• To reduce the risk of stochastic effects to consumers of food and water that may be contaminated	• Restriction of distribution and ingestion of potentially contaminated drinking water, milk and other foods
Population Monitoring and Medical Management	• To identify individuals who may require intervention to reduce internal and/or external contamination • To identify individuals who require treatment of radiation injuries or **medical follow-up** as a result of exposure	• Personal decontamination[5] • Internal contamination assessment • Medical follow-up
Off-Site Emergency Workers	• To reduce the risk of stochastic effects to off-site workers	• Restriction of activities for individual workers

[5] For the purpose of health protection, personal decontamination refers to removing external contamination when quantities are sufficient to justify action to reduce skin exposure, when there is a significant risk of inadvertent ingestion, and/or when external contamination levels interfere with the ability to detect internal contamination. Decontamination for the purposes of contamination control.

2.6 Public communications

Effective public communication is essential to achieving the goals of nuclear emergency response. This section touches very briefly on communication matters directly linked to successful use of generic criteria and OILs for nuclear emergency planning and response and is in no way a comprehensive review of the topic. More information on public communications can be found in CSA N1600-16, *General requirements for nuclear emergency management programs* (CSA 2016), and *Communication with the Public in a Nuclear or Radiological Emergency* (IAEA 2012). Additional guidance from IAEA is in development at this time.

One of the main goals of public communications during a nuclear emergency is to provide affected populations with timely, clear and appropriate information about the nuclear emergency situation and the protective actions which they should undertake (typically referred to as public alerting). Protection strategies should include arrangements to ensure that this happens using all available communication channels (e.g., the National Public Alerting System,[6] the media, and social media).

The public must also be confident that authorities are prepared and that plans are in place. To this end, information about protective actions and triggers for their implementation should be shared with the public in advance of an emergency event. If it is necessary to deviate from pre-determined criteria during an emergency, changes should be communicated quickly, clearly, and transparently.

Finally, other provinces and countries may issue advice to their citizens who may be affected by the emergency, or may impose temporary embargoes on food from the affected area. If the advice is found to be in conflict with the advice of local authorities, this may have an impact on public confidence. Therefore, coordinating and harmonizing decision-making criteria from other response authorities will assist in maintaining public confidence.

[6] The National Public Alerting System is an all-hazards system that provides emergency management organizations across Canada with the ability to alert the public of imminent or unfolding hazards via radio, television, email and text messages (PS, 2014).

3 OVERVIEW OF THE HEALTH IMPACTS OF RADIATION EXPOSURE

The reference dose level and corresponding quantities for action that are recommended in this document reflect the current scientific knowledge of the biological effects of radiation doses above and below about 100 mSv.

Humans are always being exposed to small amounts of radiation and radioactive materials that are present in the environment and in our own bodies. Small levels of radioactivity are not considered harmful to human health. While ionizing radiation can cause damage to human cells, these cells are very capable of repairing minor damage. In cases where damage cannot be repaired, or is repaired incorrectly, the cell may not be able to survive or reproduce, or the cell may remain viable but be modified. Most organs or tissues remain unaffected by the loss of a few cells.

However, if enough cells are lost, the organ or tissue may no longer be able to properly function. These effects are known as tissue reactions and may include anything from radiation-induced cataracts that can take years to manifest, to acute radiation syndrome that may even lead to death within days or weeks. Tissue reactions such as these only occur at dose thresholds that are far above the reference level stated in these guidelines and simply do not occur at lower dose levels. Above the threshold, the severity of the effect increases with increasing dose.

Alternatively, radiation exposure can cause modifications to cells without killing them, which may lead to abnormal cell growth, or cancer. This is known as a stochastic effect, where the probability of a health effect is assumed to increase with dose received. To put this in perspective, it is estimated that the fatal cancer risk from off-site emergency exposures of the order bounded by the reference level and generic criteria is 5% per Sv effective dose (ICRP 2007). This means that a member of the public who receives an effective dose of 100 mSv (0.1 Sv) is assumed to have a 0.5% increase in the probability of developing a fatal cancer, based on the ICRP risk model. For stochastic effects, the severity of the effect is not related to the dose.

It should also be noted that, below approximately 100 mSv, it is very difficult to identify the relation between radiation dose and cancer risk. This is largely due to the fact that the “normal” incidence of cancer is so high in the general population that it is extremely difficult to identify any small number of excess cancers (if any) that can be attributed to low levels of radiation exposure.

4 FUNDAMENTAL PRINCIPLES

The following principles, which emphasize overall protection of public health, have been followed in choosing the dose criteria for initiating protective actions.

4.1 Justification and optimisation

The primary considerations in the derivation of generic criteria and OILs are the protection of public health and confidence, and the achievement of a positive net benefit if a protective action is implemented. When a net benefit is achieved, the action is considered justified. Optimisation goes one step further, by extending the level of protection beyond what is required to what is reasonably achievable, with the intent to maximize the net benefit given the prevailing circumstances and taking non-radiological factors into account.

During a nuclear emergency, potential doses to the public can only be reduced through protective actions that, themselves, may introduce risks. These non-radiological risks include the physical risk associated with the protective action, economic losses, social disruption, and anxiety. For example, an evacuation order given during severe weather may introduce a higher risk from a transportation accident or other related hazard than the risk posed by waiting for safer driving conditions and incurring a slightly higher residual dose. Expected benefits and risks associated with each protective action should be taken into account during the planning stage.

Because of these additional risks, it is justified to plan to allow people to receive more dose in an emergency situation than they would under normal circumstances, to a point. This point is the reference level. If projected doses are above the reference level, some intervention to reduce doses is almost always justified (ICRP 2007; ICRP 2009). Generic criteria facilitate **optimisation of protection** below the reference level. The generic criteria in this document are considered reasonably achievable in the Canadian context, especially with advance planning.

4.2 Consideration of the most sensitive group in the population

Generally, protective actions should be applied to the entire population in the affected zone, and not just to selected individuals or age groups. However, no population group is uniform, and although it is inappropriate to use overly conservative assumptions for estimating exposures, it is reasonable to give priority to the protection of more sensitive age groups in the event of an emergency. Therefore, the generic criteria should be compared with the projected doses for the most sensitive or susceptible population group (e.g., oftentimes infants or developing fetuses are more sensitive to radiation exposure).

The OILs in this document are protective of the most sensitive age groups and the developing fetus. For instance, OILs 1_γ and 2_γ that correspond to evacuation and temporary relocation protective actions, respectively, have been evaluated for both an infants and the fetus, and the most conservative OILs were selected. Another example is in the calculation of the OIL6 values for laboratory measurements of drinking water, milk and other foods and beverages. As described in Appendix F of this document, these OILs were calculated for 5 age groups and only the most restrictive value recommended.

4.3 Consistency with international practices

Health Canada's guidance for nuclear emergencies has been updated to align with international recommendations for nuclear emergencies current at the time of this publication, including:

- *ICRP Publication 103, The 2007 Recommendations of the International Commission on Radiological Protection* (ICRP 2007);
- *ICRP Publication 109, Application of the Commission's Recommendations for the Protection of People in Emergency Exposure Situations* (ICRP 2009);
- IAEA General Safety Guide (GSG) 2: *Criteria for Use in Preparedness and Response for a Nuclear or Radiological Emergency* (IAEA 2011);

- IAEA Emergency Preparedness and Response Nuclear Power Plant (EPR-NPP) Public Protective Actions: *Actions to Protect the Public in an Emergency due to Severe Conditions at a Light Water Reactor* (IAEA 2013);
- IAEA GSR Part 3: *Radiation Protection and Safety of Radiation Sources: International Basic Safety Standards* (IAEA 2014);
- IAEA GSR Part 7: *Preparedness and Response for a Nuclear or Radiological Emergency* (IAEA 2015a); and
- IAEA Emergency Preparedness and Response (EPR-NPP-OILs): *Operational Intervention Levels for Reactor Emergencies and Methodology for Their Derivation* (IAEA 2017).

Health Canada has considered and, for the most part, adopted the values for generic criteria and OILs recommended by the IAEA (IAEA 2015a, IAEA 2017). Appendix D provides more information on how Health Canada's recommendations compare to those of the IAEA and of other industrialized countries that generate nuclear power.

5 GENERIC CRITERIA

The bases for implementing protective actions are the generic criteria. If the generic criterion for an action is exceeded, implementation of that action should be considered a priority. Table 2 identifies the generic criteria recommended by Health Canada. Doses include exposure from all pathways (e.g., external irradiation, ingestion, inhalation).

TABLE 2. Generic criteria. *E* is effective dose, $H_{thyroid}$ is equivalent dose to the thyroid; H_{fetus} is equivalent dose to the fetus, and $H_p(10)$ is personal dose equivalent at 10mm.

STRATEGY NAME	PROTECTIVE ACTIONS	GENERIC CRITERIA
Exposure Control	Stable iodine thyroid blocking	50 mSv in the first 7 days ($H_{thyroid}$)
	Evacuation	100 mSv in the first 7 days (*E* or H_{fetus})
	Sheltering	10 mSv in 2 days (*E)* *(averted dose)*
	Temporary relocation	100 mSv in the first year[7] (*E*) or 100 mSv for the full period of in utero development (H_{fetus})
Ingestion Control	Restriction of distribution and ingestion of potentially contaminated drinking water, milk and other foods	3 mSv/y (1 mSv/year for each of the following categories: drinking water, milk and other foods and beverages) (*E*)
Population Monitoring and Medical Management	Population monitoring, internal assessment, and medical follow-up	100 mSv in a month (*E*) or 100 mSv for the full period of in utero development (H_{fetus})
Off-Site Emergency Workers	Restriction of activities for individual workers	50 mSv[8] over the duration of the response ($H_p(10)$ or *E)*

The generic criteria in Table 2 have been largely adopted from the generic criteria recommended by the IAEA (IAEA 2015a). Appendix D provides a comparison.

[7] This is an initial value. As the response progresses, this generic criterion should be reduced. See sections 5.1.1 and 7.4.

[8] This value may be exceeded under some circumstances, as discussed later in this section.

5.1 Notes on the application of generic criteria

5.1.1 Generic criteria for Exposure Control and Ingestion Control

These values describe the projected dose levels at which actions should be taken to protect populations. When developing nuclear emergency plans for scenarios where the location of the radioactive source is known in advance (such as a reactor facility or a port designated for visits by nuclear-powered vessels), the likelihood of exceeding these dose levels should be considered, among other inputs, when delineating emergency planning zones and when determining non-dosimetric triggers (such as plant conditions) for protective actions. In areas where generic criteria for Exposure Control are likely to be exceeded, special arrangements should be made for populations who may be unable to relocate without assistance and for those who require extra support or accommodation.

The generic criteria for evacuation and temporary relocation reflect the relative urgency with which action should be taken to move populations out of areas with the highest potential for exposure—that is, resources should *first* be directed at helping people to safely relocate from areas where the generic criterion for evacuation will be exceeded and *then* towards areas where the generic criteria for temporary relocation will be exceeded. Once these actions have been completed, authorities should revise the generic criterion for temporary relocation downward. The default lower limit for the generic criterion for temporary relocation is 20 mSv/y, which is the equivalent of the lower limit for an emergency reference level (ICRP 2009, IAEA 2012a). Strategies to manage long-term exposures for affected populations should be developed, in consultation with all stakeholders, as part of the transition to recovery.

Sheltering should be ordered as an interim protective action when the projected dose exceeds the generic criteria for ITB or evacuation, but where prevailing circumstances prevent timely implementation. Because it is a less-disruptive protective action (IAEA 2012b), authorities may order sheltering for up to two days at lower dose levels if it will reduce exposures by at least 10 mSv. More information on scenarios where sheltering may be appropriate is provided in Section 7.

Parameters used for dose projections should correspond to the groups at greatest risk (considering, for example, age, sex and habits) and consider all pathways, but they should not be grossly pessimistic (ICRP 2009).

The limitations of the models used to predict the characteristics and dispersal of releases should be recognized, understood, and taken into account. Dose projections that are generated during an emergency, when accident/event progression may be highly unpredictable, should be used with caution, especially for making decisions to deviate from the planned protection strategy. This is because the high degree of uncertainty compromises the ability to assess whether an action is justified.

5.1.2 Generic criterion for Population Monitoring and Medical Management

This value is the level of dose that has been received by an individual (including external irradiation and **committed dose** from inhalation and ingestion) at which action should be taken to ensure medical follow-up when required. It applies equally to members of the public and to emergency workers, although this generic criterion need only be considered for individuals who were in high exposure situations. Dose should be determined by individual dosimetry (including retrospective dosimetry) and include assessments of all relevant pathways. Internal contamination levels should be determined by whole-body counting, bioassay and thyroid monitoring (if exposure includes radioiodine). Follow-up actions may include, but are not limited to registering the patient and the dose, targeted screening for health effects, counselling and long-term surveillance. Medical follow-up is elaborated in Section 7.7. More information can be found in the *Canadian Guide on Medical Management of Radiation Emergencies* (HC 2015).

5.1.3 Generic criterion for Off-site Emergency Workers

NOTE: This generic criterion is not appropriate for female workers who may be pregnant. These individuals should be excluded from emergency duties that would result in a dose greater than the relevant dose limit for non-emergency situations.

This value, when considered in terms of projected dose to individual workers, is useful for work planning and **dose management.** During the emergency response, once tasks are identified and the radiation fields in the work environment are characterized, dose management strategies should be implemented to optimize exposures, keeping all individual doses below 50 mSv except in extraordinary circumstances.

When considered in terms of dose already received, exceeding this value should result in restricting the activities of the individual worker, such that they are not in a position to receive significant additional dose as a result of the emergency. Effective dose from exposure via all pathways should be included in the assessment. If internal contamination is suspected, the off-site emergency worker should undergo internal contamination assessment and be considered for medical follow-up.

It may be necessary in some, exceptional, cases, to allow a small number of off-site emergency workers to volunteer to receive doses of 100 mSv or more. Examples of situations where this might be considered include life-saving activities and tasks that, when complete, can prevent the development of conditions that could significantly affect people and the environment. These workers should be fully aware of the health risks associated with the potential dose they may receive, and they should voluntarily accept these risks.

6 RECOMMENDED OPERATIONAL INTERVENTION LEVELS (OILS)

OILs are values that support decision-making post-release by quickly relating discrete measurements of contamination to generic criteria, thereby identifying the need for or confirming the adequacy of protective actions.

The OILs presented in this section should ensure that doses do not exceed the generic criteria recommended by this document. Measurements should be made in accordance with the details and timeframes provided in Table 3, and using properly calibrated equipment that is fit for purpose.

TABLE 3. OIL values and associated monitoring conditions.

OIL#	PROTECTIVE ACTION	MEASUREMENT DETAILS	LEVEL	TIMEFRAME FOR ACTION, RELATIVE TO RELEASE (IAEA 2013)
Exposure Control				
1_{γ}	Evacuation	Gamma dose rate (H*(10)), 1m from the ground	1000 µSv/h	Complete within a day
2_{γ}	Temporary relocation	Gamma dose rate (H*(10)), 1m from the ground, measured within 10 days of reactor shutdown	100 µSv/h	Initiate after evacuation
		Gamma dose rate (H*(10)), 1m from the ground, measured more than 10 days after reactor shutdown	25 µSv/h	
Ingestion Control				
3_{γ}	Restriction of distribution and ingestion of potentially contaminated drinking water, milk and other food	Gamma dose rate (H*(10)) at 1m from the ground	1 µSv/h	Implement with Exposure Control and extend within days
5_{α}	Confirm ingestion controls (with lab measurements)	Gross alpha activity	See Table 4	Initiate within a week to a month, depending on importance of local food and drinking water to the community
5_{β}		Gross beta activity	See Table 4	
6		Activity concentrations for specific radionuclides	See Table 12	
Population Monitoring and Medical Management				
4_{γ}	Personal decontamination and/or medical follow-up	Skin measurement at 10 cm from the hands and the face	1 µSv/h	Implement concurrently with Exposure Control

The default values for OILs 1_{γ} and 2_{γ} in Table 3 were derived specifically for an emergency involving a severe release of radioactive material from a nuclear reactor or its spent fuel (IAEA 2017). For other types of emergencies, the default values for urgent actions (evacuation, food and water restrictions) should be sufficiently protective for most scenarios involving gamma-emitting radionuclides and so can be adopted directly if necessary. However, OIL2_{γ} (10 or more days after shut-down) may not be appropriate and so should be re-assessed, as soon as time allows, based on the isotopic composition of the source term. See Appendix E for further discussion.

If default OILs are not used, the responsible emergency response authority should be prepared to promptly assess the requirement to deviate from the generic guidance and the impacts of doing so. Some considerations for doing so are provided in Appendix E.

6.1 Notes on the Application of OILs

6.1.1 OILs for Exposure Control

OILs 1_γ and 2_γ are triggers that can be directly compared to common field survey measurements, shortly after a release or other exposure situation has been identified, to enable rapid decisions and rapid actions. The default values are presented in terms of gamma dose rates (H*(10)) measured 1 metre from the ground. If the survey instrument expected to be used in the emergency response does not provide a direct output in H*(10), the default OILs 1_γ and 2_γ may not be appropriate and new values, in the units displayed by the instrument, should be calculated during the preparedness stage. This will ensure that instrument readings can be quickly compared to OILs during an event and reduce the risk of conversion errors.

When $OIL1_\gamma$ is exceeded, arrangements for safe evacuation and other urgent actions to protect the public, including ITB, ingestion controls, and population monitoring, should be implemented immediately. If it is not possible to initiate safe evacuation immediately (e.g., due to bad weather or damaged infrastructure), the public should be instructed to shelter until they are told otherwise. In some cases, such as critical patients in hospitals or care homes, the risks of being moved quickly may be significantly higher than the risks of exceeding the generic criterion. As much as possible, arrangements should be made in advance to manage these situations. Where prior arrangements have not been made or are inadequate, authorities should make it a priority to identify individuals who require special assistance and to provide it.

The basis for the default $OIL2_\gamma$ identified in Table 3 is the generic criterion for temporary relocation in the early stages of the emergency (100 mSv in the first year following the accident). Separate $OIL2_\gamma$ values are provided for use at different times after reactor shutdown. The different values take into account the expected change in dose rate within the first 10 days compared to afterwards, largely as the short-lived radionuclides decay.

As time progresses and if resources permit, the generic criterion for temporary relocation may be reduced gradually to a lower limit of 20 mSv/y. As the generic criterion is reduced, the value for $OIL2_\gamma$ (> 10 days after shut down) can be scaled down linearly, so that $OIL2_\gamma$ may eventually drop to 5 μSv/h. All populations in areas where ambient dose rates exceed default $OIL2_\gamma$ should be identified and relocated within a month.

6.1.2 OILs for Ingestion Control

Like OILs 1_γ and 2_γ, $OIL3_\gamma$ is a trigger that can be directly compared to common field survey measurements, shortly after a release or other exposure situation has been identified. Default $OIL3_\gamma$ is gamma dose rate (H*(10)) measured 1 metre from the ground. The instrument must display dose rate in H*(10) to use the default $OIL3_\gamma$; if other survey instruments are used, new values, in the units displayed by the instrument, should be calculated during the preparedness stage.

$OIL3_\gamma$ is adopted directly from IAEA (IAEA 2015a). It is an early indicator that drinking water, milk and other foods and beverages may be contaminated. If $OIL3_\gamma$ is exceeded, restrictions should be put in place and replacement supplies should be made available until more detailed assessments can be completed.[9,10]

Once the time for urgent action has passed, representative samples of restricted food and drinking water should be collected and analyzed in a lab, for comparison against OIL5 and/or 6 values.

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[9] Restricting essential drinking water, milk and other foods and beverages could result in dehydration, severe malnutrition or other severe health impacts; therefore, essential drinking water, milk, and other foods and beverages are to be restricted only if alternatives are available (IAEA 2015a).

[10] In a situation where $OIL3_\gamma$ is exceeded due to iodine contamination and replacement supplies of essential drinking water, milk and/or other foods and beverages are not available, emergency response authorities should consider ITB to prevent uptake of radioactive iodine (radioiodine) and reduce dose from ingestion. ITB would need to occur prior to or as soon as possible after exposure in order to be effective (see Section 7.1).

ALPHA/BETA SCREENING

If the relative contribution to total dose from predominantly alpha- or beta-emitting radionuclides is significant or if it is unknown, samples may also be screened by comparing gross alpha and/or beta activity against OIL5 values in order to determine whether lab analysis for specific alpha- or beta-emitters is required. Radionuclides emitting low-energy beta activity, such as tritium, and some gaseous or volatile radionuclides, such as iodine, may not be detected by standard gross activity measurements. If their presence is suspected, radionuclide-specific sampling and measurement techniques should be used (HC 2009).

Thresholds for OILs 5_{α} and $5_{ß}$ are based on the most restrictive radionuclide-specific OILs for alpha and beta emitters, respectively, and are presented in Table 4.

TABLE 4. OILs for alpha/beta screening

			MEASURED QUANTITY (Bq/L)		
OIL	Action	Measurement details	Drinking water	Milk	Other foods and beverages
5_{α}	Restrict distribution and ingestion pending radionuclide-specific analysis	Gross alpha	1	1	3
$5_{ß}$		Gross beta	10	30	30

For the gross beta laboratory analysis, the contribution from potassium-40 (^{40}K), a naturally occurring radionuclide found commonly in food and water, should be subtracted. This requires a separate determination of total potassium content in the food and water. The beta activity of the ^{40}K included in natural potassium is 2.76 x 10^4 Bq/kg (IAEA 2011).

If one or more of the alpha/beta screening OILs are exceeded, the radionuclide-specific concentrations in the drinking water, milk and other foods and beverages should be determined and compared to the radionuclide-specific OILs.

Table 12, in Appendix F, lists the radionuclide-specific OILs. Details on how they were calculated can also be found in Appendix F.

For samples with multiple radionuclides present, the following formula should be used:

$$\sum_i \left(\frac{C_i}{OIL6_i} \right) \geq 1$$

Where:

C_i is the concentration of radionuclide *i* in the drinking water, milk or other foods and beverages (Bq/kg or Bq/L);

$OIL6_i$ is the radionuclide-specific value of OIL6 for radionuclide *i* in drinking water, milk or other foods or beverages (Bq/kg or Bq/L).

If one of the radionuclide-specific OILs or if the condition for multiple radionuclides is exceeded, then the restrictions should be continued. Essential drinking water, milk and other foods and beverages should be replaced as soon as possible. If the radionuclide-specific OILs and the condition for multiple radionuclides are not exceeded, then the drinking water, milk and other foods and beverages should be considered to be suitable for consumption.

6.1.3 OILs for Population Monitoring and Medical Management

The OIL for population monitoring and medical management is a trigger for determining whether individuals require personal decontamination and/or medical follow up, based on skin measurements of the hands and face.

Default $OIL4_{\gamma}$ is gamma dose rate measured 10 cm from the hands or face. The instrument must display dose rate in $H^*(10)$[11] to use the default $OIL4_{\gamma}$; if other survey instruments are used, new values, in the units displayed by the instrument, should be calculated during the preparedness stage.

If an individual is found to be contaminated at levels above the $OIL4_{\gamma}$, monitoring staff should provide advice on how to prevent **inadvertent ingestion** and proceed with personal decontamination and internal contamination assessment. Where internal contamination is suspected, individuals should be referred promptly to internal monitoring specialists for whole body counting, bioassay and/or thyroid measurements (for exposures to radioiodine). Delays in making internal measurements will affect the accuracy of the dose estimate and the timeliness of treatment, so arrangements should be made in advance for specialized resources to quantify exposure and to initiate medical follow-up. At a minimum, medical follow-up should be implemented when the generic criterion for medical follow-up is exceeded. Monitoring results should be registered for future use during medical follow-up.

More information on medical follow-up, as well as on medical management for radiation emergencies in general, can be found in the *Canadian Guide on Medical Management of Radiation Emergencies* (HC 2015).

6.1.4 Off-Site Emergency Workers

Health Canada has not identified specific OILs for Off-Site Emergency Workers because it is not practical for us to do so. Instead, we recommend that authorities or designated radiation safety personnel develop and implement dose management strategies for off-site emergency workers based on the work that needs to be done and the exposure scenarios.

[11] Note that the calculation for $OIL4_{\gamma}$ (not reproduced in this document) includes a factor to convert activity on the skin surface to ambient dose equivalent rate ($H^*(10)$).

7 DISCUSSION OF PROTECTIVE ACTIONS

This section describes the protective actions triggered by the criteria provided in this document, and provides some information on risks, benefits, and considerations for implementation and rescinding.

7.1 Stable Iodine Thyroid Blocking

Iodine Thyroid Blocking (ITB) works by saturating the thyroid with stable iodine, thus reducing the uptake of radioactive iodine (radioiodine) and subsequent risk of radiation-induced thyroid cancer. Studies of populations affected by the nuclear accident at Chernobyl indicate that increased incidence of thyroid cancer, especially in children, is the predominant health impact directly attributable to radiation exposure (UNSCEAR 2012). Therefore, ensuring that ITB agents (usually **potassium iodide** (KI) pills) are readily available to those who might need them is an essential component of an effective protection strategy for scenarios involving radioiodine.

ITB agents are only effective at reducing internal exposure to radioiodine; they offer no protection against external radiation or internal exposure to other radionuclides (ICRP 2009). ITB is most effective when used in conjunction with other protective actions such as sheltering or evacuation

7.1.1 Implementation

ITB agents are used primarily to protect people who are at risk of inhaling airborne radioiodine during or immediately following a release.

The effectiveness of KI in limiting the uptake of radioiodine depends greatly on timing. KI administered immediately before or during a release is approximately 100% effective at blocking uptake of radioiodine by the thyroid. Administration of KI in the first few hours can still be 80% effective at blocking the uptake of radioiodine by the thyroid. The effectiveness of KI continues to decrease with time to about 20% after 24 hours (WHO 1999; NAP 2004).

Radioiodine may also enter the body through ingestion of contaminated food and drinking water, especially milk; however, preventing consumption of contaminated foodstuffs offers more protection (from all radionuclides) and is therefore considered the more appropriate action for limiting radioiodine exposure from ingestion. In situations where uncontaminated substitutes for essential foodstuffs, such as milk for children, are not available, it may be necessary to order extended administration of ITB agents while arrangements are made for alternate food and/or water supplies.

Because of the importance of timing in the effectiveness of ITB, protection strategies must include arrangements for ensuring that individuals have access to KI prior to or within the first few hours of an emergency involving radioiodine. This requires pre-distribution within communities that are most at risk of exceeding the generic criteria for ITB, as determined by the planning basis for the emergency scenario. It is the responsibility of the emergency response authority to decide on the manner and extent of KI pre-distribution, in consideration of site-specific factors, implementation plans for other urgent protective actions and/or regulatory requirements, such as those specified in CNSC REGDOC 2.10.1 *Emergency Management and Fire Protection: Nuclear Emergency Preparedness and Response* (CNSC, 2016).

Emergency response authorities should ensure that KI tablets are readily available for off-site emergency workers responding to an event involving radioiodine.

7.1.2 Risk/benefit considerations

Health risks from consuming KI at the recommended dosages and in accordance with instructions provided by public health or emergency management officials are low for most people.

KI is not recommended for people with some pre-existing conditions, such as autoimmune diseases affecting the thyroid. The prevalence of these types of health conditions increases with age. Due to this increased risk of adverse effects coupled with the extremely low risk of developing thyroid cancer after 40 years of age, administration of KI may not be beneficial for this age group (WHO, 1999).

Tincture of iodine is not an alternative to KI. Tincture of iodine is poisonous, and there are significant health risks associated with its consumption. Messaging about stable ITB should clearly differentiate between safe and unsafe sources of stable iodine, and should include warnings against self-medicating.

The pre-distribution of KI also carries both benefits and risks. Benefits include immediate access to tablets in the event of an emergency requiring their use. People do not have to leave their homes or workplaces to receive them, which may place them in a situation of potential exposure or interfere with the implementation of other protective actions. However, people may lose or misplace their tablets and not have them available at the time of the emergency, or they may take them at inappropriate times.

7.1.3 Dosages

KI should be administered at the dosage levels specified by the World Health Organization (WHO, 1999). Public health authorities should ensure that instructions on how KI must be taken are clear and easily understood, as the correct dose of KI will differ according to age. Recommended age-specific dosages are given in Table 5. Administration of KI may be repeated in the event of prolonged or repeated exposure, however, newborns (less than 1 month) and pregnant and breastfeeding women should only receive 1 dose.

TABLE 5. Recommended single dosage of KI according to age group

AGE GROUP	RECOMMENDED QUANTITY OF ELEMENTAL IODINE (mg)[12]	CORRESPONDING DOSAGE OF POTASSIUM IODIDE (KI) (mg)
Adults and adolescents (over 12 years), including pregnant and breastfeeding women	100	130
Children (3–12 years)	50	65
Infants (1 month–3 years)	25	32
Newborns (< 1 month)	12.5	16

7.1.4 Endpoint

Administration of KI should cease when outdoor air no longer contains significant amounts of radioiodine, i.e. the dose to the thyroid from exposure to radioiodine is below the generic criteria.

7.2 Sheltering

Sheltering is using the structure of a building to reduce exposure from an airborne plume and/or radioactive material deposited on the ground (ICRP 2009). At a minimum, people told to shelter should stay inside, shut their windows and doors, turn off outside ventilation systems, and pay attention to messages from emergency authorities. It is recommended to shelter in the basement of a house or in the middle floors of a multistory building, away from the walls or roof.

7.2.1 Implementation

Sheltering can be an effective protective action over a short period of time but is not intended to be implemented for more than a couple of days. It should be considered as an option for situations where the risks associated with evacuation outweigh the benefits—for example, when road conditions are unsafe or when the radiological hazard is short-lived. In some cases, such as for hospitals and long-term care facilities, the requirement for sheltering is clear in advance and arrangements should be built into the protection strategy. In others, the decision to shelter may be made by authorities based on the prevailing conditions of the emergency. Sheltering may be initiated as a standalone measure or in conjunction with other protective actions such as ITB.

[12] A 65 milligram (mg) tablet of KI contains 50 mg of stable iodine.

Ideally, sheltering should be implemented prior to a release of radioactive material. Examples of when sheltering should be considered include:

- Releases consisting mainly of noble gases and/or short-lived radioisotopes;[13]
- Situations where an evacuation may be required but cannot be carried out prior to an expected release; or
- Situations where the risks of staying in place are assessed as lower than those from evacuation, when all hazards are considered (e.g., poor weather conditions or transporting critical care patients).

During the sheltering order, emergency response authorities should provide information about the situation and further instruction via established communication channels.

7.2.2 Risk/benefit considerations

Sheltering is considered less disruptive than other protective actions, such as evacuation, but leaves individuals in a situation of potential exposure to radiation. Although discomfort to individuals will increase with the length of time sheltering is in effect, the physical risks from sheltering are not likely to be significant.

The effectiveness of sheltering as a means of dose reduction depends on the building type, size, and construction materials. Examples of dose reduction factors from different building types can be found in IAEA EPR-NPP-PPA *Actions to Protect the Public in an Emergency due to Severe Conditions at a Light Water Reactor* (IAEA 2013), among other references.

It may be difficult for some populations (e.g., some patients in hospitals) to evacuate and therefore sheltering may be preferred. These types of vulnerable populations and the staff required to care for them should be identified in advance of an emergency, to the extent practicable, as workers may need to be designated and trained as off-site emergency workers.

7.2.3 Endpoint

A sheltering order should not extend beyond two days as this represents the maximum amount of time that people can usually be expected to remain indoors. Beyond that time, they may need to obtain provisions or to escape from a confining and stressful situation. If outdoor radiation levels are still high after two days, relocation should be considered.

After confirmation that the radioactive plume has passed and outdoor air concentrations have fallen, people should be instructed to open their windows and doors and re-establish ventilation to reduce airborne radioactivity that may be trapped inside.

7.3 Evacuation

Evacuation is urgent removal of a group of people from an area in order to reduce short-term exposure to radioactivity released during a nuclear emergency. Affected people are directed to leave an identified area or zone in an urgent but controlled manner for a limited period of time. Evacuation centres are established to provide temporary accommodations.

7.3.1 Implementation

Ideally, evacuation should be implemented prior to a release of radioactive materials as evacuation has the potential to avert most or all exposure to radiation if carried out in the pre-release stage of an event. Evacuation generally does not take place during the passage of a plume. In this case, sheltering is used as an interim measure, followed by evacuation if appropriate. Evacuation may be implemented during a release if it involves a small number of people, it can be performed safely, and the doses that would be received during the evacuation are lower than the doses that would be received if the individuals remained in place. If evacuation occurs during the release, arrangements should be made for population monitoring and medical management.

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[13] As long as the residual dose from all exposure pathways can be kept below the reference level, and the population is not required to shelter for more than two straight days.

7.3.2 Risk/benefit considerations

Evacuation is among the most disruptive of the protective actions. Risks and detriments to evacuees include transportation accidents, anxiety, separation of family members, and possible exposure to severe weather conditions or competing disasters. Evacuations also impact the communities that receive the evacuees. Finally, arrangements must be in place to ensure the safety and security of people for whom evacuation is unadvisable (including vulnerable populations) and of the infrastructure and property left behind.

Actions initiated in response to previous large-scale emergencies, such as weather events, demonstrate that evacuations of large numbers of people can take place quickly and safely. This is due, in part, to the existence of elaborate systems of expressways around most North American cities, together with traffic management arrangements and the fact that many people have access to automobiles, facilitating self-evacuation. Emergency planners must ensure that transportation is available for evacuees who do not have access to private vehicles and that these arrangements are communicated to these individuals in advance of a nuclear emergency.

In order to avoid the need to urgently displace people more than once in an emergency, evacuees should be directed to areas where contamination levels are expected to remain well below the OILs.

7.3.3 Endpoint

Evacuees should be allowed to return home when contamination in the affected area has been assessed as meeting the criteria for re-occupation. These criteria will include confirmation that there is no further threat of a release of radioactive material, that the situation that gave rise to the emergency is stable and that the residual dose to returning individuals will not exceed the upper limit of the ICRP's reference band for existing exposure situations (i.e., 20 mSv/y).

Seven days is considered to be the longest time that people can be lodged in temporary accommodations such as emergency evacuation centres. Therefore, monitoring and dose assessment to support decisions regarding re-occupation should be priority activities for responsible authorities. If the assessment of the situation indicates that the criteria for re-occupation will not be met for some time, displaced persons may require support to prepare for an extended absence from their home, including gathering important possessions or tending to animals.

7.4 Temporary Relocation

Temporary relocation is the non-urgent removal of a group of people from an area in order to avoid longer-term exposure to contamination on the ground. By comparison, evacuation is the urgent removal of people in order to reduce short-term radiation exposure (threatened or actual). Evacuation may transition into temporary relocation if post-release monitoring indicates that immediate re-occupation is not possible.

Orders for temporary relocation may be in place for months or longer. Temporary relocation should transition into **permanent resettlement** if detailed assessments indicate that re-occupation will not be possible within a year.

7.4.1 Implementation

The decision to temporarily relocate people should be made based on monitoring data collected following the release of radioactivity. In order to facilitate timely decisions, protection strategies should include plans and mechanisms for establishing monitoring priorities, sharing monitoring data, and interpreting results in the context of protective actions.

Over time, as people are relocated from the most contaminated areas, the generic criteria and the OIL for temporary relocation should decrease in a step-wise manner until the annual residual dose to the remaining population will not exceed the upper limit of ICRP's reference band for existing exposure situations (20 mSv/y).

In areas where the ambient dose rates are above $OIL2_{\gamma}$ but below $OIL1_{\gamma}$, authorities may allow residents to take some time (in the order of a few days) to prepare for a prolonged absence.

7.4.2 Risk/benefit considerations

As with evacuation, temporary relocation is a highly disruptive protective action, but the extended time frame usually allows it to be conducted in a more orderly and controlled manner than evacuation. The physical risk of temporary relocation is thereby lower but the stress and anxiety may still be high because individuals find themselves in a transitory situation for an uncertain period of time. The economic costs are also significant as it disrupts normal economic and social activity in the contaminated areas. Planning for temporary relocation should include arrangements for alternate accommodations for the displaced population and for integrating them into new communities, schools and other social services. It may also involve relocating or compensating businesses and factories.

7.4.3 Endpoint

The time period for temporary relocation is variable. As time progresses, more accurate dose assessments will become available. If radiological conditions require that the period of temporary relocation extend beyond one year, then the relocation may be in the process of becoming permanent. In addition to the radiological conditions, decisions on returning populations to their residences following temporary relocation or undertaking permanent resettlement will require thorough consideration of many socio-economic factors and engagement with the affected communities.

7.5 Restriction of distribution and ingestion of potentially contaminated drinking water, milk and other foods and beverages

To prevent or reduce doses arising from consuming contaminated foodstuffs, restrictions should be placed on drinking water, milk and other foods and beverages that may have been contaminated. These restrictions apply to foodstuffs that may have been contaminated with radioactive material at the time of the emergency or that continue to be produced in contaminated areas. It should be noted that foodstuffs that were protected during the emergency such that they could not have become contaminated (e.g., packaged foodstuffs, foodstuffs stored in the pantry, fridge or freezer) would likely still be considered safe for consumption. To determine whether the drinking water, milk and other foods and beverages are suitable for international trade, the guidance values provided by the Codex Alimentarius Commission (Codex, 2010) should be consulted and will be referred to in the event of trade disputes regarding differences in national guidelines.

7.5.1 Implementation

Actions to prevent consumption of drinking water, milk and other foods and beverages, and to prevent contaminated food from entering the distribution system, should begin with the onset of the emergency. Measures to protect food and water from contamination, such as moving grazing animals inside and placing them on uncontaminated feed, should also be considered if the prevailing circumstances allow.

Further constraints should be implemented based on monitoring data collected following the release of radioactivity, beginning with dose rates measured from the ground (as per $OIL3_{\gamma}$), followed by more detailed laboratory measurements. In order to facilitate timely decisions, protection strategies should include plans and mechanisms for establishing monitoring priorities, sharing monitoring data and interpreting results in the context of protective actions.

Arrangements may need to be made to replace essential commodities, such as drinking water and some country foods.

7.5.2 Risk/benefit considerations

IAEA (2013) states that restrictions should not be applied if they could result in malnutrition or other health consequences. This is not likely going to be an issue in most parts of Canada, where the fraction of locally grown and consumed food is quite small; however, special measures may need to be implemented if remote communities are affected.

Restrictions may be in place for extended periods of time. In addition to immediate contamination through deposition, radioactivity may be transported into foodstuffs through a variety of environmental pathways, such as uptake by plants growing in contaminated soil, ingestion of contaminated forage by livestock or bioaccumulation higher in the food chain (e.g., in fish). Therefore, sampling and analysis programs should be prepared to operate throughout the transition to recovery and possibly for even longer.

7.5.3 Endpoint

Restrictions should remain in place as long as sampling and analysis indicates levels of radioactive contamination above OILs 5 and 6. The process of lifting restrictions on distribution and ingestion of potentially contaminated drinking water, milk and other foods and beverages may also be dependent on other socio-economic factors, such as international trade concerns. These types of restrictions could extend for many years, potentially into the recovery stage.

7.6 Personal decontamination

Personal decontamination is the physical removal or reduction of external radioactive contamination on an individual.[14] It may involve the removal of contaminated clothing, showering, or other types of washing. Measures to reduce internal contamination levels are addressed in Section 7.7.

7.6.1 Implementation

Personal decontamination for the purposes of health protection should be available for individuals who are at risk of being significantly contaminated, such as might be the case if protection strategies fail. The decision to attempt decontamination *in situ* should be based on knowledge of the exposure scenario and contamination levels identified on the affected individual(s). If skin contamination is the primary concern, prompt decontamination should be the priority.

When personal decontamination is carried out, contaminated clothing should be removed and contaminated skin washed, repeatedly if necessary. Authorities should plan to establish decontamination-sites in uncontaminated areas near where adequate showering facilities are available. If such a site cannot be established in a timely manner, facilities and supplies to support alternative decontamination methods, such as disrobing and/or washing with a wet cloth, should be made available.

Self-decontamination is not appropriate for individuals who exceed $OIL4_{\gamma}$.

7.6.2 Risk/benefit considerations

Risks associated with personal decontamination include the risk of inadvertently spreading contamination to personnel, facilities, equipment, or parts of the body that weren't contaminated before. Proper decontamination protocols and pre-designated, trained staff are essential to minimizing cross-contamination.

Additional considerations for decontamination include how to decontaminate vulnerable populations such as children or people with disabilities as well as considerations for social or cultural requirements related to privacy.

Internal contamination assessment is required for those who are suspected of having internal contamination with radioactive material, in order to identify the radionuclide(s) and quantify the intake. Protection strategies should include arrangements to ensure that this type of follow-up is available if it is required.

Internal assessment techniques, such as bioassay, provide an accurate estimate of internal exposure but require urine and/or faecal samples to be collected soon after exposure and sent to specialised laboratories for analysis. Techniques to measure radioactivity directly in exposed individuals (*in vivo*) include thyroid measurements as well as lung and whole body counting.

7.6.3 Endpoint

Personal decontamination can stop when measured skin levels are below $OIL4_{\gamma}$, or when repeat washings become ineffective.

If the measurement of radioactive contamination remains elevated after several attempts at decontamination, or if the exposure scenario suggests that internal contamination is likely, the individual should undergo internal contamination assessment and should be considered for medical follow-up. Even if external measurements drop to below $OIL4_{\gamma}$ after decontamination, authorities and public health officials should consider whether further assessment is necessary, based on the exposure scenario.

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[14] Decontaminating the affected area and infrastructure is considered part of the recovery stage and is outside the scope of this document.

7.7 Medical Follow-Up

Medical follow-up is the process of registering patients who have received significant exposures and/or intakes, documenting them, treating internal contamination if appropriate, and implementing a long-term surveillance plan to detect and effectively treat radiation-induced health effects. Treatment of internal contamination may involve the administration of different agents to prevent the uptake, reduce the absorption or increase the excretion of radioactive material from the body.

7.7.1 Implementation

The registration of individuals suspected to have received significant doses as early as is feasible in the emergency response is extremely important to identify people who may require medical follow-up.

Treatment of internal contamination should occur as soon as possible following the intake of radiation in order to be effective; however, any treatment should only be considered upon the advice of a qualified medical professional.

7.7.2 Risk/benefit considerations

Considerations for the treatment of internal contamination include cases where the use of a certain agent is contraindicated or may not be beneficial if too much time has passed. Treatment of internal contamination may not be possible in all cases. Medical follow-up may continue over a long period of time and be costly. This should be considered during the preparedness stage.

7.7.3 Endpoint

The various aspects of medical follow-up can occur over different time-frames. The registration of individuals should continue at least until all individuals who exceed the generic criterion for medical follow-up have been identified and their information collected.[15] Any individuals with internal contamination should participate in medical follow-up to the extent possible. If future follow-up to detect and effectively treat radiation-induced health effects is implemented, it may continue for many years, potentially for the lifetime of any individuals to which it applies.

7.8 Restriction of activities for off-site workers

This protective action protects individual workers by removing them from active duty in contaminated areas once they have exceeded the generic criterion for off-site workers.

7.8.1 Implementation

Off-site emergency workers should be clearly and comprehensively informed in advance of the potential health risks of radiation exposure.

This protective action is implemented based on measured doses to workers. In order to reduce the likelihood that individual workers will exceed this generic criterion, authorities should ensure that effective dose management practices are in place, including all necessary training and equipment. Doses from intake or skin contamination should be avoided by taking preventive measures, such as wearing appropriate **personal protective equipment** (PPE). In circumstances where workers might be exposed to radioactive iodine, ITB should also be considered.

External exposure should be monitored using personal dosimeters calibrated to measure personal dose equivalent at 10mm ($H_p(10)$). A supply of dosimeters, ideally from a licensed dosimetry service provider, should be maintained, regularly tested and calibrated so that they are ready for use during a nuclear emergency.

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[15] For epidemiological purposes, authorities may consider expanding the registry to include exposure data from more than just individuals who require follow-up for medical reasons.

The doses received by emergency workers should be recorded and reported to the workers along with any information concerning the consequent health risks (IAEA 2014).

Administrative controls, such as **turn-back limits**, **stay times** and appropriate PPE and contamination control procedures, should be implemented as part of dose management.

Further details on the planning requirements for off-site emergency workers are available in IAEA GSR Part 7: *Preparedness and Response for a Nuclear or Radiological Emergency* (IAEA 2015a) and CSA N1600-16: *General requirements for nuclear emergency management programs* (CSA 2016).

7.8.2 Risk/benefit considerations

Appropriate PPE should be worn when there is a risk of internal contamination and/or skin contamination. However, wearing PPE may increase non-radiological risks, such as heat stress or errors caused by limited visibility. These risks should be managed by on-site health and safety personnel.

Some workers may receive dose outside of work hours if they live in the affected area. In these cases, dose to individuals from all exposure scenarios should be assessed and managed so that is does not exceed the reference level for the emergency.

7.8.3 Endpoint

Restrictions on activities of individual workers who have exceeded the generic criteria should remain in effect for the duration of the emergency response.

APPENDIX A: ACRONYMS AND ABBREVIATIONS

Bq	becquerel
CANDU	Canada Deuterium Uranium
CNSC	Canadian Nuclear Safety Commission
CSA	Canadian Standards Association
E	effective dose
FERP	Federal Emergency Response Plan
FNEP	Federal Nuclear Emergency Plan
GSR	General Safety Requirements (IAEA)
***H**(10)**	ambient equivalent dose at 10mm depth
$H_p(10)$	personal equivalent dose at 10mm depth
H_{fetus}	equivalent dose to the fetus
$H_{thyroid}$	equivalent dose to the thyroid
HC	Health Canada
IAEA	International Atomic Energy Agency
ICRP	International Commission on Radiological Protection
ICRU	International Commission on Radiation Units & Measurement
ITB	Iodine Thyroid Blocking
KI	Potassium Iodide
LWR	Light Water Reactor
MAC	Maximum Acceptable Concentration
mSv	millisievert
NEF	Nuclear Emergency Function
OECD	Organisation for Economic Cooperation and Development
OIL	Operational Intervention Level
PHWR	Pressurized Heavy Water Reactor
PPE	Personal Protective Equipment
RDD	Radiological Dispersal Device
Sv	sievert
µSv/h	microsievert
WHO	World Health Organization

APPENDIX B: GLOSSARY

Absorbed Dose: A dose quantity that describes the radiation energy imparted to matter.

Ambient Dose Equivalent ($H^*(d)$): An operational environmental measurement quantity for strongly penetrating radiation. It is a measurement of the dose equivalent that would be produced by a uniform and unidirectional radiation field in the ICRU tissue equivalent sphere at depth d (ICRU, 1988). Typically set for a tissue depth of d = 10mm.

Averted Dose: The dose that can be avoided by the implementation of protective actions.

Committed Dose: Dose from radionuclide intakes (internal contamination). Radionuclides incorporated in the human body irradiate the tissues over time periods determined by their physical half-life and their biological retention within the body. The committed dose from an incorporated radionuclide is the total dose expected to be delivered within a specified time period. The committed *equivalent* dose is the committed dose to a tissue or organ. The committed *effective* dose is the product of the committed equivalent dose and the tissue weighting factor, summed for all tissues and organs in the body that are considered to be sensitive to the induction of stochastic effects. ICRP recommends a commitment period of 50 years for adults and 70 years for infants and children (adapted from ICRP 2007).

Dose Management: Includes administrative controls to limit doses, monitor doses and record doses received by emergency workers while fulfilling their duties related to nuclear emergency response (or other individuals to whom dose management may be applicable).

Effective Dose: Calculated as the product of the equivalent dose in a tissue and the tissue weighting factor, summed for all tissues and organs in the human body that are considered to be sensitive to the induction of stochastic effects. Typically used to represent whole body dose.

Emergency Planning Zones: Areas in which implementation of operational and protective actions are or might be required during a nuclear emergency, in order to protect public health, safety, and the environment (CSA 2016).

Equivalent Dose: A measure of radiation dose to a specific tissue, taking into account the relative biological effectiveness of the type of ionizing radiation and calculated by multiplying the **absorbed dose** to the organ with the radiation weighting factor.

Evacuation: In this document, evacuation is a directed protective action for the controlled displacement of the population from an area which has been or might become contaminated by radioactive substances to avoid exposure (from CSA 2016).

Generic Criteria: Dose levels at which protective actions should be taken. These are also the values used in the derivation of the OILs.

Inadvertent Ingestion: Unintentional ingestion of radionuclides as a result of eating, drinking or smoking with contamination on the hands.

Medical Follow-Up: The process of registration and documentation of individuals' exposures and intakes, treatment of internal contamination, if appropriate, and future follow-up to detect and effectively treat radiation-induced health effects.

Nuclear Emergency: A non-routine situation that necessitates prompt action to mitigate a radiological hazard which could result in adverse consequences for human health and safety, quality of life, property or the environment (ICRP 2007). In this document, the term nuclear emergency is used to refer to both nuclear and radiological emergencies.

Off-Site Emergency Worker: A person having specified duties as a worker in response to a nuclear emergency who: is required to remain in or enter areas affected or likely to be affected by radiation from an accident; might be exposed while performing his/her duties; and for whom special safety arrangements are required. This may include police officers, firefighters, medical personnel, drivers and crews of evacuation vehicles and field teams.

Operational Intervention Level: A calculated or derived quantity that corresponds to a generic criterion and above which a specific protective action is generally justified. Environmental measurements, measurements of contamination levels among affected populations and/or laboratory measurements can be directly compared to the OILs.

Permanent Resettlement: Permanent relocation of the population to a new location if their home environments are contaminated above acceptable limits and decontamination efforts are not able to restore them to habitable conditions.

Personal Dose Equivalent (H_p(d)): An operational quantity for individual monitoring . The dose equivalent in soft tissue (ICRU sphere) below a specified point on the body at an appropriate depth (d). For deep organs and the control of effective dose, a depth of 10 mm is used (ICRU, 1988).

Personal Protective Equipment: Clothing or other specialised equipment designed to prevent or reduce exposure to radioactive material.

Population Monitoring: The measurement of radioactive contamination on or in people who may have been exposed as a result of a nuclear emergency.

Potassium Iodide (KI): Substance containing stable iodine used to prevent or reduce the uptake of radioactive iodine (radioiodine) by the thyroid. Typically comes in tablet/pill form for ingestion. KI is an example of an iodine thyroid blocking agent.

Projected Dose: The dose that would be expected to be received as a result of an emergency exposure situation if planned protective actions were not taken.

Protective Action: A measure taken to reduce radiation doses which could be incurred by the population or off-site emergency workers as a result of a nuclear emergency. It is sometimes called countermeasure or protective measure (adapted from CSA 2016). In this document, it should be understood that references to implementing protective actions include the implementation of associated response actions, such as notification.

Protection Strategy: A protection strategy describes what needs to be done and how it will get done in order to achieve the goals of a nuclear emergency response, in consideration of all of the risks, constraints, and other factors that will need to be managed.

Radioactive Material: Nuclear substances as defined in the *Nuclear Safety and Control Act* (2000).

Reference Level: The level of dose above which it is judged inappropriate to allow exposures to occur, and below which optimisation of protection should be implemented. For emergency exposure situations the reference level recommended by the ICRP is 20 mSv–100 mSv (ICRP 2007). In this document, generic criteria and OILs are set for the upper bound of this band.

Representative Person: An individual that, due to his/her characteristics, habits and location of residence, is representative of the more highly exposed individuals in the population.

Residual Dose: The dose that is expected to be received after the planned protective actions have been implemented. It is the effective dose from all exposure pathways remaining after the implementation of an optimised protection strategy, and is the quantity that is compared with the appropriate reference level when selecting and assessing protection strategies. It can be assessed by estimating the exposure during emergency response planning (e.g., as the difference between the projected dose and the dose averted by implementing a protective measure or combination of protective measures), or by measuring and/or calculating the actual dose after an emergency exposure situation has occurred. (ICRP 2009)

Severe deterministic injuries: This term refers to injuries that are directly attributable to high levels of radiation exposure, irreversible in nature, and which severely impair the quality of life of individuals (ICRP 2009). This is a subset of tissue reactions.

Sheltering: A directed protective action to take immediate refuge in an enclosed structure for protection from an airborne plume, deposited radionuclides, or both (CSA 2016).

Stable Iodine Thyroid Blocking: Administration of stable iodine to block the uptake of inhaled or ingested radioiodines into the thyroid gland. Also referred to as Iodine Thyroid Blocking.

Stay Times: The calculated maximum amount of time a worker can remain in an area at a given ambient dose rate without surpassing a specified dose level.

Stochastic Effects: Radiation-induced health effects, such as cancer and heritable diseases, which are associated with a statistical risk and where no threshold has been established. The probability of occurrence is proportional to the dose (the higher the dose, the higher the probability of occurrence) but the severity of the effect is independent of dose.

Temporary Relocation: The non-urgent removal or extended exclusion of people from a contaminated area to avoid chronic exposure, for a finite period (up to a year or two, as long as eventual return is foreseeable). Temporary relocation may be a continuation of the urgent protective action of evacuation (IAEA 2007).

Tissue Reactions: Radiation-induced health effects including changes to cells and tissues that are certain to occur in an individual exposed to a radiation dose greater than some threshold dose, with a severity that increases with increasing dose. (ICRP 2012a).

Turn-Back Limit: A pre-determined dose rate used to manage exposure in a contaminated area. When an off-site emergency worker finds themselves in a field that exceeds the turn-back limit, they should automatically leave the area.

APPENDIX C: OVERVIEW OF EMERGENCY MANAGEMENT IN CANADA

It is important to place this document in the context of overall emergency management in Canada. *An Emergency Framework for Canada* (PS 2017) states that emergency management is comprised of four interdependent components (also referred to as the four pillars of emergency management[16]) which can be described as follows (PS 2017; OECD 2010):

- **Prevention and Mitigation:** Actions to prevent the occurrence or reduce the impact of a potential accident.
- **Preparedness:** Actions taken in the preparedness stage in order to be ready to respond to an emergency. Includes assessing potential threats and risks, and developing related plans, procedures and capabilities.
- **Response:** Actions taken in the response stage when there is an emergency. Includes response initiation, crisis management, consequence management and transition to recovery.
- **Recovery:** Actions taken after a disaster to repair or restore conditions to an acceptable level. This may include transitioning to a new normal. Long-term rehabilitation and capturing lessons learned are also part of recovery.

Although this document is not relevant to the prevention and mitigation of nuclear emergencies, it will be useful for emergency response authorities involved in nuclear emergency preparedness and response. Furthermore, while it does not deal specifically with recovery, some of the recommendations for protective actions implemented during the emergency response stage, such as temporary relocation and the restriction of distribution and ingestion of potentially contaminated drinking water and foods, may continue to apply while communities transition out of the emergency and into a longer-term exposure situation.

C1. Roles and Responsibilities Related to Nuclear Emergency Preparedness and Response in Canada

The preparedness for and response to a nuclear emergency in Canada is a multi-jurisdictional responsibility shared by all levels of government; however, provincial and territorial governments have the primary responsibility for protecting public health and safety, property and the environment within their borders. Provincial and territorial governments are responsible for decisions on protective actions, including the development and application of relevant criteria for decision-making. The occupational health and safety of off-site emergency workers is the responsibility of their individual employers, as outlined in the *Canada Labour Code* (1985) and/or relevant provincial legislation.

Federally, the Government of Canada's all-hazard *Federal Emergency Response Plan* (FERP) outlines the processes and mechanisms to facilitate an integrated Government of Canada response to an emergency (PS 2011b). It is designed to harmonize federal emergency response efforts with those of the provincial and territorial governments, non-governmental organizations and the private sector. The *Federal Nuclear Emergency Plan* (FNEP) is an event-specific annex to the FERP (HC 2014a). The FNEP provides the supplemental multi-departmental and inter-jurisdictional arrangements necessary to address the scientific and technical aspects of the response to a nuclear emergency. In addition to specific federal responsibilities, the federal government, under the FNEP, coordinates with and provides support to the provinces and territories in their response to a nuclear emergency. Health Canada is responsible for administration of the FNEP.

Pursuant to the *Nuclear Safety and Control Act* (2000), the operators of nuclear power plants are responsible for on-site emergency management, including the occupational health and safety of on-site emergency workers, as regulated by the Canadian Nuclear Safety Commission (CNSC). Foreign nuclear-powered or nuclear-capable vessels invited into Canada are specifically excluded under the Section 6 of the *Nuclear Safety and Control Act* (2000). Protection of on-site emergency workers at ports visited by such foreign vessels is outlined in the *Nuclear Safety Orders and Directives* (2009) issued under the authority of the Director Nuclear Safety pursuant to the Department of National Defence *Defence Administrative Orders and Directive 4002-0 Nuclear Technology Regulation and Control* (DND 2000).

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[16] Some jurisdictions refer to the five pillars of emergency management, as prevention and mitigation are considered as two separate pillars (EMO, 2010).

C2. Roles and Responsibilities Related to Food Safety in Canada

Food safety in Canada is a multi-jurisdictional responsibility shared by all levels of government. As a component of nuclear emergency preparedness and response, provincial, territorial and municipal governments have the primary responsibility for decisions on protective actions in the affected area related to food safety.

Under the *Food and Drugs Act* (1985), the Government of Canada has a responsibility for the safety of all domestic and imported food offered for sale within Canada. Health Canada is responsible for establishing standards for the safety and nutritional quality of all foods sold in Canada. Once food products have left the affected area, or if food is imported from an affected area abroad, the Canadian Food Inspection Agency is responsible for enforcing the food safety standards and guidelines established by Health Canada, which may include taking regulatory actions such as product recalls. The federal government can also provide support to the provinces, territories and municipalities in their food safety related actions.

The principal responsibility for ensuring the safety of drinking water rests with the provinces and territories, while municipalities usually ensure the day-to-day operations of treatment facilities and distribution systems. Health Canada worked with the provinces and territories to develop the *Guidelines for Canadian Drinking Water Quality* (HC 2014b). These guidelines are used by each province and territory, as well as by the federal government, as a basis to establish their own requirements for drinking water quality. This would include the development and implementation of regulations, as well as decisions regarding drinking water treatment and distribution. Health Canada also provides drinking water guidance to federal, provincial and territorial departments upon request.

APPENDIX D: RECOMMENDATIONS FROM OTHER AGENCIES

In the time since Health Canada published the *Canadian Guidelines for the Restriction of Radioactively Contaminated Food and Water Following a Nuclear Emergency* (2000) and the *Canadian Guidelines for Intervention During a Nuclear Emergency* (2003), there have been updates in the international and national guidance which are relevant to radiological protection in a nuclear emergency.

This appendix compares the recommendations in this document to the current IAEA guidance, as well as to criteria established in other countries.

D1. Generic criteria compared to IAEA

TABLE 6. Health Canada's recommended generic criteria compared to IAEA recommendations

PROTECTIVE ACTIONS	GENERIC CRITERIA (HC 2017)	GENERIC CRITERIA (IAEA 2015a)
Stable iodine thyroid blocking	50 mSv in the first 7 days ($H_{thyroid}$)	50 mSv in the first 7 days ($H_{thyroid}$)
Evacuation	100 mSv in the first 7 days (E or H_{fetus}))	100 mSv in the first 7 days (E or H_{fetus}))
Temporary relocation (starting point, see text)	100 mSv in the first year (E) or 100 mSv for the full period of in utero development (H_{fetus})	100 mSv in the first year (E) or 100 mSv for the full period of in utero development (H_{fetus})
Sheltering	10 mSv in the first 2 days (E)	—
Restriction of distribution and ingestion of potentially contaminated drinking water,[17] milk and other foods	3 mSv/y (E) (1 mSv/year for each of the following categories: drinking water, milk and other foods and beverages)	10 mSv/year (E)
Medical follow-up	100 mSv in one month (E) or 100 mSv for the full period of in utero development (H_{fetus})	100 mSv in one month (E) or 100 mSv for the full period of in utero development (H_{fetus})
Restriction of activities for off-site emergency workers	50 mSv over the duration of the response, except in exceptional circumstances ($H_p(10)$ or E)	100 mSv over the duration of the response, except in exceptional circumstances ($H_p(10)$ or E)

In most cases, Health Canada has adopted the IAEA values. Exceptions are explained below.

- Health Canada has adopted a lower dose level for ingestion controls because the lower threshold is considered reasonably achievable in the Canadian context, given the ready availability of alternative sources of food and water in those areas most likely to be impacted by a significant release of radioactivity.

[17] From water supplies that could include contaminated rainwater or contaminated surface water.

- Health Canada has maintained the practice of having a separate generic criteria for sheltering, primarily in order to accommodate the current needs of some Canadian organizations. It corresponds to two days at the daily intervention level recommended in the previous edition of the Guidelines (HC 2003).

D2. OILs compared to IAEA

TABLE 7. Health Canada recommended OILs compared to IAEA recommendations

OIL#	PROTECTIVE ACTION	OIL (HC 2017)	OIL (IAEA 2015a)
Exposure control			
1_{γ}	Evacuation	1000 µSv/h	1000 µSv/h
2_{γ}	Temporary relocation	100 µSv/h	100 µSv/h
		25 µSv/h	25 µSv/h
Ingestion control			
3_{γ}	Restriction of distribution and ingestion of potentially contaminated drinking water, milk and other food	1 µSv/h	1 µSv/h
5_{α}		See Table 4	–
$5_{ß}$		See Table 4	–
6		See Table 12	–
7		–	I-131: 1000 Bq/kg Cs-137: 200 Bq/kg
Population monitoring and medical management			
4_{γ}	Personal decontamination and/or medical follow-up	1 µSv/h	1 µSv/h See also OIL8
8_{γ}		–	0.5 µSv/h above background

In most cases, Health Canada has adopted the IAEA values. Exceptions are explained below.

- Health Canada has not adopted IAEA's OIL7. This OIL is calculated so that food and water can be efficiently screened using measurements of marker radionuclides (Cs-137 and I-131). It is based on the estimated ratios of radionuclides in a release from an accident at a nuclear power plant. Health Canada has not included it in our recommendations because it is not appropriate for all categories of emergency that are addressed in the FNEP. Instead, we have retained and expanded upon the radionuclide-specific activity concentrations presented in *Canadian Guidelines for the Restriction of Radioactively Contaminated Food and Water Following a Nuclear Emergency* (HC2000). Canadian specific ingestion data was used to inform the OIL calculations (HC 1993; HC 2011; HWC 1976).
- Thyroid monitoring is an essential activity if radioiodine exposure is suspected. However, Health Canada has not adopted IAEA's OIL8 and recommends that thyroid monitoring and dosimetry be carried out, when required, by specialists in internal assessment.

D3. Other countries

Table 8 compares recommendations in this document with generic criteria adopted by other countries. The list is not comprehensive; rather, it represents a selection of nations with nuclear power plants who have updated their guidance since the Fukushima accident.

TABLE 8. Examples of generic criteria adopted internationally. Checkmarks indicate that the criterion matches the recommendation from Health Canada.

PROTECTIVE ACTION	HEALTH CANADA (2017)	IAEA (2015a)	US EPA (2016/17)	SECRÉTARIAT GÉNÉRAL DE LA DÉFENSE ET DE LA SÉCURITÉ NATIONALE (FRANCE) (SGDSN 2014)	BUNDESAMT FÜR STRAHLENSHUTZ (BfS 2014)	NORDIC GUIDELINES[18] (2014)
ITB	50 mSv	✓	✓	✓	50 mSv for children <18 and pregnant women, and 250 mSv for people aged 18–45	50 mGy (dose to adult) or 10 mGy (dose to child)
Evacuation	100 mSv/7d	✓	10–50 mSv/4d	✓	✓	20 mSv/7d
Sheltering	10 mSv/2d	Considered with evacuation criteria	Considered with evacuation criteria	✓	10 mSv/7d	✓
Restriction on food and drinking water	1 mSv/y for each category: food, milk, drinking water	10 mSv/y All categories	5 mSv/y for food, 1 mSv/y for drinking water	–	–	–
Temporary Relocation	100, dropping to 20 mSv/y	✓	<20 mSv/y	–	–	–

D4. Summary

The generic criteria adopted by Canada are generally in line with both international and other nation- or agency-specific generic criteria. Some differences may arise due to differing definitions of protective actions and the ways in which they are carried out, as well as country-specific conditions that may affect the level of conservatism that is justifiable, optimal and/or practical.

[18] The Nordic countries who have agreed to the guidelines are Denmark, Finland, Iceland, Norway, and Sweden.

APPENDIX E: OIL CALCULATIONS FOR ENVIRONMENTAL MEASUREMENTS

The default values for OILs 1_γ and 2_γ recommended in this document are based on the default OIL values for ground monitoring that are provided by the IAEA to protect the public in an emergency involving a severe release of radioactive material from a light water reactor (LWR) or its spent fuel (IAEA OIL). Work is underway internationally to recalculate these OILs specifically for pressurized heavy water reactors (PHWR), also known as CANDU reactors; however, preliminary assessments indicate that the values will not change. Therefore, the default OILs for environmental measurements presented in Table 3 are considered appropriate for severe releases of radioactive material from nuclear reactors, including most emergencies in the following FNEP categories:

- Category A: An emergency at a nuclear power plant in Canada (or involving a Chalk River Laboratories reactor);
- Category B: An emergency at a nuclear power plant in the United States or Mexico;
- Category C: An emergency involving a nuclear-powered vessel in Canada; and
- Category E: A nuclear emergency outside of North America (if this concerns a reactor emergency).[19]

The default OILs for environmental measurements may not be appropriate for emergencies involving other sources of radioactivity (primarily FNEP Category D and some scenarios in Category E). In these cases, OILs may need to be recalculated taking context-specific conditions or assumptions into account. Due to the wide range of possible scenarios for non-reactor emergencies, this document will not provide a detailed approach to such calculations, although some considerations are discussed briefly at the end of this appendix.

E1. Overview of OIL Calculations for Evacuation and Temporary Relocation

All considerations and assumptions used by the IAEA in deriving default OILs for evacuation and temporary relocation have been adopted by Health Canada. As a result, default OIL values are the same. While it is out of scope of this document to detail the IAEA derivations in full, a general overview is provided. (For details on the complete derivations, please refer to (IAEA 2017).)

IAEA performed OIL calculations for 19 mixes of radionuclides. These mixes reflect potential releases that could occur from a LWR or its spent fuel during a severe emergency and include radionuclides that may significantly contribute to dose received by members of the public and/or affect instrument response. For each mix, OILs were determined for multiple time points over which the dose was projected. The final OIL was chosen such that it would be protective for all mixes at all relevant points in time for when the measurement should be taken. This is demonstrated in Figures 1 and 2.

[19] In the case of events abroad, this document will be considered when providing advice to Canadians in affected areas, in light of protective actions taken by the relevant local authorities and the recommendations of the international community.

FIGURE 1. $OIL1_\gamma$ (t,mix) functions (for evacuation) and default $OIL1_\gamma$ value (in red).

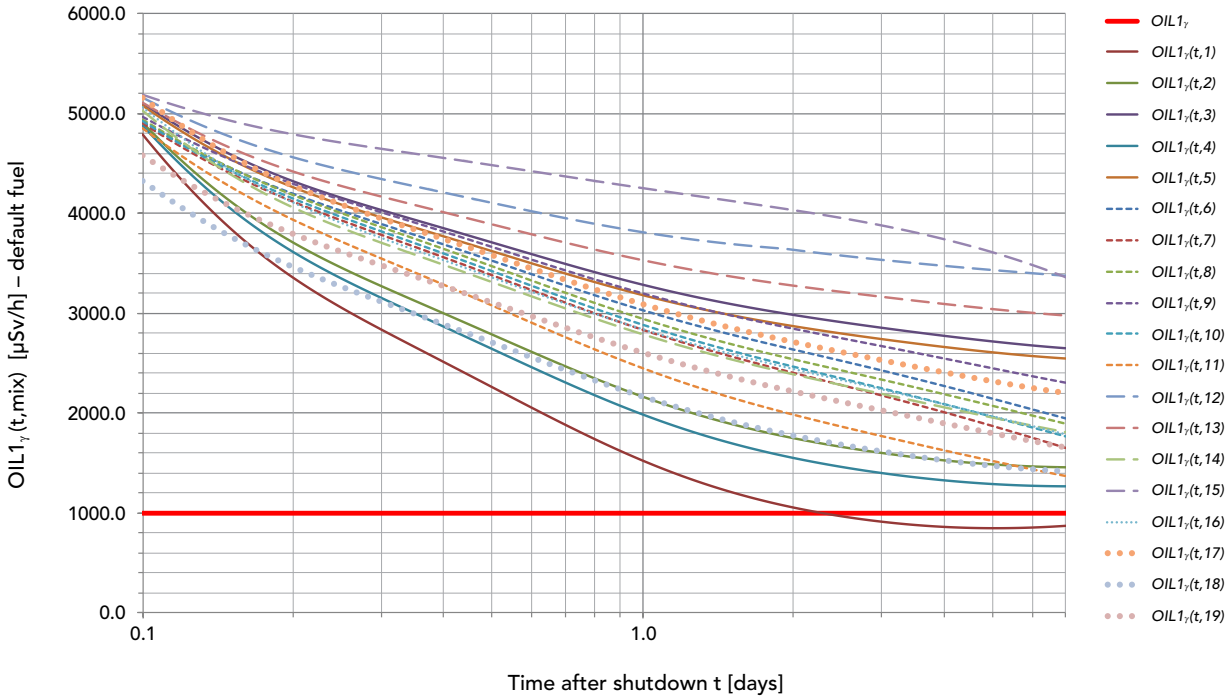
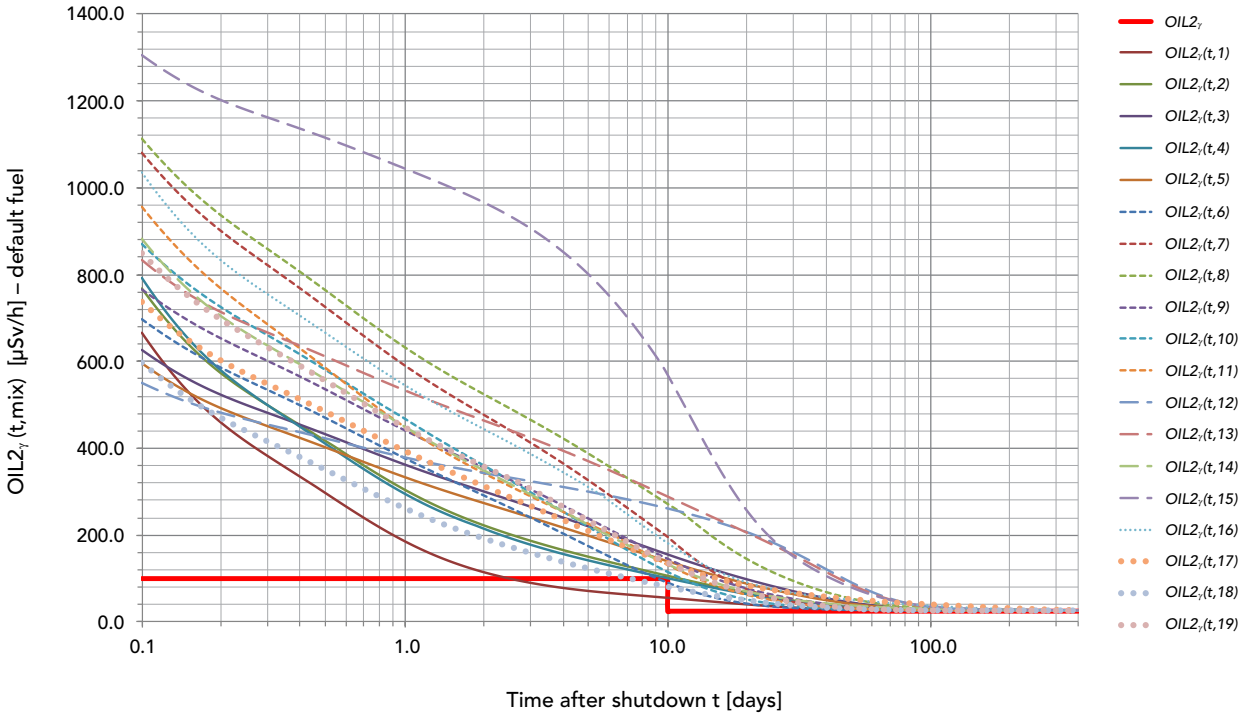


FIGURE 2. $OIL2_\gamma$ (t,mix) functions (for temporary relocation) and default $OIL2_\gamma$ value (in red).



The essential components of IAEA's approach to deriving default OILs for ground measurement are summarized in the equation below.

$$\text{OIL(t,mix) (μSv/h)} = \left[\text{Calculated}^{*} \text{ gross activity on the ground (Bq/m}^2\text{)}\right] \times \left[\text{Ambient dose equivalent rate per unit activity (μSv/h)/(Bq/m}^2\text{)}\right] \times \left[\text{Weighting factor to avoid implementation of unwarranted actions (unitless)}\right]$$

* This is a calculated value for ground deposition that will lead to an effective dose equal to the generic criteria

The calculation for gross activity on the ground considered several factors, of which some primary examples include:

- Most sensitive populations (infants, fetus)
- Decay and ingrowth of radionuclides/progeny
- Dose from groundshine
- Dose from air shine due to resuspended ground deposition
- Dose from inhalation of resuspended ground deposition
- Dose from inadvertent ingestion
- Ground roughness
- Weathering
- Shielding and occupancy factors for homes

The value for ambient dose equivalent rate per unit activity also accounted for the following:

- Ground roughness
- Effective to ambient dose rate correction factor

The weighting factor used to avoid implementation of unwarranted response actions is included to help ensure that resources are best used to protect those at highest risk.

For completeness, the summary equation is restated below so that it more closely reflects how it is presented by the IAEA (IAEA 2017):

$$OIL_{\gamma}(t,mix) = (\sum_i (RA_i(t,mix) \times H^{*}_{grd-sh,i})) \times WF_{OIL_{\gamma}} \times UC \times DA_{OIL}(t,mix)$$

Where:

- t [s] is the time after shutdown of the reactor (i.e. after the fuel was last irradiated in a reactor).
- 'mix' refers to the radionuclide mix, or postulated core to containment release scenario, for a LWR.
- $RA_i(t,mix)$ [unitless] is the relative activity of radionuclide i at time t after reactor shutdown for a specific radionuclide mix.
- $H^{*}_{grd-sh,i}$ [(Sv/s)/(Bq/m^2)] is the ambient dose equivalent rate at 1 m above ground level, per unit ground surface activity of radionuclide i.
- $WF_{OIL\gamma}$ = [unitless] is a weighting factor used to avoid the implementation of unwarranted response actions based on the default OIL_{γ} value.

- UC = 3.6E+09 (μSv/h)/(Sv/s) is the unit conversion factor from Sv/s to μSv/h.
- $DA_{OIL}(t,mix)$ [Bq/m^2] is the derived gross activity on the ground at time t after reactor shutdown, which, for the 'ground' scenario, results in any of the generic criteria specified for the OIL_γ being met, for a specific radionuclide mix.

For further details on derivations of the terms in the above equation, in addition to values and assumptions used, please refer to (IAEA 2017).

E2. OILs for other emergencies

If the assumptions outlined in the previous section do not hold for a particular emergency scenario, there is a risk that the default values for $OIL1_\gamma$ and $OIL2_\gamma$ recommended in these guidelines will not be a good basis for taking protective actions. This is potentially of concern with respect to scenarios that fall into FNEP Category D, or "other" radionuclear events. The generic criteria and protection strategies would remain the same; however, measured values might over- or under-estimate projected dose, particularly if the mix and behaviour of radionuclides differ from those considered in IAEA's LWR scenarios. This is briefly discussed below.

As indicated in Equations E.1 and E.2, calculating OILs from ground measurements requires deriving projected dose by integrating gross activity concentration on the ground over the time period specified for each generic criteria. The default OILs 1_γ and 2_γ assume that this gross activity decreases significantly during the first few days of the event, primarily due to decay of short-lived radionuclides, after which time residual contamination persists for an extended period of time (with some reduction due to decay and natural removal processes). The expected changes in gross activity over time are reflected in the curves shown in Figures 1 and 2. In emergency scenarios where gross activity is not expected to change in the same way, such as an event involving a radiological dispersal device (RDD), integrated activity (and, therefore, integrated exposure) over the same time period will be different. The dose coefficient for each radionuclide of concern is an important factor as well, as dose coefficients can vary by orders of magnitude depending on the radionuclide, the pathway of exposure and the **representative person**. Higher dose coefficients result in the calculation or selection of lower OILs.

This being said, Health Canada considers the default $OIL1_\gamma$ as protective for use in the urgent phase of most emergency situations involving gamma-emitting radionuclides.[20] This is because $OIL1_\gamma$ is meant to trigger actions that keep exposure times well below the 7 days specified in the generic criteria for evacuation/sheltering, for conservatively-selected radionuclide mixes. Therefore, as long as measurements are collected and decisions are made promptly, it should be possible to keep doses to members of the public below the generic criteria by using the default $OIL1_\gamma$ value (1000 μSv/h) for most emergency scenarios.

The default values presented in this document for $OIL2_\gamma$, however, may be less appropriate for use with different radionuclide mixes. Since the decision to relocate people is based on projected annual dose, specific knowledge about how the radioactive source will change over the year (e.g., decay, weathering) and the dose coefficients for the component radionuclides should be considered when setting OILs for temporary relocation. For this reason, emergency managers planning for FNEP Category D threats should consider calculating initial default values for $OIL2_\gamma$ for specific scenarios of concern, such that the annual projected dose does not exceed the generic criteria for temporary relocation in the early phase of the event (100 mSv in the first year).

While the value of $OIL2_\gamma$ may change for different scenarios, its purpose remains the same: it facilitates setting priorities and allocating finite resources based on risk to populations, established by measuring ambient dose rates. As populations in higher priority areas are relocated, the generic criteria for temporary relocation (and the associated OIL) should be reduced over time until the annual projected dose to people remaining in the area is no more than 20 mSv/y (ICRP 2007).

Finally, it should be noted that ground monitoring OILs are based on gamma measurements only. The contribution of other types of radiation to effective dose has been considered for the radionuclide mixes used to calculate the default OIL values; however, for other source terms where alpha- or beta-emitting radionuclides may contribute significantly to the total effective dose, these OILs should not be relied upon for decision-making.

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[20] Or mixes, where relative quantities of alpha- and beta-emitters can be derived from gamma measurements.

APPENDIX F: OIL CALCULATIONS FOR LABORATORY MEASUREMENTS

OIL6 values are calculated based on the following conservative assumptions:

- all the affected drinking water, milk and other foods and beverages are immediately contaminated and consumed throughout a full year;
- short-lived radionuclides (with a half-life of less than 13 days) are only contaminated and consumed over a two month period;
- the most restrictive age-dependant dose conversion factors (ICRP 2012b) and ingestion rates (HC 1993; HC 2011; HWC 1976) are used; and
- 100% of drinking water and milk and 20% of other foods and beverages were assumed to come from contaminated sources.

OIL6 values are calculated based on the following equation:

$$OIL_{i,j,k} = \frac{GC_{IC}}{M_{j,k} \times DC_{i,k} \times f_j} \times 1000$$

Where:

$OIL_{i,j,k}$ is the radionuclide specific OIL for radionuclide *i* in food group *j* and age group *k* (Bq/kg or Bq/L);

GC_{IC} is the generic criteria for Ingestion Control: 1 mSv (0.001 Sv) per year per food group for each of drinking water, milk and other foods and beverages;

$M_{j,k}$ is the mass of food group *j* consumed by age group *k* over the assessment period (kg or L per year);

$DC_{i,k}$ is the ingestion dose coefficient for radionuclide *i* and age group *k* (Sv/Bq); and

f_j is contamination factor, equivalent to the fraction of an individual's dietary intake of food group *j* assumed to be uniformly contaminated to the full value of the OIL.

Both the mass of food consumed and the radionuclide ingestion dose coefficients are age-specific and their values reflect the classification of the population into a limited set of representative age groups. For the purpose of this document, the six age groups recommended by the ICRP (ICRP 2012b) have been used. These are identified in Table 9.

TABLE 9. ICRP age groups (ICRP 2012a)

ICRP AGE GROUP	RANGE
3 months	From 0 to 1 year of age
1 year	From 1 year to 2 years
5 year	More than 2 years to 7 years
10 year	More than 7 years to 12 years
15 year	More than 12 years to 17 years
Adult	More than 17 years

Age-specific annual dietary intakes seen in Table 10 are based on recommended Canadian reference values derived from a 1970–1972 Canada-wide survey for food consumption and a Health Canada report on drinking water consumption rates (HC 1993; HC 2011; HWC 1976). In calculating OILs for short-lived radionuclides (those with a half-life of less than 13 days) these values are scaled to a two-month time period. Consumption rates for 3-month-old infants have been based on individuals that consume formula milk prepared with tap water at a rate of 400 mL/day (HC 1993).

TABLE 10. Food category and average consumption rates for Canadian populations

FOOD CATEGORY	CONSUMPTION RATE BY AGE GROUP					
	3 month	**1 year**	**5 year**	**10 year**	**15 year**	**Adult**
Fresh Milk (kg/y)	145	185	215	205	190	85
Other Foods and Beverages (kg/y)	155	215	380	450	520	500
Drinking Water (L/y)[21]	150	275	275	425	425	730

Committed effective dose coefficients are estimates of the integrated dose expected to be imparted to the whole body of a reference individual over a defined period of time following a single intake by ingestion of 1 Bq of activity of a specific radionuclide. Effective dose coefficients take into consideration all affected organs and tissues, accounting for their individual susceptibilities to radiation-induced harm. Committed effective dose coefficients to age 70 years[22] for the six ICRP age groups have been taken from ICRP Publication 119 (ICRP 2012b) and represent the latest international recommendations at the time of this publication.

The contamination factors provided in Table 11 describe the average fraction of an individual's intake of a food group that is assumed to be uniformly contaminated to the full value of the OIL for the duration of the assessment period. For ingestion of milk, it is assumed that the entire intake by all age groups is contaminated over the duration of the assessment period. Marketed fresh milk supplies generally come from local and regional sources and, therefore, an individual's intake may be composed entirely of supplies that have been directly affected by the emergency. A contamination factor of 1 is also assumed for drinking water drawn from public supplies, since it is usual for most individuals to obtain their water from a single source. For other foods and beverages, a contamination factor of 20% is assumed based on the expectation that normally less than 10% of the annual dietary intake of most members of the public could consist of locally-produced food directly affected by the emergency. A factor of 2 was applied to the expected value of 10% to account for sub-groups that might be more dependent on local foods.

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[21] Litres per year (L/y). Reference Values for Canadian Populations (HC 1993) recommends an adult rate of 1.5 litres per day (L/d) (550 L/y) for drinking water consumption. A value of 2 L/d (730 L/y) is used here for consistency with the *Guidelines for Canadian Drinking Water Quality: Guidelines Technical Document—Radiological Characteristics* (HC 2009).

[22] Committed effective dose coefficients are integrated over 50 years for adults and over 70 years for children (ICRP 2012b).

TABLE 11. Food group contamination factors

FOOD GROUP	CONTAMINATION FACTOR
Drinking water	1
Milk	1
Other foods and beverages	0.2

To derive the radionuclide-specific OILs presented in Table 12, individual values were calculated for each radionuclide, for each food group and for each of the six ICRP age categories. The most restrictive of the six calculated values was selected for the OIL. To reflect the uncertainty in the calculated values and to simplify implementation by minimizing the number of unique values, the calculated OILs were rounded to a value of 1, 3, 10, 30, 100, 300, 1000, 3000, 10000, 30000, 100000, 300000, or 1000000 Bq/kg.

Table 12 provides an exhaustive list of radionuclide-specific OILs. Radionuclides from this list should be chosen based on the type of emergency and laboratory capabilities.

TABLE 12. Radionuclide specific OILs for laboratory measurements of drinking water, milk and other foods and beverages

OIL6				
		RADIONUCLIDE SPECIFIC ACTIVITY CONCENTRATION		
RADIONUCLIDE	SYMBOL	DRINKING WATER (Bq/L)	MILK (Bq/kg)	OTHER FOODS AND BEVERAGES (Bq/kg)
Tritium[23]	^{3}H	100000	30000	100000
Carbon-14	^{14}C	3000	3000	10000
Sulphur-35[24]	^{35}S	3000	3000	30000
Chromium-51	^{51}Cr	10000	30000	100000
Iron-55	^{55}Fe	1000	3000	10000
Iron-59	^{59}Fe	100	100	1000
Cobalt-58	^{58}Co	1000	1000	3000
Cobalt-60	^{60}Co	100	100	1000
Zinc-65	^{65}Zn	100	100	1000
Rubidium-86	^{86}Rb	100	300	1000
Strontium-89	^{89}Sr	300	300	1000
Strontium-90	^{90}Sr	30	30	100
Strontium-91	^{91}Sr	10000	10000	30000
Strontium-92	^{92}Sr	10000	10000	30000
Yttrium-90	^{90}Y	3000	1000	10000
Yttrium-91	^{91}Y	300	300	1000
Yttrium-92	^{92}Y	10000	10000	30000
Yttrium-93	^{93}Y	3000	3000	10000
Niobium-95	^{95}Nb	1000	1000	3000

[23] Tritium is assumed to be organically bound tritium in the case of milk and other foods and beverages, and tritiated water in the case of drinking water.

[24] Inorganic sulphur

OIL6

RADIONUCLIDE	SYMBOL	RADIONUCLIDE SPECIFIC ACTIVITY CONCENTRATION		
		DRINKING WATER (Bq/L)	MILK (Bq/kg)	OTHER FOODS AND BEVERAGES (Bq/kg)
Zirconium-95	^{95}Zr	1000	1000	3000
Zirconium-97	^{97}Zr	1000	1000	3000
Molybdenum-99	^{99}Mo	3000	10000	30000
Technetium-99	^{99}Tc	100	100	300
Technetium-99m[25]	^{99m}Tc	1000	100000	300000
Ruthenium-103	^{103}Ru	1000	1000	3000
Ruthenium-105	^{105}Ru	1000	10000	100000
Ruthenium-106	^{106}Ru	100	100	300
Rhodium-105	^{105}Rh	3000	3000	30000
Silver-110m	^{110m}Ag	300	300	1000
Antimony-127	^{127}Sb	300	300	3000
Antimony-129	^{129}Sb	1000	10000	30000
Tellurium-127	^{127}Te	3000	30000	100000
Tellurium-127m	^{127m}Te	1000	1000	10000
Tellurium-129	^{129}Te	10000	100000	300000
Tellurium-129m	^{129m}Te	100	100	1000
Tellurium-131m	^{131m}Te	1000	3000	10000
Tellurium-132	^{132}Te	1000	1000	3000
Iodine-129	^{129}I	10	30	30
Iodine-131	^{131}I	100	100	300
Iodine-132	^{132}I	3000	10000	30000
Iodine-133	^{133}I	1000	1000	3000
Iodine-134	^{134}I	300	30000	100000
Iodine-135	^{135}I	1000	1000	3000
Cesium-134	^{134}Cs	100	300	1000
Cesium-136	^{136}Cs	300	300	3000
Cesium-137	^{137}Cs	100	300	1000
Barium-139	^{139}Ba	10000	30000	100000
Barium-140	^{140}Ba	300	300	3000
Lanthanum-140	^{140}La	300	300	3000
Lanthanum-141	^{141}La	1000	10000	30000
Lanthanum-142	^{142}La	1000	30000	100000
Cerium-141	^{141}Ce	1000	1000	3000
Cerium-143	^{143}Ce	100	3000	10000
Cerium-144	^{144}Ce	100	100	300

[25] m = metastable

OIL6				
		RADIONUCLIDE SPECIFIC ACTIVITY CONCENTRATION		
RADIONUCLIDE	SYMBOL	DRINKING WATER (Bq/L)	MILK (Bq/kg)	OTHER FOODS AND BEVERAGES (Bq/kg)
Praseodymium-143	^{143}Pr	300	300	3000
Neodymium-147	^{147}Nd	300	300	3000
Iridium-192	^{192}Ir	300	300	3000
Uranium-235	^{235}U	30	30	100
Neptunium-237	^{237}Np	3	3	10
Neptunium-239	^{239}Np	3000	3000	30000
Plutonium-238	^{238}Pu	1	1	3
Plutonium-239	^{239}Pu	1	1	3
Plutonium-240	^{240}Pu	1	1	3
Plutonium-241	^{241}Pu	100	100	300
Plutonium-242	^{242}Pu	1	1	3
Plutonium-244	^{244}Pu	1	1	3
Americium-241	^{241}Am	1	1	10
Curium-242	^{242}Cm	30	30	100
Curium-244	^{244}Cm	1	1	10

For samples with multiple radionuclides present, the OIL6 is exceeded if the following condition is satisfied:

$$\sum_i \left(\frac{C_i}{OIL6_i} \right) \geq 1$$

Where:

C_i is the concentration of radionuclide i in the drinking water, milk or other foods or beverages (Bq/kg or Bq/L); and

$OIL6_i$ is the radionuclide specific value of OIL for radionuclide i in drinking water, milk or other foods or beverages (Bq/kg or Bq/L).

APPENDIX G: REFERENCES

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