Health Canada Santé Canada

Canadian Guidelines for the Restriction of Radioactively Contaminated Food and Water Following a Nuclear Emergency

Guidelines and Rationale

Canada

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Our mission is to help the people of Canada maintain and improve their health.

Health Canada

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Foreword

Scope

This document sets out Health Canada's guidelines for the control of radioactively contaminated commercial foods and public drinking water following a nuclear emergency in Canada or abroad. Its purpose is to guide emergency response organizations at the federal and provincial levels on decisions concerning the withdrawal and substitution of contaminated food and water within Canada. The implementation of these guidelines following an emergency is intended to minimize the health risk associated with the consumption of contaminated foodstuffs and to preserve public confidence in the safety of the commercial food supply.

Based on the concept of risk limitation, action levels for use in the screening of foods offered for sale, and for public drinking water supplies, have been calculated for those radionuclides expected to be of greatest significance to dose due to the ingestion of contaminated food following a nuclear emergency. These values, and guidance on their implementation, are contained in Part 1 of this report. Part 2 contains the supporting rationale used in the development of the guidelines, including a review of recommendations issued by various international organizations.

By issuing these guidelines, it is the intent of Health Canada to facilitate the development of consistent national criteria for the identification and control of all radioactively contaminated commercial food and public drinking water within Canada following a nuclear emergency. The guidelines are applicable to the development of emergency response plans by federal and provincial authorities, and in the event of a nuclear emergency affecting the food supply, are intended to be uniformly implemented across the country for the screening and control of all local and imported foods.

Authority

The Government of Canada, under the *Food and Drugs Act*, has primary responsibility for the safety of all domestic and imported food offered for sale within Canada. Legislative and regulatory responsibility for the *Act* resides within Health Canada. In the event of contamination of the commercial food supply, the parts of these guidelines referring specifically to foods (i.e., not drinking water) will be implemented under the authority of Section *4A* of the *Food and Drugs Act* (Health Canada 1981/1998).

The quality of public drinking water sources, except within areas of federal jurisdiction, is the responsibility of the provinces, territories, and municipalities. The recommendations herein that refer to drinking water may be used by these governments as a basis for setting action levels for radionuclides following an emergency. Provinces may choose to adopt the guidelines in whole or in part, or to enact their own criteria. However, significant benefits relating to public confidence can be achieved by the adoption of consistent national criteria.

At the federal level, the Canadian Food Inspection Agency (CFIA) is responsible for monitoring and enforcing the food safety standards and guidelines established by Health Canada, including taking all necessary enforcement actions in food-related emergencies. The roles, responsibilities and methodologies for implementing and enforcing these guidelines are subject to the existing jurisdictional context and the relationships established by the CFIA with provincial ministries and officials, the food industry, and other stakeholders and partners. As this document deals solely with the setting of guidelines for radioactively contaminated food following a nuclear emergency, implementation issues are not discussed.

Limitations

The guidelines presented in this document deal solely with the setting of guidelines for the control of food offered for sale and to public drinking water supplies that have been contaminated as a result of an uncontrolled release of radioactive material to the environment during a nuclear emergency. They do not apply to non-emergency situations, or to non-commercial food sources and private water supplies. In the event of contamination of foods that are not marketed, these guidelines may be used to provide advice applicable to individuals producing or harvesting their own food.

These guidelines do not limit the authority of provinces and territories to enact public health legislation restricting the distribution of contaminated food products before they reach the marketplace.

Review and Consultation

Following a review within Health Canada, a draft of this document was distributed to the Canadian provinces and territories in February 1999 through the Federal-Provincial-Territorial Radiation Protection Committee, and the Federal-Provincial Nuclear Emergency Preparedness Coordinating Committee. Revision of the draft in response to comments involved only clarifications and definitions, rather than changes in concepts and rationale.

Administrative Authority

Federal guidelines for the restriction of radioactively contaminated food and water following a nuclear emergency have been developed, and are administered, by the Environmental Radiation Hazards Division, Radiation Protection Bureau, Healthy Environments and Consumer Safety Branch of Health Canada. Inquiries, suggested changes or comments concerning this document should be addressed to:

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PART 1: GUIDELINES

Introduction

This document sets out Health Canada's guidelines for the control of radioactively contaminated commercial foods and public drinking water supplies following a nuclear emergency. The principal health effect associated with low radiation doses, including those arising from the ingestion of radioactively contaminated food and water, is an increased risk of radiation-induced cancer in exposed persons and potential genetic disorders in their offspring. The guidelines described herein are based on the limitation of this risk, recognizing the need to maintain the safety of, and public confidence in, the commercial food supply, consistent with the objectives of the *Food and Drugs Act* (Health Canada 1981/1998). They have been developed following a review of current recommendations on intervention published by various international agencies, and to the extent that the health, safety and confidence of the Canadian public are protected, have taken into consideration opportunities for harmonization with recommendations of the FAO/WHO Codex Alimentarius Commission (FAO/WHO 1995). Codex guidelines apply to the international trade of food that has been contaminated with radionuclides in the first year following an emergency.

In these guidelines, intervention to protect the public from the health risks due to radiation exposure takes the form of limits placed on the levels of radionuclides allowed in commercial foods and public water supplies. Food and water containing radionuclides at concentrations above these levels, referred to herein as *Action levels*, would normally be withdrawn from sale or distribution and substituted with alternate supplies. Action levels for radionuclides not listed in these guidelines may be derived using the detailed methodology and parameters supplied in Part 2 of these guidelines. Issues concerning implementation and jurisdictional responsibility are not discussed.

Intervention Levels vs Action Levels

The nomenclature of the International Atomic Energy Agency (IAEA) Basic Safety Series No. 115 (IAEA 1996) for quantities applicable to intervention has been adopted in these guidelines.[1] Intervention in emergency exposure situations is carried out on the basis of intervention and action levels. *Intervention levels (IL)* are expressed in terms of the dose that is expected to be avoided or averted over time by a specific protective action associated with the intervention. *Action levels (AL)* are defined in terms of the dose rate or activity concentration above which protective or remedial actions are generally recommended. Action levels for food and water correspond to the radionuclide concentrations that could lead to an individual receiving a dose equal to a specified intervention level, assuming that the contaminated portion of the diet remains at the action level for the duration of the assessment period.

Action Levels for Radionuclides in Food and Water

Summary of Methodology for Calculating Action Levels[2]

Action levels for food and water are based on an intervention level of 1 millisievert (mSv) applied independently to each of three food groups, assuming that the intervention is completely effective at averting dose. The intervention level is assessed over a period of one year for long-lived radionuclides and 2 months for radionuclides with half-lives less than about 300 hours (12-13 days). The food groups considered are:

- *Fresh Liquid Milk*;
- *Other Commercial Foods and Beverages*; and
- *Public Drinking Water.*

In the derivation of action levels, it is assumed that contaminated foods comprise no more than 20% of an individual's annual intake of *Other Commercial Foods and Beverages*. The remainder consists of food unaffected by the emergency. For consumption of *Fresh Liquid Milk* and *Public Drinking Water*, which are generally drawn from local sources, it is assumed that the intake consists entirely of contaminated supplies. Dairy products other than fresh milk (e.g., butter, cheese, powdered milk), as well as labelled baby-foods are grouped with *Other Commercial Foods and Beverages*. Annual intakes for the various food groups are based on Canadian consumption data.

The radionuclides which are most likely to be predominant contributors to dose through ingestion following a nuclear reactor accident are dependent on the type of facility and the

1. French-English translations of terminology are based on *Glossaire de l'énergie nucléaire* (OECD 1992).

2. A detailed discussion of the methodology for calculating action levels is provided in Part 2.

severity of the event. Typically, those having the most significance to dose from the ingestion of contaminated food and water are $^{89/90}Sr$, $^{103/106}Ru$, ^{131}I, $^{134/137}Cs$, $^{238/239}Pu$ and ^{241}Am (IAEA 1989, 1994). For accidents involving Canadian CANDU reactors, tritium (^{3}H) may also be present, although it is not expected to be a major contributor to the ingestion dose.

Action levels for these radionuclides were calculated for six age groups per food group, using age-specific consumption rates and dose coefficients for ingestion. A single action level was chosen for each radionuclide per food group, based on the most restrictive among the six age groups. These were compared with the recommendations of the FAO/WHO Codex Alimentarius Commission (1995) for radioactively contaminated foods moving in international trade. Due to their similarity, action levels for *Other Commercial Foods and Beverages* were harmonized with Codex guideline levels for the similarly grouped *Foods Destined for General Consumption*, with the exception of ^{106}Ru, for which a lower value is recommended. Values for *Fresh Liquid Milk* were, for several radionuclides, significantly lower than the Codex values for *Milk and Infant Foods* and were thus not harmonized. Codex guidelines do not contain specific recommendations for drinking water.

Action levels recommended by Health Canada for radionuclides of potential significance are listed in Table 1.1. If there is no shortage of nutritionally adequate alternate food or other social/economic constraints, action levels for the withdrawal and substitution of food and drinking water following a nuclear emergency should be based on this table.

Table 1.1
Recommended action levels for radionuclides of potential significance to dose from the ingestion of contaminated food

	Action Levels (Bq kg^{-1})$^{(1)}$		
Radionuclide	**Fresh Liquid Milk**	**Other Commercial Foods and Beverages**	**Public Drinking Water**
^{89}Sr	300	1 000	300
^{90}Sr	30	100	30
^{103}Ru	1 000	1 000	1 000
^{106}Ru	100	300	100
^{131}I	100	1 000	100
^{134}Cs, ^{137}Cs	300	1 000	100
^{238}Pu, ^{239}Pu, ^{240}Pu, ^{242}Pu, ^{241}Am	1	10	1

Notes:

(1) Bq L^{-1} for Drinking Water.

Screening of Food Samples for Compliance with Action Levels

The screening of food is based on the assumption that the radionuclide concentration in a sample remains at the action level for the duration of the assessment period, and that the contaminated fraction of the relevant food group consists entirely of the sample in question. Food samples containing a single radionuclide are screened for compliance by comparing the measured activity in the sample with the action level for the appropriate radionuclide and food group.

If several radionuclides are present in a sample, the following summation criterion must be satisfied:

$$\sum_i \left(\frac{A_i}{AL_i} \right) \leq 1 \qquad (1.1)$$

where A_i is the measured activity of radionuclide *i*, and AL_i is its corresponding action level. In this summation criterion, all radionuclides are assessed collectively. As a result, the methodology differs from the Codex guidelines (FAO/WHO 1995), which allow the summation of activities within each of three independent radionuclide groups, but not between groups. As with the Codex guidelines, no provision is made for the summation of radionuclide activities in different food samples or food groups.

Compliance with the guidelines is based on a simple pass or fail criterion. Foods containing activity concentrations below the action levels given in Table 1.1 for single radionuclides, or satisfying Equation 1.1 for multiple radionuclides, are deemed to be in compliance with the guidelines, and would be permitted unrestricted access to the Canadian marketplace. Foods failing these conditions would normally be withdrawn from sale and replaced with alternate supplies. There is no additional requirement for further reductions in radionuclide concentrations or resulting doses. Restrictions on the marketing of food exceeding the action levels would remain in force as long as the measured samples fail to meet the intervention criteria.

Example 1:

A sample of fresh milk measured a short time after an emergency contains 150 Bq kg^{-1} of ^{137}Cs and 40 Bq kg^{-1} of ^{131}I. From Table 1.1, the action levels for the two radionuclides in the *Fresh Liquid Milk* group are:

$$AL_{milk,\ Cs\text{-}137} = 300 \text{ Bq kg}^{-1}$$
$$AL_{milk,\ I\text{-}131} = 100 \text{ Bq kg}^{-1}$$

Applying the summation criterion:

$$\sum \left(\frac{150}{300} + \frac{40}{100} \right) = 0.9 < 1$$

The milk can therefore be permitted unrestricted distribution in the commercial food supply.

Example 2:

Samples of two different food types from *Other Commercial Foods and Beverages* are to be assessed for compliance with the guidelines. The first is a sample of locally produced butter with a ^{137}Cs concentration of 200 Bq kg^{-1}. The second is a sample of fresh beef containing 500 Bq kg^{-1} of ^{134}Cs and 800 Bq kg^{-1} of ^{137}Cs. From Table 1.1, the action levels for each of these radionuclides in the *Other Commercial Foods and Beverages* group are:

$AL_{food,\ Cs\text{-}134}$ = 1 000 kg^{-1}
$AL_{food,\ Cs\text{-}137}$ = 1 000 kg^{-1}

Sample 1: The concentration of ^{137}Cs in the sample of butter is compared directly against the appropriate action level. Since it is less than $AL_{food,\ Cs\text{-}137}$, the supply of butter from which this sample has been drawn can be permitted unrestricted access to the market.

Sample 2: For the sample of meat, the summation criterion must be applied:

$$\sum \left(\frac{500}{1000} + \frac{800}{1000} \right) = 1.3 > 1$$

The summation criterion is not met, therefore the supply from which this sample has been drawn would not be permitted access to the market for public consumption.

In this example, the two food types are treated independently, since the action levels for *Other Commercial Foods and Beverages* are based on the total dietary consumption rate of the group, and not on the rates for the individual components. In applying the guidelines, no distinction is made between the various food types comprising this group.

Action levels are applied to food as prepared for consumption. In general, foods will be assessed on the basis of their fresh weight. Washing or peeling fresh fruit and vegetables may be effective at removing surface contamination, but no allowance should be made for these actions by consumers. In the case of dried or concentrated foods and beverages, the measured concentration should be divided by the factor normally used for dilution or reconstitution. For classes of food that are consumed in small quantities and represent a very small fraction of the total diet, such as spices, a dilution factor of 10 is recommended (IAEA 1994, 1996).

Although the withdrawal and substitution of food does not preclude actions that may be taken to reduce radionuclide concentrations before food reaches the marketplace, the action levels given in this document apply strictly to foods as offered for sale and to the distribution of public water supplies. Recommendations on countermeasures other than the withdrawal and substitution of food and water supplies, including the acceptability of various agricultural and industrial practices, are beyond the scope and jurisdiction of these guidelines. In all cases, the acceptability of the food supply is assessed in terms of the action levels for food as marketed and as consumed.

Supplementary Action Levels for Other Radionuclides

Following a nuclear emergency, radionuclides other than those listed in Table 1.1 may also be present in the food supply, but usually at much lower concentrations (USFDA 1998). As an aid to the responsible authorities in the event that other radionuclides are detected in food samples, action levels for a number of additional radionuclides are given in Table 1.2. These are expected to be minor contributors to the dose from ingestion.

The radionuclides listed in Table 1.2 are not specifically mentioned in the recommendations of the Codex Alimentarius Commission, and have therefore not been harmonized with the Codex guidelines. The values in Table 1.2 have been derived in a manner consistent with the action levels of Table 1.1. However, some of these values may not be acceptable to the public given that background levels are significantly lower, other jurisdictions may have lower action levels for these classes of radionuclides, or the radionuclide may be of particular public concern, as is the case with ^{3}H (tritium) in drinking water resulting from routine reactor operating emissions.

In regards to drinking water, emergency action levels may be substantially higher than those used for non-emergency conditions, since the latter are based on an intervention level of 0.1 mSv (Health Canada 1996). In cases where public concern may be of overriding importance, it is the responsibility of the decision maker to take account of the appropriate sociopolitical considerations when setting emergency levels based on the action levels given in Table 1.2.

Advice on the Alteration of Action Levels

Controls on food and water may be in place for extended periods of time, during which periodic re-assessments of the appropriateness of the action levels, in terms of public confidence and availability of alternate supplies, can be performed. In general, the variability in the values of parameters used in the derivation of the action levels, and the relative ease in obtaining nutritionally adequate alternate food supplies should preclude the need to alter the action levels given in Table 1.1, particularly during the course of an emergency. Such alterations could lead to a loss of public confidence, or possibly to international trade disputes. Specific exceptions include those situations in which implementation of this advice could result in severe shortages of essential foods or nutritionally adequate alternatives for extended periods of time. In these cases, the intervention criteria may need to be relaxed. It is unlikely that values lower than those given in Tables 1.1 and 1.2 would be required, except in the cases, discussed above, where public concern is the overriding factor.

Any modification to the recommended action levels should be taken with caution and sufficient justification, taking into account specific social and economic factors in determining suitable intervention criteria and risks. In all cases, the rationale for altering the recommended values must be clear. In the event that action levels are raised, the expected doses to the target population should be assessed and monitored, and reassurances of the safety of the food supply should be provided by public health authorities.

Table 1.2
Recommended action levels for radionuclides of lesser significance to dose from the ingestion of contaminated food

	Action Levels (Bq kg^{-1})$^{(1)}$		
Radionuclide	**Fresh Liquid Milk**	**Other Commercial Foods and Beverages**	**Public Drinking Water**
$^{3}H^{(2)}$	30 000	100 000	100 000
^{14}C	3 000	10 000	3 000
^{51}Cr	30 000	100 000	10 000
^{55}Fe	1 000	3 000	1 000
^{59}Fe, ^{60}Co	100	1 000	100
^{65}Zn, ^{91}Y	300	1 000	300
^{95}Zr	1 000	3 000	1 000
^{95}Nb	1 000	10 000	1 000
^{99}Mo	10 000	30 000	10 000
^{110m}Ag	300	1 000	300
^{132}Te	1 000	3 000	1 000
^{140}Ba	1 000	10 000	1 000
^{140}La	3 000	10 000	1 000
^{141}Ce	1 000	3 000	1 000
^{144}Ce	100	300	100
^{237}Np	3	10	3
^{239}Np	3 000	30 000	3 000
^{241}Pu	100	1 000	100
^{244}Pu	1	10	1

Notes:

(1) Bq L^{-1} for Drinking Water.

(2) Action levels for ^{3}H are based on organically-bound tritium for *Fresh Liquid Milk* and *Other Commercial Foods and Beverages*, and on tritiated water for *Public Drinking Water*.

PART 2: RATIONALE USED IN THE DEVELOPMENT OF GUIDELINES FOR RADIOACTIVELY CONTAMINATED FOOD AND WATER

An Overview of Nuclear Emergency Planning in Canada

The goals of nuclear emergency planning, preparedness, and response are the protection of the public from the immediate and delayed health effects due to exposure to uncontrolled sources of radiation, the mitigation of the impacts of a nuclear emergency on property and the environment, and the continuance of public confidence in the ability of responsible authorities to protect health. In the event of a nuclear emergency resulting in significant releases of radioactive material to the environment, emergency response organizations will be called upon to provide guidance on the management of radiological contamination, to assess the radiation doses that may be received by members of the public, and to introduce countermeasures to reduce or avert these doses. Protective actions that may be considered include evacuation, sheltering, and administration of stable iodine, as well as longer term measures such as relocation and the withdrawal of contaminated foods. The effectiveness of such measures will be influenced to a large degree by the formulation, prior to an emergency, of appropriate criteria and guidance for use by decision makers.

In Canada, the operators of nuclear facilities are responsible for on-site emergency planning, preparedness and response. Off-site, provincial governments have the primary responsibility for protecting public health and safety, property and the environment within their borders. The federal government, under the *Federal Nuclear Emergency Plan*, coordinates with, and provides support to, provinces in their response to an emergency. Health Canada administers, and is the lead federal department for, the *Federal Nuclear Emergency Plan*, which describes the federal government's preparedness and coordinated response to a nuclear emergency (Health Canada 1997). The federal government also manages nuclear liability and is responsible for coordinating the national response to a nuclear emergency in a foreign country affecting Canadians. As a result, off-site planning, preparedness and response to nuclear emergencies are multi-jurisdictional responsibilities shared by all orders of government.

The Government of Canada, under the *Food and Drugs Act* and *Regulations* (Health Canada 1981/1998), has primary responsibility for the safety of all domestic and imported food offered for sale within Canada, and has the authority to prohibit the sale of foods containing any "poisonous or harmful substance" as specified in Section *4A* of the *Act*. Legislative and regulatory responsibility for the *Food and Drugs Act* resides within Health Canada.

The quality of public drinking water sources, except within areas of federal jurisdiction, is primarily the responsibility of the provinces, territories, and municipalities. Health Canada works in collaboration with provincial health and environment ministries to establish national guidelines for drinking water quality under non-emergency situations (Health Canada 1996). The recommendations herein that refer to drinking water may be used by these governments as a basis for setting action levels for water following a nuclear emergency. Provinces may adopt these in whole or in part, or may establish their own criteria.

At the federal level, the CFIA is responsible for monitoring and enforcing the food safety standards established by Health Canada, including taking all necessary enforcement actions in food-related emergencies. The roles, responsibilities and methodologies for implementing and enforcing these guidelines are subject to the existing jurisdictional context and the relationships established by the CFIA with provincial ministries and officials, the food industry, and other stakeholders and partners. As this document deals solely with the setting of guidelines for radioactively contaminated food following a nuclear emergency, implementation issues are not discussed.

In so far as the Canadian Nuclear Safety Commission[3] constrains public doses arising from licensed nuclear practices under normal conditions by a dose limit of 1 mSv y^{-1}, there are no additional federal guidelines restricting radioactivity levels in food under non-emergency situations.

Rationale for the Restriction of Radioactively Contaminated Food and Water

Health Effects of Ionizing Radiation

Following a release of radioactive material to the environment under emergency conditions, members of the public may be exposed to ionizing radiation through a number of exposure pathways. These include immersion in radioactive airborne plumes or contaminated water, inhalation of airborne radioactivity, irradiation from deposited radionuclides and inhalation following their resuspension into the air, and ingestion of contaminated food and water. The resulting doses may be received either through direct external irradiation, or internally from radionuclides taken into the body through inhalation, ingestion or absorption through the skin.

The health effects associated with ionizing radiation exposure can be divided into those mainly linked to cell killing, called deterministic (or threshold) effects, and those linked to cell modification, called stochastic (or non-threshold) effects. Deterministic effects are characterized by a generally accepted minimum level of dose, or threshold, below which they are not expected to occur, and result from the body's inability to cope with the death of a significant number of cells in certain tissues or organs. The severity of these effects, such as nausea, skin burns or acute radiation syndrome, increases with dose above a clinical threshold, and with few exceptions appear within days to weeks after exposure. The threshold for early observable effects such as nausea or temporary blood cell changes is about 250-500 mSv received in a short period of time (ICRP 1991).

Stochastic effects result from damage to cellular DNA, and may not show up until years after the exposure has occurred. The effects of primary concern are an increased risk of radiologically-attributable cancer in exposed persons and potential genetic disorders in their offspring. The likelihood of experiencing these effects, rather than their severity, is assumed to be proportional to dose, and it is generally assumed that there is no level of radiation, however small, that is completely free of the risk of stochastic effects. These two assumptions are referred to as the linear no-threshold hypothesis. Stochastic effects are the primary health risk associated with exposure to low doses of radiation, including those due to the consumption of contaminated food and water.

Radiological risk factors for stochastic effects following low dose irradiation have been derived from epidemiological studies of humans exposed to much higher doses. Based on extrapolations from these studies, the International Commission on Radiological Protection (ICRP 1991) recommends a population-averaged lifetime risk estimate of 5.0×10^{-5} per mSv (5 in 100 000 per mSv) of effective dose for radiologically-attributable fatal cancers following exposure to ionizing radiation at low doses and dose rates. In addition to fatal cancer, risk coefficients have been estimated for the total harm produced by all non-threshold health effects, including fatal cancers, non-fatal cancers weighted for severity and ease of curing, the years of life lost or seriously impaired, and the risk of serious genetic disorders developing in subsequent generations. The ICRP risk estimate for total harm is 5.6×10^{-5} per mSv of effective dose for an adult population and 7.3×10^{-5} per mSv of effective dose for the general population (ICRP 1991). The lifetime risk of developing a fatal cancer may be about a factor of three greater for those exposed as children than as adults, with the majority of this risk expressed after age 65 years (IAEA 1994).

One consequence of the assumption of a linear no-threshold relationship between dose and health risk is that for a large population, all receiving small radiation doses, it is possible to estimate statistically the expected number of non-threshold effects that could be attributable to the exposure, even though at very low doses, these effects would not be discernible against the natural cancer incidence. There is currently some question as to whether the linear no-threshold assumption accurately predicts health risk at low doses, or whether in fact there might be a beneficial adaptive response to small doses, or a threshold dose below which no biological effects are produced. At present, the linear no-threshold hypothesis represents a convergence of international scientific and regulatory opinion, although it has been suggested that effects from doses below 10-20 mSv per year for a few years be referred to as hypothetical due to a lack of direct observable proof (ACRP 1996).

General Concepts of the ICRP and IAEA on Intervention

In the event of a nuclear emergency, the source of radiation exposure is uncontrolled, and doses to individuals and populations can only be reduced through intervention in the environment and restriction of human actions. Since any form of intervention is associated with its own degree of harm, in terms of health risk, cost, and inconvenience, the ICRP (1993) and IAEA (1994, 1996) have recommended that actions to reduce radiological risk be justified in the sense that the benefits outweigh the total risk, and that the levels of dose at which the intervention is introduced, and later withdrawn, be optimized to

3. Formerly the Atomic Energy Control Board (AECB). The public limit of 1 mSv per year for doses arising from licensed practices, such as nuclear reactor operations, applies to the dose from all exposure pathways, including food and water.

produce the maximum net benefit. As a result, the radiological risks associated with emergency intervention levels will likely be higher than risk levels associated with normal conditions, where the competing physical risk of the intervention is not relevant.

Under the ICRP and IAEA approach, intervention levels at which countermeasures are introduced are expressed in terms of the dose that is expected to be avoided by the specific countermeasure (averted dose), rather than the dose that would be received in the absence of the countermeasure (projected dose). The concept of averted dose is important since the countermeasure may not be fully effective in reducing the total projected dose, and doses received before implementation entail a health risk that will occur whether or not the countermeasure is introduced.

The ICRP states that while the input to justification and optimization studies includes factors related to radiological protection, the final decision on intervention may also depend on political and social factors. Radiological factors include those describing the averted dose, and those describing the costs and other disadvantages in averting dose. Less quantifiable factors include reassurance to the public and workers provided by the protective action, anxiety caused by its implementation or lack of implementation, and individual and societal disruption (ICRP 1993).

In order to simplify decisions concerning the introduction of countermeasures, action levels are based on measurable quantities, such as activity concentrations of radionuclides in food, above which a protective action would be implemented. Intervention and action levels established through a cost-benefit optimization depend on the specific emergency conditions. The ICRP (1993) and IAEA (1994) have provided examples of generic optimizations for various protective measures based on a strict cost-benefit approach, with sociopolitical factors intentionally excluded, in order to form a common baseline for decisions. Although these factors have been excluded from the generic optimizations, sociopolitical and psychological factors may contribute to, or even dominate, some decisions, in which case deviation from the generic levels becomes a matter of national policy, circumstances or site-specific factors (IAEA 1994).

Intervention with Regards to Contaminated Food and Water

The principal health risks associated with the ingestion of contaminated food and water are an increased probability of radiation-induced cancer in exposed persons and potential genetic disorders in their offspring. The non-radiological impacts of intervention to avoid these risks include the necessity and costs of supplying nutritionally adequate alternative supplies, the disposal or diversion of contaminated foods, and the economic liability associated with lost production and sales. Additional societal risks include the potential loss of public confidence in both the safety of the food supply and in the ability of responsible authorities to protect health.

Intervention with regards to contaminated foodstuffs typically takes the form of limits placed on the levels of radionuclides allowed in the commercial food and public water supplies. Food and water containing radionuclides at concentrations above the action levels would normally be withdrawn from sale or distribution and substituted with alternate supplies. The ICRP and IAEA provide general advice on intervention in relation to food, and propose generic optimized action levels for the withdrawal and substitution of foodstuffs, taking into consideration the radiological risk and the estimated costs of intervention. The IAEA stresses that action levels for food should take due account of the need for consistency with national food and public health laws, and the need to build and maintain public confidence (IAEA 1994).

Health Canada’s Guidance for Intervention in Relation to Food

Health Canada has developed its advice for intervention in relation to contaminated food and water on the principle of dose and health risk limitation, recognizing the need to maintain the safety of, and public confidence in, the commercial food supply, consistent with the objectives of the *Food and Drugs Act*. This approach establishes upper limits on radiological risks, and results in unambiguous operational limits against which foods can be measured, regardless of assumptions about the type of accident and contamination, the composition of diet, or the costs of food substitution.

The decision to base action levels on health risk limitation follows from a review of international recommendations for food intervention (Appendix B), including the generically-optimized action levels recommended by the ICRP (1993) and IAEA (1994). Consideration has also been given to opportunities for harmonization with recommendations of the FAO/WHO Codex Alimentarius Commission (1995) for the international trade of food that has been contaminated with radionuclides in the first year following a nuclear emergency, to the extent that the health, safety, and confidence of the Canadian public are protected.

Calculation of Action Levels for Radionuclides in Food

Action levels for radionuclides correspond to the activity concentrations in consumed foodstuffs that could lead to an individual receiving a dose equal to a specified intervention level, assuming that a portion of the diet remains at the action level for the duration of the assessment period. In order to provide an adequate level of protection to all segments of the population, action levels have been derived using conservative assumptions. Therefore, radiation doses to members of the public will likely not exceed the intervention level if the action levels are not exceeded.

The action level for a given radionuclide within a particular food and age group is calculated as:

$$AL_{i,j,k} = \frac{IL}{M_{j,k} \times DC_{i,k} \times f_j} \qquad (2.1)$$

where

$AL_{i,j,k}$ = action level for radionuclide i in food group j and age group k (Bq kg^{-1})

IL = intervention level (Sv)

$M_{j,k}$ = mass of food group j consumed by age group k over the assessment period (kg)

$DC_{i,,k}$ = ingestion dose coefficient for radionuclide i and age group k (Sv Bq^{-1})

f_i = 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 $AL_{i,j,k}$

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. The above definition of the action level results in a distinct value for each radionuclide, age and food group combination. The data used in the derivation of the action levels are discussed in the following sections.

Radionuclides of Interest

The radiological impact of a particular radionuclide released into the environment during a nuclear emergency is a function of its abundance and its environmental, biological and radiological properties. The radionuclides which are most likely to be predominant contributors to dose through ingestion following a nuclear reactor accident are dependent on the type of facility and the severity of the event. Typically, those having the most significance to dose from the ingestion of contaminated food and water are $^{89/90}Sr$, $^{103/106}Ru$, ^{131}I, $^{134/137}Cs$, $^{238/239}Pu$ and ^{241}Am (IAEA 1989, 1994). For accidents involving Canadian CANDU reactors, tritium (^{3}H) may also be present, although it is not expected to be a major contributor to the ingestion dose. Other radionuclides may also be detected, but they are generally of lesser importance.

Intervention Level

The intervention level, *IL*, defines the committed effective dose received by an individual consuming contaminated foods over a specified time period, above which the necessity of withholding food from the marketplace should be assessed in terms of the availability of nutritionally adequate alternate supplies.

The primary consideration in the choice of the intervention level is the need to maintain the safety of, and public confidence in, the commercial food supply, particularly with regards to infants and children, recognizing that food is only one of several potential exposure pathways. Based on the principle of dose and risk limitation, Health Canada regards the dose from food and water above which intervention would be warranted to be on the order of 3 mSv apportioned equally among three food groups, or *1 mSv per food group*. The rationale for this decision is discussed below.

The intervention level of 1 mSv per food group follows from the judgement that the maximum projected dose from the total dietary consumption above which intervention would be warranted is in the range of about 1-10 mSv in one year, assuming that the withdrawal and substitution of food is completely effective at averting dose. This range is consistent with intervention levels recommended by international agencies, and corresponds to a lifetime risk of hypothetically-attributable fatal cancers of about 5-50 in 100 000 from the ingestion of contaminated food for one year, based on the ICRP (1991) population-averaged risk coefficient. Higher levels are considered unjustified given the primary goal of protecting public health and preserving confidence in the safety of the food supply by minimizing radiological risk. Notwithstanding the potential disruption to farmers and producers, it is expected that food countermeasures can be introduced with relative ease compared to other more disruptive countermeasures having higher intervention levels (e.g., evacuation or relocation).

The radiological risk from contaminated foods is related to the dose received from the total diet. However, to avoid confusion in implementing restrictions, the decision to ban a specific supply of food must be independent of the contamination of other foods and other exposure pathways. Food samples should be directly measured against the applicable action level, using standardized assumptions about diet and contamination levels. Consequently, the diet has been divided into three distinct groups, discussed later, to which the intervention criterion is independently applied. To ensure that the dose received from all food will not exceed a few millisievert, the range of maximum projected dose for the total diet is apportioned equally among the three diet groups on the basis that restrictions placed on a single food group are independent of the contamination in other groups.

The apportioning of total dose results in a range of intervention levels for each food group of about 1 to 3 mSv to the most radiosensitive age group. In general, radiological risk factors are higher in infants and children than in adults (ICRP 1991a), and therefore additional protection should be provided to infants, who often eat the same food as adults. Consequently, the intervention level has been set at the lower end of this range, i.e., 1 mSv per food group,[4] from which action levels for individual radionuclides are calculated. Higher levels would generally only be warranted if nutritionally adequate alternate supplies of essential foods are unavailable, or if the intervention could result in food shortages, as the health risk from an inadequate diet should not be greater than the radiological risk in the absence of intervention. The period over which the dose is assessed is one year for long-lived radionuclides and 2 months for radionuclides with half-lives less than about 300 hours (12-13 days), after which time they will be essentially absent from the food supply.

It is emphasized that the intervention level of 1 mSv per food group is conceptually different from the public dose limit of 1 mSv per year recommended by the ICRP (1991) for licensed facilities. The intervention level for emergencies refers only to doses arising from the consumption of contaminated food, and it is applied independently to each of the three food groups. Additionally, the intervention level, and by inference the action levels, do not represent maximum values which must not be exceeded, as is the case with the public dose limit for licensed practices. Rather they represent levels above which action would generally be warranted in order to minimize potential health effects, and sustain public confidence.

Population Age Groups

Age-specific parameters used in the calculation of action levels include the ingestion rates for the various foods consumed by Canadians, and the radionuclide dose coefficients. Six age groups, shown in Table 2.1, are used in the calculation of action levels, using the categorization employed by the ICRP (1996) for specifying age-dependent dose coefficients.

Table 2.1
ICRP age groups

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

Food Groups and Consumption Rates

The identification and control of contaminated food is facilitated by specifying a minimum number of distinct food groups to which the intervention criterion is independently applied. The following groups are used in the specification of action levels:

- *Fresh Liquid Milk*;
- *Other Commercial Foods and Beverages*; and
- *Public Drinking Water*.

Fresh Liquid Milk appears as a separate food group due to the importance of this food in infant diets and the fact that marketed supplies of fresh milk are typically drawn from local sources. *Public Drinking Water* also generally comes from a single, local source and is typically contaminated by environmental pathways that are different than for the other groups. *Other Commercial Foods and Beverages* include all other fresh or processed foodstuffs that are offered for sale, including all other dairy products (e.g., butter, cheese, powdered milk), and labelled baby-foods. Unlike the other two groups, this group will typically be composed of a much lower percentage of contaminated local products due to the larger production and distribution network from which supplies are drawn. This is discussed later in relation to contamination factors.

Average annual age-specific consumption rates are based on recommended Canadian reference values derived from a 1970-1972 Canada-wide survey for food consumption and a 1977-1978 survey for water consumption (Health Canada 1993; HWC 1976, 1981). Annual consumption rates for the various food types and for tap water are given in Appendix A: Tables A.1 and A.2, respectively, for age groups defined by Health Canada. Consumption rates for water include all beverage forms.

The annual dietary intakes for the age groups of Table 2.1 were derived from the Health Canada age-specific consumption rates using the methodology shown in Appendix A: Table A.3. The resulting age-specific reference consumption rates used in the calculation of action levels are given in Table 2.2. In calculating action levels for short-lived radionuclides, 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^{-1} (Health Canada 1993).

4. For water, an intervention level of 1 mSv per year represents a ten-fold increase over the reference dose level used to derive drinking water guidelines for use in normal situations (Health Canada 1996).

Table 2.2
Food groups and average consumption rates for Canadian populations

Food Group	Consumption Rate (kg y^{-1}) by Age Group(1)					
	3 month	1 year	5 year	10 year	15 year	Adult
Fresh Milk	145	185	215	205	190	85
Other Commercial Foods and Beverages	155	215	380	450	520	500
Drinking Water (2)	150	275	275	425	425	730

Notes:
(1) In calculating action levels for short-lived radionuclides, annual consumption rates are to be divided by 6 for use in equation 2.1.
(2) Units of L y^{-1}. *Reference Values for Canadian Populations* (Health Canada 1993) recommends an adult rate of 1.5 L d^{-1} (550 L y^{-1}) for drinking water consumption. A value of 2 L d^{-1} (730 L y^{-1}) is used here for consistency with the *Canadian Drinking Water Guidelines, 6th edition* – Radiological Characteristics (Health Canada 1996).

Contamination Factor

The contamination factor describes 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 action level for the duration of the assessment period. In general, the distribution of food is widespread, and individuals are likely to obtain most of their food from a wide variety of sources. Consequently, only a portion of the total diet is likely to be directly contaminated as a result of an accident. This amount is dependent on several factors, including the types of food consumed, the proximity to the source of contamination, the time and severity of the accident, and the growing season. Most people eat a varied diet, and are unlikely to rely upon a few highly contaminated foods. The dietary contributors that are most likely to be locally produced are fresh milk, seasonal vegetables, and water and locally bottled beverages.

For *Other Commercial 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 food directly affected by the emergency (1987, OECD 1989). This assumption has been supported by measurements of different levels of environmental contamination following the Chernobyl accident (OECD 1989), and recognizes the importance and ready availability of uncontaminated food from unaffected areas, as well as the many factors that could reduce or eliminate contamination of local food by the time it reaches the market (USFDA 1998). A factor of two has been applied to the expected value of 10% to account for sub-groups that might be more dependent on local foods and may therefore be consuming a larger fraction of foods directly impacted by the emergency.

In situations where a significant portion of the diet may be composed of food that is produced and consumed locally, a higher contamination factor may be appropriate. For the consumption of *Fresh Liquid Milk*, it is assumed that the entire intake by all age groups is contaminated over the duration of the assessment period (i.e., f =1). Marketed fresh milk supplies (rather than processed dairy products) 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.

Ingestion Dose Coefficients

Ingested radionuclides may remain in certain tissues and organs for extended periods of time, resulting in an exposure that is received over the lifetime of the radionuclide in the body. This is dependent on the radiological and biological half-lives of the radionuclide, and the age of the individual at intake. 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 time period following a single intake by ingestion of 1 becquerel 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 for the six age groups given in Table 2.1 have been taken from ICRP Publication 72 (1996) for ingestion by members of the public. These values represent the latest international recommendations at the time of publication of these guidelines. Values used in the calculation of action levels are provided in Appendix A: Table A.4.

Calculated Action Levels

The parameters used to calculate action levels for the various radionuclide, food, and age groups are summarized in Table 2.3.

Guidelines implemented to protect the general population must protect the most susceptible age-group, since infants and young children often consume the same food as adults. Accordingly, age-specific action levels have been calculated for radionuclides of potential importance in each food group using the parameters listed in Table 2.3. This results in six values per radionuclide and food group. The requirement for straightforward, practical guidelines leads to a single action level for each radionuclide per food group, selected as the most restrictive among the six age groups (Appendix A: Table A.5).

Table 2.3
Parameter values used to calculate action levels

Food Group	Intervention Level (mSv)[(1)]	Contamination Factor, *f*	Age Groups	Radionuclides of Interest	Dose Coefficients
Fresh Liquid Milk	1	1	3 months	$^{89/90}$Sr	Default age-dependent values from ICRP 72 (1996)
			1 year	$^{103/106}$Ru	
Other Commercial Foods and Beverages	1	0.2	5 years	$^{134/137}$Cs	
			10 years	$^{238/239/240/242}$Pu	
Drinking Water	1	1	15 years	^{241}Am	
			Adult	^{131}I	

Notes:
(1) Assessment period for intervention level is 12 months for long-lived radionuclides and 2 months for radionuclides with radioactive half-lives less than about 300 hours.

In order to reflect their uncertainty and simplify implementation by minimizing the number of unique values, the calculated action levels were grouped into similar categories based on two numerical values per order of magnitude.[5] Rounding to within a factor of three, the calculated action levels were assigned to representative single values of 1, 3, 10, 30, 100, 300 or 1 000 Bq kg^{-1}, shown in Appendix A: Table A.6.

The screening of food using the values in Table A.6 will ensure that, in terms of radiological risk, the food supply is safe for consumption by Canadians in the event of a nuclear emergency. However, as unnecessary differences in guidelines between jurisdictions may jeopardize public confidence and interfere with international trade, opportunities for harmonization with the FAO/WHO Codex Alimentarius Commission (1995) recommendations were investigated. Differences in values will exist due to the choice of age groups, diets and dose coefficients used in the derivation. Although not binding on a country, the Codex recommendations may be referred to in the event of disputes regarding differences in national guidelines. The generically optimized levels recommended by the IAEA for food are based on, and consistent with the Codex guideline values, but are limited to the radionuclides usually considered relevant to emergency exposure situations (IAEA 1994, 1996). The advantages of harmonization therefore include consistency with international trade guidelines, and reasonable assurance that recommended action levels represent a balance of risk and benefit, based on the IAEA (1994) generic optimization.

Codex guidelines, which apply in the first year following a nuclear emergency, are specified for three groups of radionuclides, classified by their dose coefficient values ($10^{-5}/10^{-6}$, 10^{-7}, and 10^{-8} Sv Bq^{-1}), and for two food groups: i) *Foods Destined for General Consumption*, and ii) *Milk and Infant Foods* (Appendix B: Table B.5). Representative radionuclides are given for each dose coefficient class. With few exceptions, the action levels calculated for *Other Commercial Foods and Beverages* for the most significant radionuclides are similar to the Codex recommendations for *Foods Destined for General Consumption* (Appendix A: Table A.6). Consequently, these values have been harmonized with values in the Codex and IAEA guidelines, with the exception of ^{106}Ru, for which a lower limit is recommended in these guidelines.

With the exception of ^{103}Ru, ^{131}I and the actinides, levels for *Fresh Liquid Milk* are generally less than those recommended by Codex for *Milk and Infant Foods*. Action levels for *Fresh Liquid Milk* have therefore not been harmonized with Codex values. As fresh milk is generally not an internationally traded commodity, differences in national guidelines should not give rise to trade disputes. Codex guidelines do not contain specific recommendations for public drinking water, although the IAEA (1996) has recommended grouping *Drinking Water* with *Milk and Infant Foods*.

In determining compliance with these guidelines, the contribution from all radionuclides in the food sample is assessed using Equation 1.1 (Part 1). This approach, while ensuring that the total dose from the ingestion of contaminated food remains below the intervention level, differs from the Codex guidelines (FAO/WHO 1995), which allow the summation of activities within each of three independent radionuclide groups, but not between groups. This difference could result in situations where food acceptable under the Codex guidelines is unacceptable under these guidelines[6]; however, the same criteria would apply to all domestic and imported food. With regards to food exports, products meeting these criteria would also meet Codex guidelines. As with Codex guidelines, no provision is made for the summation of radionuclide activities in different food samples or groups.

5. Some international organizations, such as the IAEA and Codex Alimentarius Commission have grouped action levels based on dose coefficient ranges. This method is not used here since the limiting age groups upon which Health Canada's action levels are based are not the same for all radionuclides.

6. For example, a sample containing two radionuclides in different radionuclide groups as specified in the Codex guidelines, each at an activity greater than 50% of its action level, would meet the Codex guidelines (since the groups are independent), but would fail these guidelines.

Table 2.4
Recommended action levels for radionuclides of greatest significance to dose from ingestion, and dose to most limiting age-group

Radionuclide and Half-life		Action Levels ($Bq\ kg^{-1}$)(1) and *Dose to Limiting Age Group* (mSv)(2)		
		Fresh Liquid Milk	Other Commercial Foods and Beverages	Public Drinking Water
^{89}Sr	50.5 d	300 (*1.6*)	1 000 (*1.1*)	300 (*1.6*)
^{90}Sr	29.1 y	30 (*1.0*)	100 (*0.8*)	30 (*1.0*)
^{103}Ru	39.3 d	1 000 (*1.0*)	1 000 (*0.2*)	1 000 (*1.3*)
^{106}Ru	1.01 y	100 (*1.2*)	300 (0.8)	100 (*1.3*)
^{131}I	8.04 d	100 (*0.6*)	1 000 (*1.3*)	100 (*0.8*)
^{134}Cs	2.06 y	300 (*1.1*)	1 000 (*2.0*)	100 (*1.4*)
^{137}Cs	30 y	300 (*0.9*)	1 000 (*1.4*)	100 (*0.9*)
^{238}Pu	87.7 y	1 (*0.6*)	10 (*1.2*)	1 (*0.6*)
^{239}Pu	24 100 y	1 (*0.6*)	10 (*1.3*)	1 (*0.6*)
^{240}Pu	6540 y	1 (*0.6*)	10 (*1.3*)	1 (*0.6*)
^{242}Pu	376 000 y	1 (*0.6*)	10 (*1.2*)	1 (*0.6*)
^{241}Am	432 y	1 (*0.5*)	10 (*1.1*)	1 (*0.6*)

Notes:
(1) $Bq\ L^{-1}$ for Drinking Water
(2) Doses (in parentheses) in the above table do not correspond exactly with the intervention level of 1 mSv due to rounding of the calculated action levels and harmonization with Codex guidelines. Actual doses will likely be lower since not all food will be contaminated to the action level.

Recommended Action Levels for Radionuclides of Interest

Recommended action levels for the most significant radionuclides (Part 1: Table 1.1), and the corresponding doses to the limiting age groups, are given in Table 2.4 for the three food groups, based on the assumption that the consumed food is contaminated at the action level for the duration of the assessment period. This assumption is very conservative and will likely overestimate potential doses by a significant amount. These action levels for the withdrawal and substitution of food and drinking water following a nuclear emergency are appropriate if there is no shortage of food or other social or economic constraints.

While radionuclides other than those given in Table 1.1 may be detected in food following a radiological emergency, these are generally of less significance to the total ingestion dose. In the event that some of these are present in food samples, corresponding action levels have been presented in Part 1: Table 1.2. These radionuclides are not specifically listed in the recommendations of the Codex Alimentarius Commission, and have therefore not been harmonized. A more detailed discussion on implementation is given in Part 1 of these guidelines.

Implications of Guidelines on Dose, Risk, and Public Confidence

Implications on Dose and Risk

In the screening of food for compliance with the guidelines, it is assumed that an individual's total consumption of the relevant food group will be contaminated to the level measured in the sample for the entire assessment period. By way of illustration, if a sample of fresh milk contains a given concentration of ^{90}Sr, the screening criteria assumes that an individual consumes this milk at the measured ^{90}Sr concentration for the entire year, regardless of the time of sampling, or of the radionuclide levels measured in other samples. No allowance is made for milk already consumed, since only those supplies which meet the screening criteria will be allowed into the marketplace. Application of the summation criterion given in Part 1 ensures that, if multiple radionuclides are present, the intervention level will not be exceeded.

The avoidance of doses arising from the ingestion of *Fresh Liquid Milk* or *Public Drinking Water* is straightforward since each group consists of only one food type. With regards to *Other Commercial Foods and Beverages*, which is composed of many different food types (Appendix A: Table A.1), action levels have been derived using the total dietary intake of all the food types comprising the group. However, when a food sample is evaluated against the applicable action levels, it is assumed that the total dietary intake is composed exclusively of the specific food type in question. Therefore, if an individual consumes only food that meets the screening criteria for single or multiple radionuclides, the intervention level will not be exceeded. This conservative assumption allows each food type to be assessed independently, without having to account for actual dietary patterns or contamination levels in other foods.

In practice, not all food will be contaminated to the same level following a release of radioactive material to the environment, or with the same radionuclides. The dose an individual receives from ingestion reflects the levels of radionuclide concentrations in the food consumed, and will therefore vary between individuals. The effect of intervention is to limit the maximum dose that could be received from contamination in the food and water supply, and thereby to limit the expected number of radiologically-attributable health effects in the entire population.

The hypothetical population-averaged risk of fatal cancer associated with the intervention level of 1 mSv is about 5 in 100 000. If the three food groups were each continuously contaminated at the action levels and consumed at the estimated fraction of the total diet, the effective dose received from the commercial food and public water supply would be on the order of 3 mSv in the first year following the emergency.[7] At this dose, the hypothetical excess lifetime risk of radiologically-attributable fatal cancers in the general population would be on the order of 15 in 100 000 from one year of exposure, based on the ICRP (1991) population-averaged risk coefficient. The annual effective dose from ingestion due to contamination in the years following an emergency is likely to be considerably less than that received in the first year, and would approach background levels within a few years.

In general, the average level of radionuclide contamination of the diet will be much lower than the action levels. Therefore, the actual dose received by individuals, and the corresponding radiological risk, will be substantially less than would be estimated on the assumption that all food is contaminated at the action level for the duration of the assessment period (IAEA 1994). Further, the assumptions on which the action levels are derived would most likely over-estimate the expected dose to most members of the population by a substantial amount, since the limiting age groups are not the same for all food groups and radionuclides. Therefore, it is very unlikely that doses would be higher than the intervention level, even if an individual’s diet is significantly different from the assumptions used in the derivations of the action levels.

The doses received by individuals of the population will vary depending on the specific emergency conditions, and the type and quantities of food consumed. However, the action levels recommended in this document should not need adjustment unless it is shown that they are excessively inappropriate for the situation (see Part 1).

Perspective on the Dose and Risk from Contaminated Food

The health risks associated with the emergency intervention level of 1 mSv per food group are higher than what would be expected from background levels of radionuclides in food under normal conditions, as they must be balanced against the physical risks associated with intervention. The following section compares these risks with other natural and man-made radiological risks.

In Canada, the average dose due to naturally occurring background radiation is about 2 mSv per year (AECB 1995), of which about one-half comes from the inhalation of naturally-occurring radon and its short-lived decay products. About 0.7 mSv per year, nationally-averaged, arises from cosmic and terrestrial gamma radiation (Tracy, *et al.*, 1996). The portion of the background dose resulting from ingestion of natural radionuclides in food is about 0.25-0.4 mSv (Jacobi 1988; Harley 1988).

In addition to the background radiation, doses arising from the routine operation of nuclear power stations are typically in the range of 0.002-0.02 mSv per year to the most exposed groups (Health Canada 1998), of which only a portion is due to the consumption of food. Guideline levels for natural and man-made radionuclides in drinking water under non-emergency conditions are based on a dose level of 0.1 mSv y^{-1} (Health Canada 1996), although actual doses received from the consumption of water are typically much less. For example, the average annual dose from tritium in water supplies near all Ontario nuclear reactors is on the order of 0.0001-0.0005 mSv. The hypothetical health risks associated with these exposures are shown in Table 2.5.

The hypothetical excess lifetime risk associated with one year of exposure to the total background radiation dose is about 1 in 10 000 for attributable fatal cancers. The risk associated with a lifetime exposure (70 years) is about 7 in 1 000. This is 2.5% of the total cancer mortality of 280 per 1 000 observed in the Canadian population in 1991 and 1992 (Health Canada 1998; Statistics Canada 1993, 1995). The impacts from the ingestion of contaminated food, although not negligible, would be difficult to detect against the total cancer incidence.

7. This is an approximate value since the harmonized action levels do not correspond exactly with the intervention level, and the summation criterion for multiple radionuclides combines different assessment periods for long- and short-lived radionuclides.

Table 2.5
Comparison of dose and health risk associated with the intervention level and other radiation sources

Source	Effective Dose	Risk of Fatal Cancer
Emergency Intervention Level for Contaminated Food and Water	1 mSv y^{-1} for each of 3 food groups	1 mSv: 1 in 20 000 y^{-1} per group 3 mSv: 1 in 6 500 y^{-1} maximum (for duration of contamination)
Dose Level for Drinking Water Guidelines (non-emergency)	0.1 mSv y^{-1} from water	1 in 200 000 y^{-1}
Natural Background Radiation, including:	2 mSv y^{-1}	1 in 10 000 y^{-1} 7 in 1 000 lifetime (70 years)
■ radon and decay products	■ 1 mSv y^{-1}	■ 1 in 20 000 y^{-1}
■ external gamma dose	■ 0.7 mSv y^{-1}	■ 1 in 30 000 y^{-1}
■ internal radionuclides from food and water	■ 0.25 – 0.4 mSv y^{-1}	■ 1 in 50 000 – 80 000 y^{-1}
Nuclear Power Plants[(1)], including:	0.002 – 0.02 mSv y^{-1}	1 in 1×10^6 – 1×10^7 y^{-1}
■ tritium in drinking water	■ 0.1-0.5 µSv y^{-1}	■ 1 in 4×10^7 – 2×10^8 y^{-1}

Note:
(1) For the most exposed groups.

Implications for Public Confidence

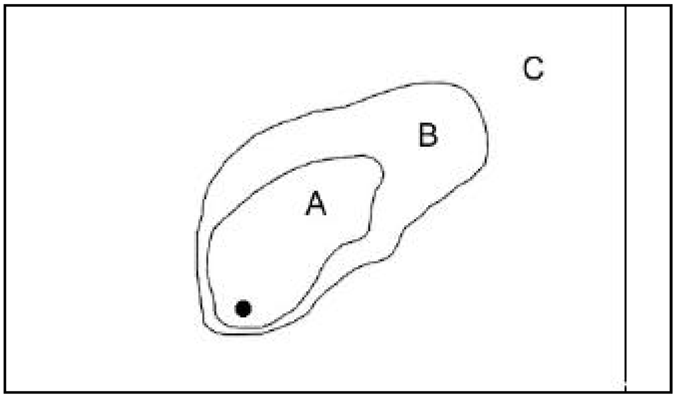
As the intervention level decreases, the quantity of food failing the criteria is likely to increase. The ICRP (1994) and IAEA (1996) address the general cost-benefit implications of this relationship in their generic optimizations by setting action levels for emergency conditions that are not site- or country-specific, based on estimates of the typical costs and benefits of intervention. However, when applied within a particular national context, intervention and action levels based solely on cost-benefit analysis may not necessarily take account of societal tolerance for an additional health risk due to unforeseen or uncontrolled events at a nuclear facility. Although excluding sociopolitical factors from its generic analysis, the IAEA (1996) has stated that action levels for food should take due account of the need for consistency with national food and public health laws, and the need to build and maintain public confidence.

It is Health Canada's judgement that food intervention levels based on strict radiation protection criteria and cost-benefit analysis, without consideration to social factors relevant to a post-emergency situation, may result in levels that could be regarded by consumers, distributors, and the food industry as unacceptable. This will increase the risk of a loss of confidence in the safety of the food supply, and the potential rejection of all foods from an affected region or province, regardless of actual contaminant levels, if alternate supplies are available. A comparable reaction was observed in the general public outside of the former Soviet Union following the 1986 Chernobyl accident, due to a lack of confidence in the advice received from public officials (OECD 1996).

In the event of a nuclear emergency in Canada or abroad, unaffected provinces and countries will likely impose immediate, temporary embargoes on all foods imported from the affected region, pending confirmation of any contamination. This underscores the need to maintain public confidence in food safety, and the low tolerance of the public for radiation risk, particularly from food, which may have a radiological health impact far beyond the affected region. Other experiences concerning risk acceptability, including public consultations on proposed criteria for tritium in Ontario drinking water (ACES 1994), have shown the public's aversion to any additional radiological risk. In developing a single guideline for contaminated food, Health Canada has taken into consideration a lower acceptability of risk in unaffected regions to which food may be exported.

It is possible to factor the economic impact of rejecting a food supply into a cost-benefit analysis; however, this would be very complex and has only been considered qualitatively in the following discussion. Referring to Figure 2.1, an intervention level set at a higher value, IL_A, would lead to the banning of food from a relatively small area *A*. Lowering the intervention level to IL_B extends the area of interdiction to a somewhat larger area *B*. However, an intervention level set at a value that, while theoretically resulting in a smaller area of interdiction (e.g., IL_A), could result in a loss of public confidence, may lead to a boycott of all foods from area *C*, representing the entire region or province. A boycott of food that is perceived to be unsafe will result in a much larger quantity of unmarketable foods, and hence a more severe economic impact. Even with a larger area of interdiction, fresh foods that are withheld from market may nevertheless be suitable for alternate uses, or processes that can reduce the levels of contamination (IAEA 1992).

Figure 2.1
Comparison of areas from which locally produced foods would be unmarketable (hypothetical)



A: Area affected by intervention level, IL_A
B: Area affected by intervention level, $IL_B < IL_A$
C: Area affected by a boycott of all food originating in region or province

This risk is significant for restrictions placed on foods originating in the affected zone, and which may be distributed and marketed in regions not directly impacted by the emergency. In the context of the Canadian marketplace, foods produced in a variety of areas within and outside the country are readily available to consumers, who will have the option of purchasing or rejecting products originating from regions affected by the emergency.

In these guidelines, the food supply is considered 'safe' in the sense that radiation dose and health risk are limited, if the expected ingestion dose is below the intervention level of 1 mSv per food group. It is Health Canada's judgement that this intervention level provides an adequate degree of safety, and represents a reasonable expectation of what the public will accept in the event of an emergency, in that the level provides assurance that doses for a single food group will not be above the limit for normal practices. This is important for food, as it may be exported to regions that are not directly affected by the accident, and will potentially affect a larger population. Action levels based on 1 mSv per food group will be greater than the normal levels detected in food, but as shown in the preceding rationale, are similar to the guidelines of the Codex Alimentarius Commission. (FAO/WHO 1995). Intervention levels exceeding 1 mSv per food group could significantly increase the risk of a loss of public confidence in the safety of the food supply, and the ability of regulators and officials to protect public health.

Comparison with International Recommendations – Summary

Appendix B presents an overview of the approaches taken by various international organizations and foreign governments in the development of intervention criteria for foods following an emergency. The two main approaches used in the development of action levels for contaminated food and water are dose limitation and optimization of intervention. The manner in which these are applied by the various organizations is shown in Table B.1. A comparison of the resulting recommended action levels is given below in Table 2.6, which shows that although the approaches taken by different organizations may vary, there is a general consistency in the recommendations.

As stated previously, Health Canada's guidelines for contaminated food and water have been developed on the basis of dose limitation as this approach does not require information that may not be readily available during the early phases of an emergency. In developing these recommendations, Health Canada has taken into consideration the need to maintain the safety of, and public confidence in, the commercial food supply, consistent with the objectives of the *Food and Drugs Act*.

The action levels given here for contaminated food and water are generally consistent with the guidelines of other organizations, in spite of the differences in the choice of intervention level, the number of food groups, and national versus globally-averaged food consumption rates. The fact that these levels are in reasonable agreement with those of the IAEA for developed countries provides assurance that they are not inconsistent with action levels derived from cost-benefit analysis.

As with all approaches to controlling doses resulting from accidental contamination of food and water, these recommendations represent a balance between the benefits and risks of intervention; they do not represent boundaries between safe and unsafe levels of radiation exposure. The approach recommended in these guidelines attempts to limit health risk and ensure public confidence, while providing an easily implemented methodology of control. In all cases, the specific conditions following a radiological emergency should be considered to ensure that these guidelines are implemented in an appropriate manner.

Table 2.6
Comparison of action levels recommended by different organizations

Radionuclide	Health Canada	CODEX and IAEA	CEC[1]		WHO[2]		USFDA[3]	ICRP[4]
		International Recommendations for Equivalent Food Groups (Bq kg^{-1})						
Fresh Liquid Milk		Milk and Infant Foods	Dairy	Infant Foods	Milk	Infant Milk	Total Diet	Single Foodstuff
^{134}Cs	300	1 000	1 000	400	4 500	–	1 200	10^3-10^4
^{137}Cs	300					1 800		
^{103}Ru	1 000					–	6 800	
^{106}Ru	100					–	450	
^{89}Sr	300		125	75		–	–	
^{90}Sr	30	100				160	160	
^{131}I	100		500	150		1 600	170	
^{241}Am	1	1	20	1	45	–	2	10-100
$^{238/239}$Pu	1					7		
Other Commercial Foods and Beverages								
^{134}Cs	1 000	1 000	1 250	(n/a)	3 500 - 35 000	(n/a)		
^{137}Cs	1 000							
^{103}Ru	1 000							
^{106}Ru	300							
^{89}Sr	1 000		750					
^{90}Sr	100	100						
^{131}I	1 000		2 000					
^{241}Am	10	10	80		35 - 350			
$^{238/239}$Pu	10							
Public Drinking Water								
^{134}Cs	100	1 000	1 000		700	700		
^{137}Cs	100							
^{103}Ru	1 000							
^{106}Ru	100							
^{89}Sr	300		125					
^{90}Sr	30	100				160		
^{131}I	100		500					
^{241}Am	1	1	20		7	7		
$^{238/239}$Pu	1							

Notes:

AL — Numbers within solid outlined box indicates that contributions from radionuclides are summed. Dotted lines indicate summed values with different action levels.

(1) Council of European Communities (CEC).

(2) World Health Organization (WHO). Contribution from all detected radionuclides is summed over all food and radionuclide groups.

(3) United States Food and Drug Administraiton (USFDA).

(4) ICRP: Applies to a single foodstuff, with range of optimized values given as:
1 000-10 000 Bq kg^{-1} (beta/gamma emitters); 10-100 Bq kg^{-1} (alpha emitters).

APPENDIX A: PARAMETERS USED IN THE CALCULATION OF ACTION LEVELS FOR FOOD AND WATER

The following tables contain information on the parameters used to derive the action levels given in these guidelines. They may also be used to assist in deriving action levels for different radionuclides or situations.

Table A.1
Mean annual consumption of various food types by Canadians (Health Canada 1993, HWC 1976)

Food Group	Consumption (kg y^{-1})(1)				
	0- 6 mo	7 mo - 4 y	5-11 y	12-19 y	20+ y
Fresh Liquid Milk	145	230	205	190	85
Other Commercial Foods and Beverages	156	309	450	519	499
Other Commercial Foods include:					
■ Infant Formula(2)	33	–	–	–	–
■ Diary Products (non-fresh milk)	22	14	16	18	19
■ Meat, Poultry, Fish, Eggs	14	33	44	62	67
■ Cereal Products	19	61	109	119	90
■ Fruit and Fruit Products	41	69	74	58	68
■ Vegetables	15	46	72	91	91
■ Fats	0.3	4	8	11	9
■ Nuts and Dried Legumes	0.1	2	5	7	4
■ Foods Primarily Sugar	9	17	21	24	21
■ Mixed Dishes and Soups	2	26	30	33	37
■ Soft Drinks, Alcohol	0.7	37	71	96	93

Notes:
(1) Calculated from daily intake values in g day^{-1} provided by Health Canada (1993).
(2) Tap water consumption of 400 mL day^{-1} is assumed for the preparation of concentrated formula.

Table A.2
Average annual tap water consumption and ranges for Canadians (Health Canada 1993, HWC 1981)

Age Group	**Tap Water Consumption ($L\ y^{-1}$)(1)** Mean	10th Percentile	90th Percentile
5 y and under	277	84	548
6-17 y	416	135	807
18 and over	544	234	946

Notes:
(1) Calculated from daily intake values in $L\ day^{-1}$ provided by Health Canada (1993).

Table A.3
Relationship between Health Canada (1993) consumption rates by age group and ICRP age groups

ICRP Age Group	**Health Canada (1993) Food and Water Consumption Rates** Fresh Liquid Milk / Other Commercial Foods (from Table A.1)	Public Drinking Water (from Table A.2)
3 months	0-6 mo value	400 $mL\ day^{-1}$ for bottle-fed infants
1 year	Average of 0-6 mo and 7 mo-4 y values (excluding rate for infant formula)	Mean value for 5 y and under
5 year	Average of 7 mo-4 y and 5-11 y values	Mean value for 5 y and under
10 year	5-11 y value	Mean value for 6-17 y
15 year	12-19 y value	Mean value for 6-17 y
Adult	20+ y value	Adult value from *Guidelines for Canadian Drinking Water, 6th Edition* (Health Canada 1996)

Table A.4
Age-specific committed effective dose coefficients for ingestion (ICRP 1996)

Radionuclide	Half-life	Ingestion Dose Coefficient, e(t), to Age 70 y (Sv Bq^{-1})					
		3 month	**1 year**	**5 year**	**10 year**	**15 year**	**Adult**
Radionuclides of Potential Significance to Ingestion Dose							
^{89}Sr	50.5 d	3.6e-08	1.8e-08	8.9e-09	5.8e-09	4.0e-09	2.6e-09
^{90}Sr	29.1 y	2.3e-07	7.3e-08	4.7e-08	6.0e-08	8.0e-08	2.8e-08
^{103}Ru	39.3 d	7.1e-09	4.6e-09	2.4e-09	1.5e-09	9.2e-10	7.3e-10
^{106}Ru	1.01 y	8.4e-08	4.9e-08	2.5e-08	1.5e-08	8.6e-09	7.0e-09
^{131}I	8.04 d	1.8e-07	1.8e-07	1.0e-07	5.2e-08	3.4e-08	2.2e-08
^{134}Cs	2.06 y	2.6e-08	1.6e-08	1.3e-08	1.4e-08	1.9e-08	1.9e-08
^{137}Cs	30 y	2.1e-08	1.2e-08	9.6e-09	1.0e-08	1.3e-08	1.3e-08
^{238}Pu	87.7 y	4.0e-06	4.0e-07	3.1e-07	2.4e-07	2.2e-07	2.3e-07
^{239}Pu	24 100 y	4.2e-06	4.2e-07	3.3e-07	2.7e-07	2.4e-07	2.5e-07
^{240}Pu	6 540 y	4.2e-06	4.2e-07	3.3e-07	2.7e-07	2.4e-07	2.5e-07
^{242}Pu	376 000 y	4.0e-06	4.0e-07	3.2e-07	2.6e-07	2.3e-07	2.4e-07
^{241}Am	432 y	3.7e-06	3.7e-07	2.7e-07	2.2e-07	2.0e-07	2.0e-07
Radionuclides of Lesser Significance to Ingestion Dose							
^{3}H *tritiated water*	12.35 y	6.4e-11	4.8e-11	3.1e-11	2.3e-11	1.8e-11	1.8e-11
Organically-bound tritium		1.2e-10	1.2e-10	7.3e-11	5.7e-11	4.2e-11	4.2e-11
^{14}C	5 730 y	1.4e-09	1.6e-09	9.9e-10	8.0e-10	5.7e-10	5.8e-10
^{51}Cr	27.7 d	3.5e-10	2.3e-10	1.2e-10	7.8e-11	4.8e-11	3.8e-11
^{55}Fe	2.7 y	7.6e-09	2.4e-09	1.7e-09	1.1e-09	7.7e-10	3.3e-10
^{59}Fe	44.5 d	3.9e-08	1.3e-08	7.5e-09	4.7e-09	3.1e-09	1.8e-09
^{60}Co	5.27 y	5.4e-08	2.7e-08	1.7e-08	1.1e-08	7.9e-09	3.4e-09
^{65}Zn	244 d	8.5e-09	5.6e-09	3.0e-09	1.9e-09	1.2e-09	9.5e-10
^{91}Y	58.5 d	2.8e-08	1.8e-08	8.8e-09	5.2e-09	2.9e-09	2.4e-09
^{95}Zr	64 d	8.5e-09	5.6e-09	3.0e-09	1.9e-09	1.2e-09	9.5e-10
^{95}Nb	35.1 d	4.6e-09	3.2e-09	1.8e-09	1.1e-09	7.4e-10	5.8e-10
^{99}Mo	2.75 d	5.5e-09	3.5e-09	1.8e-09	1.1e-09	7.6e-10	6.0e-10
^{110m}Ag	250 d	2.4e-08	1.4e-08	7.8e-09	5.2e-09	3.4e-09	2.8e-09
^{132}Te	3.26 d	4.8e-08	3.0e-08	1.6e-08	8.3e-09	5.3e-09	3.8e-09
^{140}Ba	12.7 d	3.2e-08	1.8e-08	9.2e-09	5.8e-09	3.7e-09	2.6e-09
^{140}La	1.68 d	2.0e-08	1.3e-08	6.8e-09	4.2e-09	2.5e-09	2.0e-09
^{141}Ce	32.5 d	8.1e-09	5.1e-09	2.6e-09	1.5e-09	8.8e-10	7.1e-10
^{144}Ce	284 d	6.6e-08	3.9e-08	1.9e-08	1.1e-08	6.5e-09	5.2e-09
^{237}Np	2.14e+06 y	2.0e-06	2.1e-07	1.4e-07	1.1e-07	1.1e-07	1.1e-07
^{239}Np	2.36 d	8.9e-09	5.7e-09	2.9e-09	1.7e-09	1.0e-09	8.0e-10
^{241}Pu	14.4 y	5.6e-08	5.7e-09	5.5e-09	5.1e-09	4.8e-09	4.8e-09
^{244}Pu	8.26e+07 y	4.0e-06	4.1e-07	3.2e-07	2.6e-07	2.3e-07	2.4e-07

Table A.5
Calculated action levels for radionuclides of greatest significance to dose from ingestion, based on limiting age-group

Radionuclide	Half-life	Calculated Action Levels (Bq kg^{-1})		
		Fresh Liquid Milk	Other Commercial Foods and Beverages	Public Drinking Water
^{89}Sr	50.5 d	190	895	185
^{90}Sr	29.1 y	30	120	30
^{103}Ru	39.3 d	970	4 540	790
^{106}Ru	1.01 y	80	385	75
^{131}I	8.04 d	180	775	120
^{134}Cs	2.06 y	265	505	70
^{137}Cs	30 y	330	740	105
^{238}Pu	87.7 y	2	8	2
^{239}Pu	24 100 y	2	8	2
^{240}Pu	6 540 y	2	8	2
^{242}Pu	376 000 y	2	8	2
^{241}Am	432 y	2	8	2

Table A.6
Comparison of preliminary action levels with recommendations of the FAO/WHO Codex Alimentarius Commission (1995) and IAEA (1996)[(1)]

Radionuclide	Preliminary Action Levels (Bq kg^{-1}), and Codex/IAEA Recommendations					
	Fresh Liquid Milk		Other Commercial Foods and Beverages		Public Drinking Water[(2)]	
^{89}Sr	300	*(1 000)*	1 000	*(1 000)*	300	*(1 000)*
^{90}Sr	30	*(100)*	100	*(100)*	30	*(100)*
^{103}Ru	1 000	*(1 000)*	3 000	*(1 000)*	1 000	*(1 000)*
^{106}Ru	100	*(1 000)*	300	*(1 000)*	100	*(1 000)*
^{131}I	100	*(100)*	1 000	*(1 000)*	100	*(100)*
^{134}Cs	300	*(1 000)*	300	*(1 000)*	100	*(1 000)*
^{137}Cs	300	*(1 000)*	1 000	*(1 000)*	100	*(1 000)*
$^{238/239/240/242}$Pu, ^{241}Am	1	*(1)*	10	*(10)*	1	*(1)*

Notes:
(1) Preliminary values in the above table are only for comparison with Codex/IAEA values before harmonization.
(2) Only IAEA has given action levels for drinking water.

APPENDIX B: INTERNATIONAL GUIDANCE ON FOOD INTERVENTION

Prior to the 1986 Chernobyl accident, general principles on the planning of intervention in the event of a nuclear emergency had been given by several national and international radiation protection agencies, including the ICRP (1984), WHO (1984) and IAEA (1985). Recommended intervention levels for various countermeasures were based on two levels of effective dose, the lower below which intervention would unlikely be warranted, and the higher above which it would almost certainly be necessary.

Since that time, the ICRP has published new recommendations for protection against ionizing radiation under both normal and emergency situations (ICRP 1991, 1993). Following an uncontrolled release to the environment, the ICRP recommends that the levels at which countermeasures are introduced and later withdrawn should be expressed in terms of the dose expected to be avoided by the action, and should be optimized to produce the maximum net benefit. This approach has also been recommended by the IAEA in its Basic Safety Series (IAEA 1996). However, these recommendations are not binding on individual countries.

The following section discusses the current approaches to intervention in the distribution of food by various national and international organizations. A comparison of methodologies (Table B.1) is provided first. This table, together with the comparison of action levels recommended by different organizations (Part 2: Table 2.6) demonstrates that although the methodologies may vary, there is a general consistency in the recommended action levels for food and water.

Table B.1
Comparison of methodologies adopted by various international organizations

Organization	Intervention Level	Food Groups	Contamination Factor	Action Level Groups	Implementation
Health Canada	1 mSv per food group	3 food groups	f = 1 for fresh liquid milk and tap water; f = 0.2 for all other foods.	For individual radionuclides.	Applied independently between food groups; all radionuclides additive within single food group.
ICRP	10 mSv averted dose for a single food – optimized values for specific foods based on cost-benefit analysis.			For 2 dose coefficient categories.	Applied independently to single foodstuffs – actual intervention criteria based on real accident conditions.
IAEA	Optimized action levels derived from cost-benefit analysis.	2 groups classified by cost per kg	Not applicable.	For 3 dose coefficient categories.	Applied independently between food and radionuclide groups; additive within single group.
Codex	5 mSv whole body	2 groups	f = 1.0	*As above*.	*As above*.
CEC		5 groups		For 4 radionuclide groups.	*As above.*
WHO	5 mSv whole body, 50 mSv thyroid	Adult – 8 groups Infants – 1 group	f = 1.0	For 2 dose coefficient categories.	Additive between all food and radionuclide groups.
USFDA	5 mSv whole body, 50 mSv thyroid	Applied to total diet.	f = 0.3, except f = 1.0 for I & Te in infant milk diet	For 5 groups of 9 radionuclides.	Applied independently between radionuclide groups; additive within single group.

International Commission on Radiological Protection

In 1993, the ICRP introduced revised guidance on intervention following a radiological emergency, superceding its previous recommendations (ICRP 1984). The ICRP recommends that intervention be justified and optimized in order to produce the maximum net benefit, recognising that any action that minimizes radiation risk may itself be associated with its own degree of cost and detriment. The ICRP advocates the use of these two principles to determine the appropriate level at which intervention should be considered, rather than the use of pre-determined limits as the basis for providing intervention. Justification and optimization studies should be based on the dose averted by a specific protective action. The sum of the remaining doses from all pathways after implementation of protective actions should be kept under review.

To aid in the implementation of its recommendations, generic intervention levels for which action is almost always justified have been established for various protective measures. For the control of radiologically-contaminated food and water, the ICRP recommends that for any single foodstuff, an intervention level that is almost always justified is an averted effective dose of 10 mSv in a year, providing that there are nutritionally adequate alternative supplies.

Using the cost of the food per unit mass, the consumption rate of the food per person, and the appropriate dose coefficients, a simplified generic optimization has been carried out, resulting in the optimized intervention levels shown in the following table. Higher values would be expected in the case of severe food shortages. It is assumed that, in general, contaminated food contributes only a fraction of the total diet of a consumer.

Table B.2
ICRP recommendations

Radionuclide Category	Action Levels (Bq kg^{-1})
Radionuclides with low dose coefficients (e.g., most beta and gamma emitters, such as ^{137}Cs, ^{131}I)	1 000 – 10 000
Radionuclides with high dose coefficients (e.g., alpha emitters, such as ^{239}Pu)	10 – 100

Table B.3
IAEA recommendations

Radionuclide	Action Levels (Bq kg^{-1})	
	Foods for General Consumption	Milk, Infant Foods, Drinking Water
^{134}Cs, ^{137}Cs, ^{103}Ru, ^{106}Ru, ^{89}Sr	1 000	1 000
^{131}I		100
^{90}Sr	100	
^{241}Am, ^{238}Pu, ^{239}Pu, ^{240}Pu, ^{242}Pu	10	1

International Atomic Energy Agency

The latest IAEA recommendations provide a set of generic intervention levels for the major protective measures to be taken in the event of a nuclear emergency, based on justification and optimization (IAEA 1994, 1996). Generic levels have been based on radiological protection principles, and on the premise that the level of effort allocated to such protection should be at least as great as the level of effort and resources allocated to the protection of public health from other risks of a similar magnitude and nature. Psychological and political factors have been excluded in the development of generic levels, in order to form a common baseline for decisions on protective measures. Although excluded from the generic optimizations, these factors may contribute to, or even dominate, some decisions, in which case deviation from the generic levels becomes a matter of national policy, circumstances or site-specific factors (IAEA 1994).

Generic action levels for the withdrawal of food have been calculated by applying a simple cost-benefit analysis. The food supply has been classified into two broad groups defined by their value per kilogram, with associated annual consumption rates. Action levels are specified for three groups of radionuclides with similar dose coefficients, leading to a set of six generically optimized ranges of values for which withdrawal and substitution of foods should be considered. On the basis of these ranges, but with account taken of existing national and international legislation and of the issue of practicality, a single set of action levels has been selected that encompass the Codex Alimentarius Commission's guideline values for foods moving in international trade (FAO/WHO 1991).

These levels apply to food as consumed. Levels are applied independently of one another; however, within a single group, the radionuclide concentrations are additive. Classes of food consumed in small quantities (less than 10 kg y^{-1}) may have action levels ten-fold higher.

World Health Organization

WHO issued guidelines in 1988 (WHO 1988), intended to assist national authorities in countries at some distance from the accident site in developing intervention levels for food.[8] WHO recommends a simple and conservative methodology based on a limiting annual individual dose, and the assumption that all food is contaminated at the intervention level. WHO has chosen an intervention level of 5 mSv in a year, based on a comparison with global variations in the effective dose due to natural radiation, and because no remedial measures have been recommended for avoiding exposure from other natural sources at doses of 5 mSv or less. WHO has pointed out that cost-benefit analysis based on a population dose criterion results in an intervention level of several mSv per year. However, when the cost of intervention is low, it may well be justified to reduce the detriment to a lower level of dose. An intervention level of dose for the thyroid of 50 mSv has been set as a secondary limit.

8. WHO has not issued new guidance following the latest recommendations of the ICRP (1991), which include revisions in its methodology and terminology for expressing radiation doses. WHO uses terminology previously defined in the former ICRP recommendations (ICRP 1977).

Table B.4
WHO recommendations

Class of Radionuclide	Derived Intervention Levels by Food Group (Bq kg^{-1})							
	Cereals	Roots and Tubers	Vegetables	Fruit	Meat	Milk	Fish	Drinking Water
i. High dose coefficients, 10^{-6} Sv Bq^{-1}	35	50	80	70	100	45	350	7
ii. Low dose coefficients, 10^{-8} Sv Bq^{-1}	3 500	5 000	8 000	7 000	10 000	4 500	35 000	700
Guideline values for infants on milk diet								
^{90}Sr	160							
^{131}I	1 600							
^{137}Cs	1 800							
^{239}Pu	7							

WHO has divided the food supply into eight categories, including drinking water. The annual consumption rate of a particular food category is derived from a hypothetical diet based on above-average consumption rates of different food components in different parts of the world, normalized to a total consumption of 550 kg y^{-1}. The radionuclides most likely to be of significance in food pathways after a nuclear emergency have been grouped into 2 broad categories of high and low dose coefficients. Separate guidelines were developed for infants on a milk and water diet, as it was felt that the rounded dose coefficients and normalized hypothetical diet did not provide adequate protection.

If several food categories are contaminated by one or more radionuclides, a summation over all radionuclides and food groups is required to ensure that the 5 mSv level is not exceeded. Guideline values apply to food as it is consumed.

FAO/WHO Codex Alimentarius Commission

The FAO/WHO Codex Alimentarius Commission, a body set up jointly by the Food and Agriculture Organization (FAO) of the United Nations, and the WHO, adopted guideline levels for radionuclides in food in 1989 (FAO/WHO 1989, 1991, 1995). These guidelines apply only to potentially contaminated food moving in international trade during the first year following an emergency. Although not binding on a country, Codex recommendations will be referred to in the event of trade disputes regarding differences in national guidelines.

Codex guidelines are largely based on WHO guidance, but with further simplification. An intervention level of 5 mSv is used, but there is minimal distinction between food types. The Codex Commission has recommended intervention levels for two food groups: *Foods Destined for General Consumption*, and *Milk and Infant Food*. Infant foods are those foods prepared and packaged specifically for infants in their first year of life. Levels in both groups are based on a single annual consumption rate 550 kg y^{-1}, all of which is contaminated.

The Codex Commission has grouped the dose coefficients for the radionuclides of concern into three classes (10^{-5} or 10^{-6} depending on food group, 10^{-7} and 10^{-8} Sv Bq^{-1}). Levels for representative radionuclides in each dose coefficient group are listed, although any radionuclide can be placed into its appropriate group. There is no provision in the Codex guidelines for summation across radionuclide groups; each level applies independently of one another. Within groups, radionuclide contributions are to be added for comparison with the level.

Table B.5
Codex Alimentarius recommendations

Dose Coefficient (Sv Bq^{-1})	Representative Radionuclides	Level (Bq kg^{-1})
Food Destined for General Consumption		
10^{-6}	^{241}Am, ^{239}Pu	10
10^{-7}	^{90}Sr	100
10^{-8}	^{131}I, ^{134}Cs, ^{137}Cs	1 000
Milk and Infant Foods		
10^{-5}	^{241}Am, ^{239}Pu	1
10^{-7}	^{131}I, ^{90}Sr	100
10^{-8}	^{134}Cs, ^{137}Cs	1 000

Nuclear Energy Agency of the Organization for Economic Co-operation and Development

The Nuclear Energy Agency (NEA) has issued guidance (OECD 1989, 1990) intended to assist national authorities in the development of policies and criteria for the management of the consequences of a nuclear emergency. As with the ICRP and IAEA, the basic principles for intervention are those of justification and optimization, while recognizing the value to emergency planning of predetermined criteria. In the planning and preparedness phase, a generic optimization is recommended in order to develop generic intervention levels for use immediately following an emergency. In the event of a real emergency, a more precise optimization is recommended, resulting in specific intervention levels for use in the medium and long-term (OECD 1990).

While no specific action levels for food have been given, the NEA suggests that these be derived on the basis of groupings of radionuclides rather than for individual nuclides. Radionuclides may be grouped on the basis of comparable radiotoxicity, and the most restrictive dose coefficient in each group, for the most restrictive age group, should be selected as the basis for the derived intervention level. Four radionuclide groups are suggested, namely, iodine isotopes (e.g., ^{131}I), cesium isotopes (e.g., ^{137}Cs), other long-lived radionuclides (e.g., ^{90}Sr), and alpha-emitting radionuclides (e.g., ^{239}Pu). Derived intervention levels should be developed only for the major components of the diet; additivity should be considered only if the contributions to the ingestion dose from different foods are of a similar degree of importance, and individually represent a significant fraction of the corresponding derived intervention level.

Council of the European Communities; National Radiological Protection Board of the United Kingdom

Following the 1986 Chernobyl accident, the Council of the European Communities (CEC) issued Regulations on maximum permitted levels of radionuclides in food that would be legally binding on its member countries following a radiological emergency (CEC 1989, 1989a, 1989b, 1990, 1992). There are further Regulations dealing with foods imported from, and exported to, countries outside of the European Communities (CEC 1987a, 1989b).

Council Food Intervention Levels (CFILs) have been established for four radionuclide groups, and five food categories, and apply to food as marketed, rather than to food as consumed. Within each radionuclide and food group, the sum of the concentrations of all the specified radionuclides detected in the food is compared with the intervention level. However, each intervention level is applied independently of one another. CFILs have also been derived for radioisotopes of Cs in animal feeds.

Although the liquid foods group does not explicitly cover drinking water, the Regulations state that CFILs for such foods should be applied to drinking water at the discretion of competent authorities in member states. In its guidelines, the National Radiological Protection Board (NRPB 1994) has recommended that levels for liquid food be adopted for all drinking water supplies in the United Kingdom.

Table B.6
CEC recommendations

Radionuclide	Council Food Intervention Levels ($Bq\ kg^{-1}$)				
	Baby Foods	Dairy Produce	Minor Foods	Other Foods	Liquid Foods
Isotopes of Sr, notably ^{90}Sr	75	125	7 500	750	125
Isotopes of I, notably ^{131}I	150	500	20 000	2 000	500
Alpha-emitting isotopes of Pu and trans-Pu elements	1	20	800	80	20
All others with half-lives greater than 10 days, notably ^{134}Cs, ^{137}Cs	400	1 000	12 500	1 250	1 000

The NRPB emphasizes that these intervention levels represent the approach of the CEC towards balancing the harm and benefit of food restrictions. Consumption of food contaminated at levels well in excess of the intervention levels for short periods (up to a few weeks) need not give rise to significant radiation risks. Therefore, for the purpose of avoiding significant doses from food consumption, the immediate withdrawal of contaminated food supplies is, in general, not essential.

United States Food and Drug Administration

The USFDA, Department of Health and Human Services, has issued recommendations for state and local agencies for intervention following accidental contamination of food and animal feeds (USFDA 1998). Derived intervention levels (DILs) for the distribution of food in the United States are based on a Protective Action Guide for committed effective dose from ingestion of 5 mSv, or 50 mSv committed equivalent dose to any organ or tissue, whichever is more limiting.[9] They are intended to apply to the distribution and use of food produced during the first year after an emergency. If contamination extends beyond the first year, an evaluation of local longer-term conditions should be conducted to determine if the DILs should be continued, or if other guidance may be more appropriate. Food with concentrations below the DILs is permitted unrestricted distribution. However, State and local officials have flexibility in whether or not to apply restrictions in special circumstances.

DILs recommended by the USFDA have been derived for those radionuclides, under various accident scenarios, that are expected to deliver the major portion of the radiation dose from ingestion during the first year following an emergency. For each class of radionuclide, DILs have been calculated for the six ICRP age groups based on the total annual dietary intake for each age group, and assuming that contamination would occur in 30% of the dietary intake. An exception was made for ^{131}I in the diets of the 3-month and 1-year age groups, where the entire intake over a sixty-day period was assumed to be contaminated. Dose coefficients were taken from ICRP Publication 56 (ICRP 1989). A single DIL was selected for each radionuclide group based on the most limiting age group for the radionuclide group.

Table B.7
USFDA recommendations

Radionuclide Group	Derived Intervention Level (Bq kg^{-1}) for Components of the Total Diet
^{90}Sr	160
^{131}I	170
^{134}Cs + ^{137}Cs	1 200
^{238}Pu + ^{239}Pu + ^{241}Am	2
^{103}Ru + ^{106}Ru[(1)]	$\frac{C(^{103}Ru)}{6\ 800} + \frac{C(^{106}Ru)}{450} < 1$

(1) The USFDA states that, “Due to the large differences in DILs for ^{103}Ru and ^{106}Ru, the individual concentrations of ^{103}Ru and ^{106}Ru are divided by their respective DILs and then summed. The sum must be less than one” (USFDA 1998). C(^{103}Ru) and C(^{106}Ru) are the concentrations at the time of measurement.

The DIL for each radionuclide or radionuclide group is applied to all components of the diet, and to foods as prepared for consumption. They are applied independently for each radionuclide group since they relate to different types of accidents, or in the case of nuclear reactor accidents, to different limiting age groups.

9. The USFDA uses terminology defined in the former ICRP (1977) recommendations, as there is not yet a consensus among federal agencies in the United States on the use of the 1990 ICRP recommendations, which include revisions in its methodology and terminology for expressing radiation doses.

APPENDIX C: REFERENCES

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