Health Canada Santé Canada

Canadian Guidelines for Intervention During a Nuclear Emergency

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Canada

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Executive Summary

This document sets out Health Canada's guidelines for intervention following a nuclear emergency in Canada or affecting Canadians. The introduction of countermeasures to protect the public in an event of an emergency is based on a set of quantitative criteria known as Intervention Levels (ILs). Intervention Levels are specified levels of radiation dose that would justify the introduction of certain countermeasures during a nuclear emergency. This document provides guidance at the national level on Intervention Levels for the following countermeasures: evacuation, relocation, sheltering, iodine prophylaxis, and food controls.

These guidelines have been prepared as part of Health Canada's responsibilities as the lead department under the Federal Nuclear Emergency Plan (FNEP) (Health Canada, 2002). For nuclear emergencies within their own boundaries, provincial governments have primary responsibility for off-site emergency planning and response to protect public health, property and the environment. The federal government, under FNEP, coordinates with, and provides support to, the provinces in their response. National intervention level guidelines give a harmonized basis and approach for preparing provincial nuclear emergency plans. They are intended to assist federal and provincial emergency response authorities who must decide when to introduce various countermeasures. However, these guidelines are not intended to supercede existing Intervention Levels in provincial plans, but rather to serve as reference values when these plans are reviewed or modified.

The guidelines developed here apply primarily to countermeasures to be implemented by an off-site authority in the early phase of an emergency at a nuclear facility with potential off-site consequences. They are intended to supplement, rather than supercede, automatic precautionary actions based on plant status or other indicators of accident severity. They can also be used for other radiological or nuclear emergency situations falling within federal jurisdiction, for example, a re-entering satellite or an emergency occurring in another country with impacts on Canada, or a terrorist event.

The Intervention Levels have been developed on the basis of the following general principles, emphasizing the protection of public health as the foundation for intervention:

- To avoid deterministic effects and reduce the risk of stochastic effects
- To achieve a positive net benefit
- To base Intervention Levels on *averted* dose
- To provide a single Intervention Level for each of a limited number of countermeasures
- To base Intervention Levels on doses to the most sensitive group in the population
- To be consistent with international practices and in particular with generic Intervention Levels recommended by the International Atomic Energy Agency.

Based on the above considerations, the following Intervention Levels are recommended for use in Canada:

Health Canada Recommended Intervention Levels

Countermeasure	Intervention Level (averted dose)
Sheltering	5 mSv in 1 day
Evacuation	50 mSv in 7 days
Relocation	50 mSv in 1 year (return when <50 mSv in a year and < 10 mSv in 1 month)
Stable Iodine Prophylaxis	100 mSv to thyroid
Food Controls[1]	1 mSv from each of 3 food groups

The numerical values recommended here for the introduction of the various countermeasures are meant as guides rather than as absolute standards to be rigidly applied. Although expected to be generally applicable, specific circumstances may lead the responsible authority to introduce a given countermeasure at a lower or higher averted dose than that recommended. In the final analysis there is no substitute for the exercise of discretion and good judgement on the part of the authority.

[1] The subject of food controls has been dealt with more extensively in the companion document "Canadian Guidelines for the Restriction of Radioactively Contaminated Food and Water Following a Nuclear Emergency" (Health Canada 2000)

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Introduction and Scope

The goals of nuclear emergency planning, preparedness, and response are:

- protection of the public from immediate and delayed health effects as a result of a nuclear emergency
- mitigation of impacts on property and the environment
- maintenance of public confidence in the responsible authorities.

In the event of significant releases of radioactive material, emergency response authorities will be required to introduce countermeasures to reduce radiation doses received by the public. The effectiveness of such measures will be influenced to a large degree by the formulation, prior to an emergency, of appropriate criteria, guidance and planning. One important set of criteria for the introduction of countermeasures are Intervention Levels (ILs)[2]. Intervention Levels are specified levels of radiation doses that would justify the introduction of certain countermeasures during a nuclear emergency, and are given in terms of the dose to an individual that could be averted if the countermeasure is taken. Issues such as protection of emergency workers, property and the environment lie outside the scope of this document, as well as criteria for permanent resettlement and operational issues related to the implementation of the guidelines.

These guidelines have been prepared as part of Health Canada's responsibilities as the lead department for the Federal Nuclear Emergency Plan (Health Canada 2002). For nuclear emergencies within their own boundaries, provincial governments have primary responsibility for off-site planning to protect public health, property and the environment. The federal government, under the Federal Nuclear Emergency Plan (FNEP), coordinates with, and provides support to, the provinces in their response. National intervention level guidelines provide a basis for federal preparedness and give a harmonized approach for preparing provincial nuclear emergency plans. They are intended to assist federal and provincial emergency response authorities who must decide when to introduce various countermeasures. However, these guidelines are not intended to supercede existing Intervention Levels in provincial plans, but rather to serve as reference values when these plans are reviewed or modified.

The guidelines developed here apply primarily to countermeasures to be implemented by an off-site authority in the early phase of an emergency at a nuclear facility with potential off-site consequences. They are also applicable to other radiological or nuclear events. The countermeasures considered are evacuation, relocation, sheltering, administration of stable iodine, and food controls. The document does not attempt to resolve all issues regarding stable iodine administration but merely to set forth dose criteria and specific instructions for the utilization of stable iodine, should the responsible authority decide to undertake this countermeasure. The subject of food controls has been dealt with more extensively in the companion document; "Canadian Guidelines for the Restriction of Radioactively Contaminated Food and Water Following a Nuclear Emergency" (Health Canada 2000).

These Intervention Levels are intended for emergency planning purposes and as guidance for the introduction of countermeasures. They should not be confused with more detailed criteria used during the response phase of an emergency, known as Operational Intervention Levels or Action Levels. Operational Intervention levels are derived from the basic Intervention Levels, and are given in terms of dose rates or concentrations that would trigger the initiation of a countermeasure. This permits timely initiation of countermeasures. For example, the food guidelines document (Health Canada 2000) specifies concentrations of specific radionuclides in foods that would trigger removal from the market place. The Intervention Levels proposed here should serve as the starting point for the derivation of specific Operational Intervention Levels. This lies outside the scope of this document.

[2] The terminology of IAEA Basic Safety Series No. 115 (IAEA 1996) is adopted here for quantities applicable to intervention. Other publications may refer to Intervention Levels as Protective Action Guides (PAGs) or Protective Action Levels (PAL)

The Intervention Levels in this document should be considered generic levels, above which a specific protective action is generally justified. Since the consequences of a nuclear emergency will be specific to each type of accident, it is not possible to base nuclear emergency response plans on a unique accident sequence. Even among Canadian nuclear power reactors a wide range of accident scenarios are possible.

The Intervention Levels therefore make no reference to in-plant or source conditions. A local or provincial emergency plan may well include automatic precautionary actions based on in-plant conditions, with or without reference to numerical criteria for off-site doses. These guidelines are intended to supplement, rather than supercede, any such automatic precautionary actions. Furthermore, there is a broad category of emergencies where considerations of in-plant conditions do not apply, e.g., a threat involving an improvised radiation dispersal device, a re-entering nuclear satellite, a nuclear submarine accident at a Canadian port, etc. In such cases, numerical criteria are the only means for deciding when certain protective actions should be considered.

Basic Definitions

Action Level
A measurable quantity of radiation or radioactivity above which a specific protective action is generally justified.

Averted Dose
An individual dose that can be averted by a single protective action. It is the difference between the expected, or projected dose, and the residual dose which would occur even if the protective action were taken.

Countermeasure
An intervention or protective action taken to counter a danger or a threat. Examples include evacuation and sheltering.

Deterministic Effects
A radiation-induced health effect that is certain to occur in an individual exposed to a radiation dose greater than some threshold dose, with a severity that increases with increasing dose. Examples include radiation sickness and skin burns.

Evacuation
Temporary displacement of the population, or a part of the population, from an area which has been, or may become, contaminated with radioactive substances. Evacuation should not last longer than about a week.

Intervention
Any protective action or countermeasure aimed at reducing, or averting, human exposure to radiation during a nuclear or radiological emergency.

Iodine Prophylaxis
Administration of stable iodine to block the uptake of inhaled radioiodines into the thyroid gland.

Intervention Level
A radiation dose above which a specific protective action is generally justified.

Operational Intervention Level
A measurable quantity of radiation or radioactivity above which a specific protective action is generally justified.

Permanent Resettlement (Relocation)
Permanent resettlement of the population in new locations if their home environments are badly contaminated and decontamination efforts are not able to restore them to habitable conditions.

Protective Action
An action, countermeasure or intervention which reduces the radiation exposure of workers or members of the public.

Relocation (Temporary)
Prolonged displacement of the population from a contaminated area for a time period of several weeks, months or even over a year.

Residual Dose
The difference between the projected, or expected, dose and the dose averted by a protective action.

Sheltering
Staying indoors to reduce radiation exposure from external gamma radiation and internal exposure due to inhaled radioactivity.

Stable Iodine Prophylaxis
Taking potassium iodide, according to specific instructions, when outdoor air is expected to contain significant amounts of radioactive iodine.

Stochastic Effects
A radiation-induced health effect which generally occurs without a threshold of dose. Examples include cancer and leukemia. The probability of occurrence is proportional to the dose, but the severity of the effect is independent of dose.

An Overview of Nuclear Emergency Planning in Canada

It is important to place these guidelines in the context of overall nuclear emergency planning in Canada. Planning, preparing and responding to nuclear emergencies are multi-jurisdictional responsibilities shared by all levels of government. The operators of Canadian nuclear facilities are responsible for on-site emergency planning for events involving their facilities. Off-site, provincial governments have the primary responsibility for protecting public health and safety, property and the environment within their own boundaries. In addition to specific federal responsibilities, the federal government, under FNEP (Health Canada 2000), coordinates with, and provides support to, provinces in their response to an emergency. Health Canada is responsible for managing FNEP. The Plan applies to nuclear emergencies or events occurring in the following situations:

- At a nuclear facility within Canada or near the Canada/United States border
- At a distant nuclear facility in another country, if the event has an impact on Canadians
- In a nuclear-powered vessel at a Canadian port or in transit through Canadian waters
- For other serious radiological events, such as a re-entering nuclear-powered satellite or a threat involving an improvised radiation dispersal device, occurring in Canada or over Canadian air space.

For an emergency occurring at a nuclear facility in Canada, FNEP would normally be activated after the relevant provincial plan has been implemented. The three provinces with nuclear generating stations (Ontario, Quebec and New Brunswick) have developed their own nuclear emergency response plans, and have the primary responsibility for implementing off-site urgent countermeasures to protect public health. In addition to its specific responsibilities at the federal level, the chief contribution of the federal government to a provincial response would be to provide assistance and advice when requested by the provincial authority. The federal Plan would also coordinate the response in adjacent provinces that might be affected by transboundary effects. This would be particularly important if an adjacent province did not have its own emergency response plan. For all other categories of nuclear events, FNEP would most likely provide the primary Canadian response to the event.

The federal government is also responsible for the international aspects of a nuclear emergency in Canada, i.e., notifying other countries and international organizations, gathering and coordinating all information for the international community and keeping them informed of developments, liaising with the United States under the *Canada-United States Joint Radiological Emergency Response Plan* (EPC-FEMA 1996), and requesting and coordinating international assistance. In all cases, the federal government must evaluate and respond to the impacts of the emergency on federal programs, and has primary responsibility for issues dealing with food controls, international transportation, international relations, liability, and compensation.

Principles Followed in Deriving the Intervention Levels

The primary considerations in the derivation of Intervention Levels are the protection of public health and confidence and the achievement of a positive net benefit if a countermeasure is implemented. Since the release of radioactive material to the environment may occur during a nuclear emergency, potential doses to the public can only be reduced through protective actions that restrict normal activities. However, the protective actions themselves may introduce additional risks. Each countermeasure will have its own intervention level because the risk it introduces will differ from other countermeasures. Expected benefits and risks associated with each countermeasure are taken into account during the planning stage, but may be different at the time of implementation. The following principles, which emphasize overall protection of public health, have been followed in choosing the dose criteria for initiating protective actions:

1. To avoid deterministic effects and reduce the risk of stochastic effects to as low a level as reasonably achievable

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. A deterministic effect, such as nausea or acute radiation sickness, generally does not occur below a certain dose threshold, typically 500 mSv or more. Once above the threshold, the severity of the effect increases with the amount of radiation received. A stochastic effect is one where there is no assumed threshold and the probability of occurrence increases with the amount of radiation received. This document follows the advice of ICRP (1991) in assuming a linear no-threshold hypothesis.

The goal of all protective actions and countermeasures is to prevent deterministic effects. This means that all possible efforts should be made to keep doses received in a relatively short period of time below 500 mSv. Another goal of protective actions is to restrict stochastic effects. Since stochastic effects have no threshold, protective actions aim at keeping the doses as low as reasonably achievable. Cancer is the most important stochastic effect of radiation. The fatal cancer risk in high dose, high dose rate situations is about 10% per Sv effective dose, or 5% per Sv effective dose for low dose, low dose rate situations(<0.2Gy, 0.1 Gy/hr). This means that a person who receives an effective dose of 100 mSv (0.1 Sv) will have a 0.5% increase in the probability of developing a fatal cancer.

2. To achieve a positive net benefit

Countermeasures, while averting radiation risk, may introduce other risks. Hence, countermeasures should be introduced only if they will do more good than harm. Benefits of intervention include the reduction or avoidance of radiological risk and public reassurance. Risks include the physical risk associated with the countermeasure, economic losses, social disruption, and anxiety. The maximum net benefit associated with any countermeasure is difficult to determine due to the uncertainties in the individual risks and benefits and different approaches are used. Nevertheless, the reduction of radiological risk and the reassurance provided by the countermeasure should more than offset any other societal risks associated with the action. For example, an evacuation order given during severe weather may introduce a higher risk from a transportation accident or other related hazard than the radiological risk expected to be averted. Although the economic costs of a countermeasure should be taken into consideration, rigorous cost-benefit analyses have not been attempted in this document.

An important aspect of the overall benefit of a countermeasure is the public reassurance provided by the countermeasure. The Three Mile Island and Chernobyl accidents have shown the significance of psychological stress as a major health impact (Eisenbud and Gesell 1997). The public must be assured that authorities have the situation under control and that every reasonable precaution is being taken to protect their health.

3. To base Intervention Levels on *averted* dose rather than *projected* dose

With the exception of automatic precautionary actions based on plant status or other indicators of accident severity, decisions to implement countermeasures are based on estimates of radiation doses that might be received by the population as a result of the emergency.

The *projected* dose is the radiation dose which would be expected to occur if no protective actions were taken. The *averted* dose is the difference between the projected dose and the *residual* dose which would occur even if protective actions were taken. International agencies (ICRP 1993; IAEA 1994, 1996) generally recommend basing criteria for protective actions on the averted dose as the best way to maximize the benefit of the protective actions. The use of averted dose gives decision makers latitude in balancing the benefits and risks of intervention. The estimation of averted dose, however, may be more complex and subject to greater uncertainties (e.g., due to uncertainties in the effectiveness of sheltering or stable iodine administration). The averted dose is most useful in emergency planning, but may not be practical in a response situation. There are a number of cases where the simple projected dose may be the more useful quantity:

- If the projected dose is approaching the Intervention Level for a certain protective action, this can serve as a trigger for the responsible authority to begin consideration of the action.
- If the contemplated action can avoid the entire projected dose (e.g., evacuation before release of radioactivity), then the averted dose is simply equal to the projected dose.
- In cases where uncertainties in averted dose might delay appropriate interventions, actions based simply on the projected dose will generally ensure that authorities act cautiously and that the public is adequately protected.

4. To base Intervention Levels on doses to the most sensitive group in the population

Generally, countermeasures should be applied to the entire population in the affected zone, and not just to selected individuals or age groups. However, no population group is uniform, and although it is inappropriate to use extreme assumptions when calculating averted dose, it is reasonable to give priority to the protection of more sensitive age groups in the event of an emergency. Therefore, Intervention Levels should be compared with the averted doses calculated for the most sensitive or susceptible population group, typically children. In fact, most members of the public expect emergency actions to explicitly protect children. Age-dependent dose coefficients for various pathways of exposure are readily available (ICRP 1996; Health Canada 1999).

It is to be noted, however, that countermeasures are most effective when introduced in a timely manner. If dose estimates are available only for a single age group (e.g., adults) then decisions should be based on this information. Given the uncertainties in the dose estimates and the degree of conservatism built into assessment models, this approach should not introduce an unacceptable risk to any age group. Regardless of the age-group used in the dose assessment, the countermeasures should be applied to the entire population in the affected zone.

5. To provide a single Intervention Level for each of a limited number of countermeasures

The intent of these guidelines is to facilitate rapid decision-making in any emergency. Therefore, to avoid uncertainty and indecision concerning the initiation of countermeasures, only a single value of dose, rather than a range of doses, is given for each countermeasure. As mentioned previously, expected benefits and risks associated with each countermeasure during the planning stage, may be different at the time of implementation. A responsible authority must always exercise discretion and judgement in deciding when to implement a certain action. Also, the formulation of a standard set of reference values is more easily achieved if the numbers of countermeasures and dose levels are limited. Levels for other specific actions, including operational intervention levels, may vary between sites or accident scenarios, even when based on the same reference Intervention Levels. Consequently, the number of protective actions considered here has been limited to sheltering, evacuation, relocation, iodine prophylaxis, and food controls. Local or provincial authorities may develop further actions and more detailed guides.

6. To be consistent with international practices and in particular with generic Intervention Levels recommended by the International Atomic Energy Agency

Public trust and confidence are best served if different jurisdictions adopt similar approaches to establishing Intervention Levels. One such approach is provided by the International Atomic Energy Agency (IAEA) in its 1996 Basic Safety Standards, which in turn is based on the previous document “Intervention Criteria in a Nuclear or Radiation Emergency” (IAEA 1994). The IAEA document sets forth generic recommendations for intervention criteria in emergency exposure situations. IAEA Standards are co-sponsored by a number of radiation protection organizations and represent an international consensus on appropriate radiation safety criteria. Their generic recommendations are based on the following principles: 1) intervention to avoid serious prompt health effects should be carried out as a first priority; 2) protective actions to avoid delayed health effects should be initiated when they will produce more good than harm in the affected population; and 3) these actions should be introduced and withdrawn at levels that produce a maximum net benefit to the population. These principles are consistent with those outlined above, and therefore provide a useful starting point for establishing national guidance. The IAEA recommendations have been examined to determine their applicability and appropriateness to the Canadian situation. While this may lead to some variations from the IAEA recommendations, consistency in the principles underlying the Intervention Levels is maintained. A more detailed discussion of the IAEA guidance for intervention is contained in Appendix A.

The generic Intervention Levels do not take into account site or accident specific factors. Furthermore, there may be situations where the intervention levels normally used would not be appropriate. For example, evacuation at the level appropriate under normal circumstances would not be appropriate in hazardous weather conditions, when there is a compounding disaster, or other circumstances that would make the protective action impractical or dangerous. Given the uncertainties and variability inherent in their derivation, the generic levels in Table A.1. are judged by the IAEA to provide protection that would be justified and reasonably optimized for a wide range of emergency situations.

Recommended Intervention Levels for Various Countermeasures

Primary considerations in the derivation of Intervention Levels are the protection of public health, preservation of public confidence and the achievement of a positive net benefit. In these guidelines, risk *versus* benefit considerations have been dealt with intuitively rather than through rigorous quantitative analyses. The Intervention Levels below follow from consideration of the ranges of values for which the benefits or the specific countermeasure are expected to outweigh the risks. In accordance with basic principles, a single representative value has been chosen from each range as the Intervention Level for each countermeasure. The IAEA (1996) recommendations have served as the starting point for this review.

Sheltering

What is sheltering?

Sheltering is a directive to remain indoors with closed doors and windows, with ventilation systems shut off, for a brief period of time (a few hours to two days).

What is the goal of sheltering?

The goal of sheltering is to avert inhalation and external irradiation doses arising primarily from the actual passage of the radioactive plume (cloud shine) and from radioactive material deposited on the ground (ground shine).

Sheltering can reduce inhalation doses from particulates by a factor of about two (IAEA 1994) but this advantage is lost after a few hours, with a gradual air exchange between inside and outside. The dose reduction for the inhalation of vapours (eg., elemental radioiodine) is negligible (NRPB 1990). Brick buildings and large commercial structures may reduce cloudshine doses by up to an order of magnitude.

When would sheltering be implemented?

Sheltering can be an efficient protective measure in an acute situation, but is not intended to be implemented for more than about two days. In the near zone, the lack of time available in which to make decisions and implement them successfully, may make it necessary to take prompt precautionary actions, even when there is only limited information about the accident. Consequently, sheltering may be initiated, before the actual release occurs, as a stand alone measure or possibly in conjunction with iodine prophylaxis and precautionary evacuation.

After a release of radioactivity, sheltering, as a stand-alone countermeasure, is most effective against:

- releases consisting mainly of noble gases (ie., short-lived radioisotopes)
- releases which would result in relatively low doses
- situations where evacuation could not be carried out in time or is not possible (ie., poor weather)

Sheltering may also be used in conjunction with other countermeasures, for example, to facilitate orderly evacuation or the administration of stable iodine. Emergency response authorities will provide information about the situation and further instruction via established communication channels.

What are the risk/benefit considerations?

Sheltering is considered less disruptive and less costly than evacuation, but leaves individuals in a situation of potential exposure to radiation. Although social disruption and monetary cost will increase with the length of time sheltering is in effect, the physical risks from sheltering are not likely to be significant. Due to the lower risks and costs involved in sheltering, sheltering is justified at doses about an order of magnitude lower than for evacuation.

What Intervention Level is recommended by IAEA for sheltering?

In the judgement of the IAEA (1994), sheltering is broadly justified and optimized if the dose averted is about 1.5 to 6 mSv/day, or 3 to 12 mSv over a maximum of two days. A value of 10 mSv in 2 days has been chosen by the IAEA to allow for the costs, risks and detriment associated with sheltering, irrespective of duration. However, if sheltering was expected to have a duration of only several hours, then it could be undertaken to avert a lower dose, provided that it could be justified.

What Intervention Level is recommended by Health Canada for sheltering?
Sheltering is recommended if the action will avert a dose of at least 5 mSv over a period of 1 day. This value is consistent with IAEA recommendations of 10 mSv in two days, but recognizes that the effectiveness of sheltering is significantly decreased after about 1 day. Furthermore, scenarios for which sheltering of more than 1 day would be effective would likely involve ground contamination with short-lived radionuclides, for which evacuation may be more appropriate. At a dose of 5 mSv, the lifetime fatal cancer risk for a member of the public is 1 in 4000 (based on the linear no-threshold hypothesis), or 1 in 2750 if non-fatal cancers and hereditary effects are included. A sheltering order to avert a dose significantly below 5 mSv is not clearly justified, since annual exposure to normal background radiation amounts to 2 to 3 mSv/year (NCRP 1987). However, consideration should be given to situations that may require a higher intervention level to targeted segments of the population, for example, to critical personnel in industry whose absence could result in security or safety issues.

When should the order for sheltering be lifted?
Once a protective action is ordered, continuous monitoring of the situation by emergency management officials is necessary to ensure that the protective action continues to the appropriate. In the early and intermediate phase of the accident, this involves expert assessment of the accident, weather conditions and environmental monitoring results, as well as economic and social factors.

A sheltering order should not extend beyond two days, as this represents the maximum feasible time that people can be required to remain indoors. Beyond that time, they may need to obtain provisions or to escape from a confining and stressful situation. After confirmation that the radioactive plume has passed and outdoor air concentrations have fallen, people should be instructed to open shelters and re-establish ventilation in order to reduce airborne activity that may be trapped inside. If outdoor radiation levels are still high after two days, evacuation may still have to be considered. A persistent radiation level of more than 5 mSv/day could easily approach the evacuation criterion of 50 mSv in 7 days, or possibly the relocation criterion if continuous releases are expected.

Evacuation

What is evacuation?
Evacuation is the displacement of the population, or a part of the population, from an area which has been, or may become, contaminated with radioactive substances. Affected people are directed to leave an identified area or zone in an urgent but controlled manner, for a limited period of time (up to one week). Evacuation should not last longer than about a week. Evacuation generally does not take place during the passage of the plume. In this case, sheltering is used as an interim measure. In some cases, it may be implemented during the release if it involves a small number of people and it can be performed safely.

What is the goal of evacuation?
The goal of evacuation is to avert elevated short-term doses arising mainly from the radioactive plume (external irradiation and inhalation) and from radionuclides deposited on the ground (external irradiation).

When would evacuation be implemented?
Evacuation has the potential to avert most or all doses if carried out in the pre-release phase of an accident. Evacuation is effective for reducing exposures in cases where the release is of uncertain size or duration. Also, after a release is completed, it can reduce exposure from radionuclides deposited on the ground.

In the near zone, the lack of time available in which to make decisions and implement them successfully, may make it necessary to take prompt precautionary actions, even when there is only limited information about the accident. Consequently, evacuation may be initiated in conjunction with preventative sheltering and iodine prophylaxis, even when there is a mere threat of release.

What are the risk/benefit considerations?
Evacuation is the most disruptive of protective actions. Risks and detriments include transportation accidents, anxiety, separation, and possible exposure to severe weather conditions or competing disasters. However, experience gained from other emergency situations have shown that evacuations of large numbers of people can be conducted in a safe and orderly manner. The United States has had considerable experience evacuating people from areas threatened by hurricanes. A significant number of evacuations per year are carried out in that country, with

little or no mishap (NRC 1998). The Canadian experience of the Mississauga, Ontario, evacuation in 1979 is relevant here (EPC 1990). With the threat of chlorine gas escaping from a derailed tank car, 225 000 people were evacuated without serious mishap. The existence of elaborate systems of expressways around most North American cities, together with the fact that most people have automobiles, make evacuation quite feasible on this continent. Thus, under favourable conditions, and with proper planning and preparation, the evacuation of large numbers of people can be conducted in a safe and orderly manner, with minimal risk and disruption.

What Intervention Level is recommended by the IAEA for evacuation?

The IAEA (1994) has judged that evacuation would be broadly justified and optimized if the dose averted by the evacuation exceeds 3-12 mSv/day. The length of time over which this is expressed must be long enough that any initial costs and risks are warranted. It must be long compared with the implementation time, but not so long that conversion to temporary relocation will have become more appropriate. An assumed period of one week results in a range of intervention levels from 20 to 80 mSv/week. A generic level of 50 mSv was selected by the IAEA. If evacuation was expected to last only a day or so, then a lower dose could be justified.

What Intervention Level is recommended by Health Canada for evacuation?

Based on the above considerations, evacuation is recommended if the action will avert a dose of at least 50 mSv over a period of up to 7 days. At a dose of 50 mSv, the lifetime fatal cancer risk for a member of the general public is about 1 in 400. If non-fatal cancers and hereditary injury are included, this risk increases to about 1 in 275 (ICRP 1991). During an emergency, decisions makers may choose to evacuate at lower levels if it can be carried out quickly and easily, if only a small population is affected, or if it will be for a shorter length of time. Conversely, complications could arise if the weather conditions are adverse at the time when the evacuation is being considered. In such a case the dose criterion for evacuation can be raised significantly without reaching deterministic threshold, although the increased risk of stochastic effects needs to be balanced against the physical risk of the evacuation.

When should the order for evacuation be lifted?

Once a protective action is ordered, continuous monitoring of the situation by emergency management officials is necessary to ensure that the protective action continues to the appropriate. In the early and intermediate phase of the accident, this involves expert assessment of the accident, weather conditions and environmental monitoring results, as well as economic and social factors.

Seven days is taken to be the longest time that people can be lodged in temporary accommodations. People would be allowed to return to their homes if the dose avertable by a continued evacuation were less than 10 mSv per month. The detriment of continuing an evacuation (or relocation) is less severe than that of the original order to evacuate. However, if conditions prevented return after a week, or a reassessment of the situation indicated persistent high levels of radioactivity, the countermeasure would be converted to a longer-term relocation (see next section).

Relocation

What is relocation?

Displacement of the population from a contaminated area for a time period of several weeks, months or even over a year. Relocation is a separate countermeasure from evacuation – it is a longer-term protective action. Relocation involves moving people and belongings from their homes, or from emergency evacuation centres, to live in alternate accommodations for a period of several weeks to one year, with the expectation of being able to return to their homes in due course. If times longer than a year are indicated, then permanent resettlement would need to be considered.

What is the goal of relocation?

The goal of relocation is to avert doses occurring over a period of weeks or months. These doses can result from deposited or resuspended radionuclides, and in areas where power reactors have vacuum containment buildings, suspended radionuclides from protracted venting.

When would relocation be implemented?

Relocation usually takes place in the intermediate and recovery phases of an accident, not the early phase. Analyses of environmental samples and more extensive environmental monitoring will be needed to provide the information which is needed to make a decision about longer term protective actions.

In general, relocation would be considered a continuation of evacuation. However, relocation could also occur as an entirely separate countermeasure or could follow a sheltering order. For example, an accident might lead to a moderate deposition of long-lived radionuclides, such that the criterion for evacuation of 50 mSv in 7 days was not exceeded, yet a dose exceeding 50 mSv over one year could be expected. In this case relocation could be ordered, even if an initial evacuation had not been carried out. In a different situation, it may be known at the outset that the criteria for relocation will be triggered, however, sheltering or evacuation is likely to occur first in order to make necessary arrangements for relocation.

What are the risk/benefit considerations?
As with evacuation, relocation is a highly disruptive countermeasure, but the extended time frame usually allows it to be conducted in a more orderly and controlled manner than evacuation. The physical risk of relocation is thereby lower, but the stress and anxiety may still be high. It places individuals in a transitory situation for an uncertain period of time. The economic costs of relocation are also significant, as it involves providing alternate accommodations for the displaced population, integrating them into new communities, schools, and other social services. It may also involve relocating or compensating businesses and factories. In these guidelines, it is expected that the range of averted doses for which the benefits of relocation will outweigh the risks to be about the same as evacuation.

What Intervention Level is recommended by the IAEA for relocation?
The IAEA (1994) has recommended two separate intervention levels for relocation: one for introduction of the countermeasure for avertable doses of 10 to several tens of mSv in the first month, and one for cessation when the avertable dose drops below a few to a few tens of mSv per month. Generic values of 30 and 10 mSv/month have been selected for initiating and terminating temporary relocation, respectively. Two levels are specified because of the relatively higher detriment of initiating relocation compared to maintaining it. Values for the first month include transportation costs for leaving and returning, whereas values for subsequent months exclude these costs. If doses are not expected to fall below 10 mSv/month within a year or two, permanent resettlement should be considered (IAEA 1996). In selecting generic ILs for relocation, the IAEA has excluded factors of social disruption and reassurance, stating however that both could be important in the decision making process.

What Intervention Level is recommended by Health Canada for relocation?
Relocation should be considered if the action will avert a dose of at least 50 mSv for a period of up to one year following the time of the assessment. The difference between the initiating criteria of 50 mSv/year recommended here and the 30 mSv/month recommended by the IAEA is more apparent than real. Because of rapid decay of short-lived radionuclides, a large fraction of an annual dose of 50 mSv would be delivered during the first month.

When should the order for relocation be lifted?
Once a protective action is ordered, continuous monitoring of the situation by emergency management officials is necessary to ensure that the protective action continues to the appropriate. This involves expert assessment of the levels of contamination, as well as economic and social factors. The time period for relocation is variable. As time progresses, more accurate dose projections will become available. The relocation may be discontinued when the avertable dose falls below 50 mSv/year and 10 mSv/month (the same level as for ending a short-term evacuation). The detriment of continuing a relocation is less severe than that of the original order to relocate.

However, if radiation conditions require that the period of temporary relocation extend beyond one year, then the relocation is in the process of becoming permanent. Both the ICRP and IAEA (ICRP 1993, IAEA 1994) have set a lifetime dose limit of 1000 mSv for permanent resettlement. Such a consideration lies beyond the scope of this document, which is meant to deal only with short-term and intermediate-term countermeasures. At the time of an emergency, it may be impossible to predict the lifetime dose in the affected zone. Such a prediction may only be possible after the first year has passed.

Stable Iodine Prophylaxis

What is stable iodine prophylaxis?
Stable iodine prophylaxis involves taking potassium iodide orally, according to specific instructions, when outdoor air is expected to contain significant amounts of radioactive iodine. This action will effectively block the absorption of radioactive iodine by the thyroid gland.

What is the goal of stable iodine prophylaxis?

The goal of stable iodine prophylaxis is reduce the risk of thyroid cancer. The thyroid gland is protected by reducing or preventing the uptake of radioactive iodine. Radioiodine released during a nuclear emergency may enter the body through inhalation of contaminated air, or through ingestion of contaminated foods, especially from the grass 6 cow 6 milk pathway. Once in the bloodstream, about 20% of the iodine is absorbed by the thyroid, where it is used to manufacture hormones essential for metabolism. The thyroid cannot distinguish between stable and radioactive iodine. It is particularly susceptible to beta and gamma irradiation from radioisotopes of iodine, especially I-131. This radionuclide is rapidly eliminated from the rest of the body, but its elimination from the thyroid gland is effectively controlled by its radiological half life of eight days. Flooding the thyroid with stable iodine at about 100 times the normal daily level actually blocks subsequent iodine uptake in a number of ways – saturating iodine transport mechanism, increasing the storage time of iodine already present in the thyroid, impeding the re-circulation of iodine, and temporarily causing the cessation of thyroid hormone production.

Radioiodine exposure can result in both deterministic effects (hypothyroidism and acute thyroiditis) and stochastic effects (thyroid cancer and benign thyroid nodules). More detailed information on the effects and risks from radioiodine exposure can be found elsewhere (GMA 1995, WHO 1989, WHO 1999). The cancer risk from irradiation of the thyroid is greatest in children, and decreases with increasing age.

When would it be implemented?

Stable iodine administration is recommended for the reduction of doses from inhalation when a release of radioiodines is expected. Iodine administration should not be regarded as a stand-alone countermeasure, as it protects against only one exposure pathway and one radionuclide. It is most effective when used in conjunction with other countermeasures (sheltering, evacuation), however the manner of implementation of this countermeasure must not delay implementation or reduce the effectiveness of these other countermeasures.

The effectiveness of stable iodine prophylaxis depends highly on its administration just before or shortly after release of radioiodine to the environment. A decision on prior distribution of stable iodine tablets is the responsibility of the local/provincial authority, and should be based on site-specific conditions and the manner in which emergency plans for all early countermeasures are to be implemented.

Prior distribution carries both benefits and risks. Benefits include immediate access to tablets in the event of an emergency requiring their use. People do not have to leave their homes or workplaces in order to receive them, which may otherwise place them in a situation of potential exposure or interfere with the implementation of other countermeasures. However, people may loose or misplace their tablets and not have them available at the time of the emergency. Also, some individuals may undertake to medicate themselves even if conditions do not justify stable iodine administration. In this regard, a warning should be issued for people not to undertake self-medication with tincture of iodine, as this substance is poisonous.

Prior distribution may be considered for a scattered population in a rural area, where there would be logistical problems in distributing stable iodine after the emergency has been declared. If reliance is to be placed on post distribution, then adequate stocks of stable iodine must be available at convenient locations. Hospitals, clinics, nursing homes, schools, police stations, and fire stations near the nuclear facility are all obvious locations. Emergency workers should have supplies of stable iodine tablets, or know where to get them quickly. In addition, stable iodine could be stocked by local pharmacies, and pharmacists could distribute the pills when instructed to do so by the responsible authority.

What are the risk/benefit considerations?

The benefits and risks of stable iodine prophylaxis are expected to be similar to those for sheltering, with minimal disruption or side effects. The Polish experience following the Chernobyl accident (Nauman and Wolff 1993) showed that over 17 million doses administered, including 10 million to children, resulted in no treatment related fatalities and only two serious allergic reactions, both of which were successfully treated. The stable iodine content of the typical Canadian diet is relatively high, reducing these risks.

What Intervention Level is recommended by the IAEA for stable iodine prophylaxis?

In making its recommendations for stable iodine prophylaxis, the IAEA (1994) has noted that due to different levels of radiation detriment and countermeasure risk, the optimum intervention levels for infants are typically of the order of a few mGy thyroid avertable dose. For the elderly, the optimum levels are of the order of a few hundred mGy. The value selected for a generic intervention level is 100 mGy to the thyroid. A single value is given for practical reasons, and has been selected towards the higher end of the range of optimized levels to be consistent with the recommendations of ICRP (1993). However, the IAEA advises national authorities to ensure that their own recommendations are consistent with their overall level of emergency preparedness.

What Intervention Level is recommended by Health Canada for stable iodine prophylaxis?

Operational issues surrounding the administration of stable iodine are the responsibility of the provinces and municipalities. This document sets forth dose criteria and specific instructions for the utilization of stable iodine, should the responsible authority decide to undertake this countermeasure. The recommendations are as follows:

Administration of potassium iodide to the whole population in the affected area is recommended at the dosage levels specified by the World Health Organisation (WHO 1989) if the action will avert a thyroid dose of at least 100 mSv. Dosage levels recommended by the U.S. Food and Drug Administration (FDA 2001) differ slightly from the WHO dosage levels, but are also acceptable. Recommended age-specific administration quantities are given in Table 1. A brief rationale for administering stable iodine to avert a 100 mSv thyroid dose is given below:

- A dose saving of 90 % or more can be achieved if there is sufficient advance warning to administer stable iodine several hours before exposure. This can lead to a substantial reduction in thyroid cancer risk.
- The side effects of stable iodine prophylaxis are minimal.
- The likelihood of restoring public confidence and relieving anxiety is increased if authorities take specific and concrete countermeasures. Since the timely administration of stable iodine can avert practically all of the dose from inhaled radioiodine, the reassurance provided should more than offset the anxiety associated with the measure.
- The benefits and risks of stable iodine prophylaxis are expected to be similar to those for sheltering, with minimal disruption or side effects. Based on the tissue weighting factor of 0.05 for the thyroid (ICRP 1990), the cancer risk associated with a 100 mSv thyroid dose is equivalent to an effective whole body dose of 5 mSv, which is the intervention level for sheltering.
- For practical reasons, a single intervention level of 100 mSv is recommended for all ages, which is consistent with the recommendations of the IAEA.

When is the order for stable iodine prophylaxis be lifted?

Administration of stable iodine is ceased when outdoor air no longer contains significant amounts of radioiodine. Dosage is restricted for pregnancy and breast-feeding women and nenoates. There are also specific contraindications to the use of stable iodine.

Table 1:
Recommended single dosage of stable iodine according to age group

Age Group	**Recommended quantity of elemental iodine (mg)[1]**	**Corresponding dose Potassium Iodide (KI) (mg)**
Adults and adolescents[2]		
(over 12 years)	100	130
Children		
(3 – 12 years)	50	65
Infants		
(1 month – 3 years)	25	32
Newborns		
(< 1 month)	12.5	16

[1] A 65 mg tablet of potassium iodide contains 50 mg of iodine.

[2] For logistical simplicity in dispensing and administering KI, the U.S. FDA recommends a standard dose of 65 mg for all school age children, while allowing for the adult dose (130 mg) in adolescents approaching adult size (FDA 2001).

Food Controls

What are food controls?

Food controls are restrictions on sale of radioactively contaminated food.

What is the goal of food controls?

The goal of food controls is to avert doses arising from the ingestion of food that has been radioactively contaminated as a result of a nuclear emergency. The federal government, under the *Foods and Drugs Act* (Health Canada 1981/1998), has primary responsibility for the safety of all food offered for sale within Canada, and has the authority to prohibit the sale of foods deemed unsafe. Intervention guidelines for contaminated foods are discussed in detail in the document "Canadian Guidelines for the Restriction of Radioactively Contaminated Food and Water Following a Nuclear Emergency" (Health Canada 2000). A brief summary is provided below.

What is the basis for Health Canada's Intervention Levels?

Guidelines for foods controls are based on the concept of risk limitation and the objectives of the *Food and Drugs Act* (Health Canada 1981/1998). The guidelines recognize the need to maintain the safety of, and public confidence in, the commercial food supply. They have been developed following a review of current recommendations on intervention published by various international agencies. To the extent that the health, safety and confidence of the Canadian public are protected, the guidelines have taken into consideration the recommendations of the FAO-WHO Codex Alimentarius Commission (FAO/WHO 1995) for food moving in international trade.

What Intervention Level is recommended by Health Canada for food controls?

The Intervention Level for food controls has been set at 1 mSv per year for each of three food groups (fresh milk, other commercial foods and beverages, and public drinking water). This is based on an intervention level of about 3 mSv per year for the total diet, apportioned equally amongst the three groups. The intervention level has been used to derive concentrations of specific radionuclides in foods that would lead to the 1 mSv dose per food group (Action Levels). These action levels form the basic food screening criteria following a nuclear emergency, and are consistent with the guidelines of the Codex Alimentarius Commission (FAO/WHO 1995).

The hypothetical lifetime risk of fatal cancer and non-fatal effects associated with a dose of 1 mSv is about 7 in 100 000, based on the ICRP (1991) population-averaged risk coefficient. If the three food groups in the reference diet were each continuously contaminated at the action levels, 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, giving a lifetime risk of about 22 in 100 000. 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 following a major accident.

Comparisons with Recommendations From Other Agencies

The recommended Canadian Intervention Levels for countermeasures following a nuclear emergency are summarized in the Table 2 below. The recommendations from other agencies are discussed more fully, and references given, in Appendix A. The recommendations of the IAEA have been published in its International Basic Safety Standards (IAEA 1996), whose purpose is to establish basic requirements for radiation protection, but which are generally non-binding on national authorities. The guidelines set forth here are consistent with IAEA recommendations with some variations in the criteria for sheltering and relocation, which are deemed to be more appropriate for the Canadian context.

The sheltering criterion of 5 mSv in one day is consistent with the IAEA recommendation of 10 mSv over two days and the Quebec value of 5 mSv in the early phase of the accident. It falls within the range of 1-10 mSv in the Ontario guidelines and is consistent with the lower end of the EPA guidelines.

The adoption of an evacuation limit of 50 mSv in seven days is generally consistent with the current recommendations of the Canadian provinces and the United States (see Appendix A for a more complete explanation of the United States guidelines). The IAEA Safety Series 109 (1994) recommends 50 mSv averted dose as a generic optimized value for evacuation. The adoption of this guideline would create no serious inconsistencies with the current recommendations of the provinces, the United States, or the international community.

The relocation criterion of 50 mSv/year is generally consistent with the recommendations of other agencies. Some have simply set monthly dose rates, e.g., 5-15 mSv/month (ICRP 1993); 30 mSv in the first month and 10 mSv in subsequent months (IAEA 1994). The 50 mSv in one year recommended here corresponds to an average of 4 mSv per month, although most of this dose would presumably be delivered in the early months following the emergency. The United States Environmental

Table 2:
Intervention Levels (mSv) recommended by Health Canada for countermeasures following a nuclear emergency and comparison with recommendations from other agencies.

Agency	Sheltering (mSv)	Evacuation (mSv)	Relocation (mSv)	Stable iodine (mSv committed equivalent dose)	Food Control (mSv)
Health Canada*	5 in 1 day	50 in 7 days	50/y	100	1(3)**
Ontario	1 – 10	10 – 100	20/y	100 – 1000	5
Quebec*	5 during the early phase of the accident	10 during the early phase of the accident	20 for the first year	50	2 per food group in the first year; 1 per food group in following years
New Brunswick		50		100	5
USA (EPA)	5 – 50	10 – 50	50 lifetime	250	5
UK (NRPB)*	3 – 30	30 – 300		30 – 300	3
IAEA (1994)*	10 in 2 days	50 in 7 days	30/mo	100	5
ICRP (1993)*	5 – 50	50 – 500	5 – 15/mo	50 – 500	10

Notes: All doses are expressed in millisieverts (effective dose) unless otherwise indicated.

* Values are doses averted.

** Apportioned equally among each of three food groups, or 1 mSv per food group.

Protection Agency has also adopted a criterion of 50 mSv for relocation, although it is for lifetime rather than one year.

The criterion for stable iodine administration of 100 mSv to the thyroid is close to the lower end of values recommended by other agencies. Health Canada's Action Levels for food controls as derived for individual radionuclides from the Intervention Level are consistent with the Action Levels of other agencies, including the guidelines of the Codex Alimentarius Commission for foods moving in international trade (Health Canada 2000; FAO/WHO 1995).

Appendix A
Recommendations From Other Agencies

This Appendix is a distillation of the more extensive document, "A Review of Protective Action Guides for Nuclear Emergencies Currently in Use by the United States and Canada" (Tracy and Baweja 1997). It begins with the recommendations of international agencies since they represent a consensus of world opinion and serve as a basis for guidelines adopted by various jurisdictions. This is followed by a review of guidelines in the United Kingdom, the United States and the three Canadian provinces that have nuclear emergency plans – Ontario, New Brunswick, and Quebec.

International Atomic Energy Agency

The Agency, in its Safety Series 72; "Principles for Establishing Intervention Levels for the Protection of the Public in the Event of a Nuclear Accident or Radiological Emergency" (IAEA 1985) expanded upon the basic philosophy and recommended intervention levels of ICRP Publication 40 (1984). The IAEA document highlighted the importance of harmonizing the intervention levels in neighbouring countries and also introduced the concept of a Derived Intervention Level (DIL), i.e., a dose rate or Becquerel concentration of activity that would correspond to a prescribed dose level for intervention. No numerical values were recommended for DILs in this document.

The Agency revised the recommendations of this document in Safety Series 109 AIntervention Criteria in a Nuclear or Radiation Emergency (IAEA, 1994), based on the more recent ICRP advice (ICRP-60 1991) and (ICRP-63 1993). This document abandoned the concept of a range of doses between upper and lower limits, and instead recommended single numerical values, called *generic* intervention levels, for the various countermeasures. Each generic intervention level is based on an optimization procedure for a generic accident scenario. When details of a specific accident become available, it would then be possible to carry out a further optimization to obtain *specific* intervention levels. The document argued that the generic level provided a common basis for understanding between different jurisdictions, and would be reasonable for most situations. If, for any reason, a certain jurisdiction were unable to carry out its own optimization, then the generic level would provide an adequate degree of protection. These recommendations, reaffirmed in the Basic Safety Standards (IAEA 1996), are shown in Table A.1.

The generic levels for food controls are Action Levels, based on optimization and encompassing values recommended by WHO (1988) and Codex Alimentarius (1991, 1995). These, in turn, were based on a dose of 5 mSv in one year.

Table A.1
Generic intervention levels recommended by the IAEA (1994, 1996)

Protective Action	Generic Intervention Level (dose avertable)
Sheltering (< 2 days)	10 mSv
Evacuation (< 1 week)	50 mSv
Iodine Prophylaxis	100 mGy thyroid
Temporary Relocation	30 mSv in the first month / 10 mSv in a subsequent month
Permanent Resettlement	1 Sv in a lifetime
Food Controls: Cs-134, Cs-137, Ru-103, Ru-106, Sr-89, I-131	Action Levels: 1000 Bq/kg, except 100 Bq/kg for I-131 in infant food
Sr-90	100 Bq/kg
Am-241, Pu-238, Pu-239, Pu-240, Pu-242	10 Bq/kg, except 1 Bq/kg in infant food

The IAEA recommendations are based on the need for a simple set of internally consistent intervention levels that could have some generic application internationally. The basic principles were that protective actions should prevent serious deterministic effects wherever possible, be justified, and be optimized to produce the maximum benefit. The following working premises were employed:

- under most conditions, at least as much effort and resources are placed into avoiding radiation induced health effects as into avoiding other health risks of similar magnitude and nature;
- that account is taken of the normal physical risks from the action itself;
- that disruption to individuals affected by the protective action is taken into account;
- that other factors of sociopolitical, psychological or cultural nature are excluded;
- that the generic levels are consistent, and as simple as possible to understand and to apply.

The IAEA has adopted cost-benefit theory as the rationale for developing generic intervention levels. In this approach, alternative strategies are selected by comparing the advantages and disadvantages that would result from the countermeasure. Specific factors included in the derivation and optimization of intervention levels include:

- the net benefit of the action;
- the detrimental effects due to radiation associated with taking no action;
- the residual detrimental effects due to radiation when the action is taken;
- the physical risk of the countermeasure itself;
- the resources and effort needed to implement the countermeasure;
- the individual anxiety and disruption caused by the countermeasure;
- the social disruption caused by the countermeasure; and
- the reassurance benefit from the countermeasure.

Values assigned to these parameters have been evaluated based on global estimates of direct costs of effort and resources, and the concepts of “willingness to pay” or “willingness to accept” (IAEA 1994). Ranges have been assigned to some of these values based on estimates for highly developed countries.

International Commission on Radiological Protection (ICRP)

The earlier ICRP document, “Protection of the Public in the Event of a Major Radiation Accident: Principles for Planning” (ICRP 1984), has been superceded by “Principles for Intervention for Protection of the Public in a Radiological Emergency” (ICRP 1993). However, the earlier document sets forth some important principles. First of all, the normal system of dose limitation should not apply to an unforeseen emergency situation. Annual dose limits correspond to very low levels of risk; costly countermeasures are not necessarily justified if these dose limits are slightly exceeded. The three basic principles of ICRP (1984) for planning interventions are:

- Serious non-stochastic (deterministic) effects should be avoided.
- The countermeasures should achieve a positive net benefit for the individuals involved.
- The collective dose should be minimized, as far as reasonably practicable.

These principles correspond roughly to the three basic tenets of radiation protection philosophy, i.e., dose limitation, justification, and optimization. Dose levels for the introduction of various countermeasures are summarized in the table below. ICRP (1984) utilizes the concepts of an *upper dose level*, above which the countermeasure is almost always justified to avoid deterministic effects, and a *lower dose level*, below which the countermeasure is clearly not justified. The zone between the two levels gives responsible authorities some leeway in optimizing their response.

More recently, the Commission presented revised recommendations in the document “Principles for Intervention for Protection of the Public in a Radiological Emergency” (ICRP 1993). This revision was carried out in the light of lowered dose limits (ICRP 1991) and with

Table A.2
Upper and lower dose levels recommended in ICRP (1984) and expressed as projected dose equivalent in mSv during the first year after the accident.

Countermeasure	Upper Dose Level (mSv)	Lower Dose Level (mSv)
Evacuation	500 whole body	50 whole body
Relocation	500 whole body	50 whole body
Sheltering and Stable Iodine	50 whole body or 500 thyroid	5 whole body or 50 thyroid
Control of Foodstuffs	50 whole body or 500 thyroid	5 whole body or 50 thyroid

experience gained from the Chernobyl accident in 1986. ICRP (1993) made the distinction between projected and averted dose and recommended the averted dose as the basis for protective actions in order to maximize the benefit of the actions. Instead of rigid upper and lower dose levels, it utilized a levels at which the action is “almost always justified” and also of a “range of optimized values”. The “almost always justified” levels are virtually identical to the “upper dose levels” of ICRP (1984).

Nuclear Energy Agency

The Nuclear Energy Agency of the Organization for Economic Cooperation and Development (NEA 1990) recommended optimization procedures for establishing intervention levels that would be appropriate to each country and each situation. They proposed an Overall Upper Bound of 0.5 Gy, above which short-term countermeasures would become mandatory, regardless of the outcome of the optimization procedure. They also proposed a Minimum Lower Boundary of 0.1 to 1 mSv in the first year after the accident. At this level, the risk would be of “no particular concern” and interventions would not be justified.

United Kingdom

In 1997 the National Radiological Protection Board of the UK recommended intervention levels or “Emergency Reference Levels” for urgent countermeasures (NRPB 1990, 1997). These are based on dose ranges for the whole body and for single organs.

United States of America

The United States Environmental Protection Agency provides intervention levels for nuclear emergencies in the document: “Manual of Protective Action Guides and Protective Actions for Nuclear Incidents” (EPA 1992). These guides are based on four principles:

- Acute effects of radiation exposure on human health should be avoided.
- Human populations should be adequately protected against cancer and genetic effects under emergency conditions.
- The cost of protective actions versus avoided dose should be optimized.
- Regardless of the above principles, the risk from a protective action should not itself exceed the risk from the dose that would be avoided.

Table A.3
Intervention levels recommended by ICRP (1993), expressed as dose averted (mSv), unless specified otherwise.

Type of Intervention	Almost Always Justified	Range of Optimized Values
Evacuation (< 1 week)	500 whole body 5000 equivalent skin dose	Not more than a factor of 10 lower than the justified value
Relocation	1000 lifetime	5 – 15 mSv/mo for prolonged exposure
Sheltering	50	Not more than a factor of 10 lower than the justified value
Administration of Stable Iodine	500 equivalent thyroid dose	Not more than a factor of 10 lower than the justified value
Food Restrictions	10 (in 1 year) for any single foodstuff	1000 – 10,000 Bq/kg $\beta\,\gamma$ 10 – 100 Bq/kg α

Table A.4
NRPB recommended dose equivalent levels for different countermeasures and organs (mSv).

Countermeasure	Body Organ	Lower	Upper
Evacuation	whole body thyroid, lung, skin	30 300	300 3000
Sheltering	whole body thyroid, lung, skin	3 30	30 300
Administration of Stable Iodine	thyroid	30	300

The numerical criteria for the various protective actions refer to *projected* rather than *averted* doses. However, the rationale for the choice of values is based on a consideration of the dose *averted* by the action. For example, the dose range for evacuation is based on the assumption that one-half of the projected dose can be averted by the action. An optimization procedure has also been carried out, based on dollar values of $12 000 to 200 000 per person-Sievert. The United States Food and Drug Administration has set a Protective Action Guide for the consumption of contaminated foodstuff at an equivalent dose of 5 mSv for the whole body and at 50 mSv to the thyroid (FDA 1998). These levels are summarized below.

With regard to iodine prophylaxis, there has been some discussion in the United States as to whether the risks of stable iodine intervention on a massive scale might exceed the benefits. At present there appears to be no consistent policy between the different states. The Environmental Protection Agency (EPA1992) has recommended widespread usage of stable iodine to avoid a thyroid dose of 250 mSv. In 1998 the Nuclear Regulatory Commission (NRC 1998) issued a draft document stressing that more reliance should be placed on evacuation as a first line of defence. Furthermore, an attempt to distribute stable iodine after the accident might actually interfere with the orderly progression of the evacuation. Later, the NRC withdrew the draft discussion paper and moved to a position that the use of stable iodine be considered at each stage in an ongoing nuclear emergency and that adequate stockpiles be maintained in the vicinities of major nuclear facilities. The NRC revised a section of its emergency preparedness regulations and now requres that States with a population within the 10-mile emergency planning zone of commerical nuclear power plants consider including potassium iodide as a protective measure for the general public to supplement sheltering and evacuation in the event of a nuclear emergency (NRC 1999, 2000, 2001). In November 2001, the Food and Drug Administration released its guidance document (FDA 2001), in which proposed dose thresholds and KI dosage levels are lower than previously recommended (EPA 1992).

Province of Ontario

The Protective Action Levels or PALs for the province of Ontario (Ontario 1999) are given in the table below. PALs are given for exposure controls measures (sheltering, evacuation, and thyroid blocking) and for ingestion control measures as radionuclide concentrations in food or water. The action levels are based on projected dose rather than averted dose; otherwise they conform to the guidance in the Safety Series of the IAEA (1985, 1994, 1996). The ingestion control measures in the Ontario PALs are taken from the IAEA Safety Series (1994). In addition to specifying PALs, the Ontario document gives guidance on the application of other protective measures such as entry controls, decontamination measures, and the closing of schools, workplaces, and recreational areas.

The Ontario policy on thyroid follows WHO and GMA advice on administration and dosage levels. Prior distribution to the general public is not recommended, but the designated nuclear installation is required to maintain adequate stocks of stable iodine for the Primary Zone population. In addition, the nuclear installation is required to provide a one-to three-day supply of stable iodine tablets to schools, daycares, nursing homes, hospitals, prisons, and essential service establishments in the Primary Zone. Emergency workers, evacuation centres, and municipalities should also have access to adequate supplies of stable iodine.

Table A.5
United States Protective Action Guides for the early phase of a nuclear accident.

Protective Measure	Projected Dose (mSv)	Comments
Evacuation	10 – 50	
Relocation	50 lifetime	(12.5 – 20 in 1st yr; 4-5 in 2nd yr; <1 after)
Sheltering	5 – 50	Under unusually hazardous conditions, doses up to 100 mSv may be justified
Stable iodine administration	250 thyroid	Some states not in agreement; requires approval of state medical officials
Food restrictions	5	From all sources

Province of New Brunswick

The province of New Brunswick (1990) gives Emergency Reference Doses for quick and easy interpretation by emergency response teams. It bases further Action Guides on measured dose rates. New Brunswick has arranged for prior distribution of stable iodine because there are only a few hundred scattered residents in the vicinity of the Point Lepreau Nuclear Generating Station.

Province of Quebec

In 2001, Quebec adopted, for protective measures in the initial phase, the intervention levels proposed in the document *Bases de planification du PMUNE-G2 en matière de scènarios d'accident de niveaux d'intervention pour les mesures de protection et de zone de planification d'urgence pour l'exposition au panache (ZPU-P)*[3] (Grenier, 2002). These are presented in Table A.10. The

Table A.6
Exposure Control Measures in Ontario (mSv).

Protective Measure	Effective Dose	Thyroid Dose	Effective Dose	Thyroid Dose
	Lower Level (mSv)		*Upper Level (mSv)*	
Evacuation	10	100	100	1000
Sheltering	1	10	10	100
Thyroid Blocking	–	100	-	1000

Table A.7
Ingestion Control Measures in Ontario (Bq/kg).

Banning of Food and Water Consumption	Cs-134, Cs-137, Ru-103, Ru-106, Sr-89	I-131	Sr-90	Am-241, Pu-238, Pu-239, Pu-240, Pu-242
Foods for General Consumption	1000	1000	100	10
Milk, Infant Foods, Drinking Water	1000	100	100	1

Table A.8
Emergency Reference Doses in the Province of New Brunswick.

Countermeasure	Emergency Reference Dose
Evacuation	50 mSv whole body dose saved
Sheltering, Stable Iodine Pills Issued	500 mSv infant thyroid dose saved
Control of Food, Drinking Water, Recreational Activities	5 mSv whole body (current dose limit to public)

Table A.9
Action Guides in the Province of New Brunswick.

Action	Action Guide
Traffic control	10 μ Gy/hr
Distribution of Stable Iodine and Stay-in order	50 μ Gy/hr
Planned Evacuation (to save 50 mSv in 1 week)	1 mGy/h
Prompt Evacuation (before planned evac. takes effect)	5 mGy/h
Curtail Use of Drinking Water	airborne release of 100 weekly DELs
Curtail Sail and Consumption of Seafood	liquid release of 10 monthly DELs [1]
Curtail Use of All Food Pathways	5 mSv/y

[1] DEL = Derived Emission Limit

[3] Only available in French.

disparity between the intervention levels defined by the province of Quebec and those proposed by Health Canada or by the IAEA exists because two different approaches were followed: the IAEA followed a cost-benefit approach, while Quebec followed a health risk-health benefit approach.

With regard to stable iodine prophylaxis, a plan for access to iodine tablets was decided on; it includes pre-distribution to residences, schools, childcare centres and public places (businesses, sports centre), as well as to industries in the Bécancour industrial and harbour park.

The relocation intervention levels are at the discussion paper stage and should be adopted by the end of 2003. For food controls, the levels are those adopted in the document *Plan des mesures d'urgence nucléaire à la centrale nucléaire Gentilly-2 (PMUNE-G2)* (Quebec, 1996).

Table A.10
Protective Measures in the Province of Quebec.

Protective Measure	Intervention Level	Criterion for Lifting Measure
Sheltering	5 mSv in the early phase	Maximum time exceeded (approximately 3-4 hours); Doses to come in intermediate phase < IL temporary relocation
Evacuation	10 mSv in the early phase	Early phase over or maximum application time reached (7 days); Doses to come < IL temporary relocation
Iodine Administration	50 mSv (equivalent dose to the thyroid)	Children 0-18 years old (multiple doses possible): daily dose for child to come < 50 mSv to the thyroid; Adults, newborns: a single dose
Temporary Relocation	20 mSv for the first year (proposed)	
Permanent Relocation	50 mSv in a lifetime (proposed)	
Food Controls	2 mSv per food group in the first year; 1 mSv per food group in subsequent years	

Appendix B
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