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Generic intervention levels for protecting the public in the event of a nuclear accident or radiological emergency

Interim report for comment

INTERNATIONAL ATOMIC ENERGY AGENCY

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GENERIC INTERVENTION LEVELS FOR PROTECTING THE PUBLIC
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FOREWORD

In 1985 the International Atomic Energy Agency published Safety Series No. 72, which set out guidance on the principles for establishing intervention levels of dose for the protection of the public in the event of a nuclear accident or radiological emergency. That guidance was aimed at assisting those having responsibility for emergency response planning, nationally, regionally and at nuclear facilities, to specify levels of projected dose at which it may be necessary to introduce relevant protective measures. It recognized a need for practical quantities that could be readily compared with the results of measurements made in environmental materials and in foodstuffs, so-called Derived Intervention Levels (DILs). Shortly after the accident at the Chernobyl nuclear power plant in 1986, the Agency published Safety Series No. 81, which addressed the principles, procedures and data needed to establish these DILS. Guidance was also given on the extent to which the supportive numerical data and the illustrative DILs might have more generic application.

Following the accident at Chernobyl, it became evident that some clarification of the basic principles for intervention was necessary, as well as more internationally recognized numerical guidance. Developments such as the new recommendations of the International Commission on Radiological Protection, the FAO/WHO Codex Alimentarius Commission Guideline Levels of Radionuclides in Food Moving in International Trade, and the International Chernobyl Project, have all been considered in the review of the existing guidance. In 1991, a revised Safety Series No. 72 was developed that clarified the guidance with respect to intervention, and provided illustrative examples of how intervention levels are established in emergency plans. The document stopped short of providing numerical intervention levels that might have some generic application.

In revising Safety Series No. 81, two aspects are being addressed. Firstly, because intervention levels for foodstuffs can be obtained directly using the illustrative examples of Safety Series No. 72, the need for so-called Derived Intervention Levels was obviated. Secondly, there was a need for a simple set of consistent Intervention Levels that could have some generic application internationally, because many of the Agency's Member States do not have nuclear power systems and do not have detailed emergency plans for intervention. Thus the revised Safety Series No. 81 will contain Generic Intervention Levels that can be used by such States without their own emergency plans and, secondly, transfer and dosimetric factors and other useful information that can assist the user assess the seriousness of any environmental contamination. This Technical Document addresses the first of these aspects.

The FAO, IAEA, ILO, NEA(OECD), PAHO and WHO are currently developing common Basic Safety Standards (BSS) for protection against ionizing radiation and for the safety of radiation sources. Part of the BSS concerns the intervention levels at which actions of various kinds to protect members of the public following an accident are advised. The present document is intended to provide input to the final specification of these intervention levels. It provides the radiation protection principles underlying such intervention levels, and proposes numerical values for these levels, based on an analysis of some of the more directly quantifiable factors involved. Factors such as social disruption, psychological factors and political considerations are discussed, but are explicitly excluded from the derivation, as it is beyond the expertise of the members of the Advisory Group to include these in a quantitative manner. The document serves as a basis for the judgements required to select appropriate intervention levels for the final version of the BSS. It is therefore being issued formally now for comment in order to obtain input from Member States.

A second document giving transfer factors, dosimetric information etc. for the purposes of assessing the seriousness of any accident based on key measurements will be drafted during 1993. The present intention is to publish the two parts as a Safety Series document in 1994 to be fully consistent with the final version of the Basic Safety Standards adopted by the governing bodies of the aforementioned international organizations. That Safety Series document will naturally take into account comments received by the Agency over the intervening period.

EDITORIAL NOTE

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EXECUTIVE SUMMARY

S1. GENERAL

S1.1. Introduction

1. This Executive Summary sets forth the radiation levels (termed "intervention levels") at which actions of various kinds to protect members of the public following an accident is advised and the scientific assumptions and radiation protection principles underlying these levels. The individual responsible for decisions to take these actions may also have to accommodate social and political factors that have not been considered here. This Summary may then serve as a starting point for the judgments required for decisions to implement protective actions based on this advice, modified in the light of relevant social and political factors.

2. Intervention levels for each type of action are developed separately because there are differences in the benefits and penalties from their application, as well as in the conditions under which they should be applied. Levels for the different protective actions have been derived in a consistent manner and are consistent with international recommendations.

3. These intervention levels are "generic" in nature. That is, they are chosen to be reasonable for the majority of situations. Deviation will be appropriate when the technical assumptions used here are not valid for a specific situation, or due to the need to accommodate relevant social or political factors.

S1.2. The harm from radiation: prompt and delayed effects on health [1]

4. For most prompt effects, there is a practical threshold radiation dose and the severity of the effect is related to the level of dose to the individual. The most severe possible consequence is early death, which for sensitive individuals may occur at doses of about 1 gray (Gy) or above[2] delivered promptly to the whole body, due to bone marrow failure. Serious effects may also occur in other organs. Most of the threshold doses for these are above that for bone marrow and will normally be avoided if the whole body dose is below 1 Gy. However, some individual organs, such as the thyroid and the lung, may receive high doses due to breathing or swallowing certain radionuclides and must be considered separately.

5. Delayed effects include a wide range of cancers and hereditary effects, for which the **probability** of occurrence (not the severity) increases with dose[3]. They usually appear many years after exposure, and, although they do not occur in every exposed individual, there is no threshold for their induction. Because of the assumed linear (proportional) relationship between dose and the

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[1] The effects on health differentiated here as "prompt" and "delayed" are commonly denoted "deterministic" and "stochastic," respectively, in radiation protection literature.

[2] The "gray" (Gy) is a unit for energy deposited in tissue; it is used in place of the more usual dose unit (sievert) for those situations involving radiation doses delivered promptly at high dose rates.

[3] The additional probability of dying from a radiation-induced cancer is assumed to be directly proportional to the dose, and is estimated as approximately one in twenty for a dose of one sievert (Sv), or one in twenty thousand for a dose of one millisievert (mSv). The risks of serious hereditary effects are estimated as about five times smaller.

probability of these effects, it is possible to estimate the number expected to occur in a large exposed population even if the chance of an effect is very small for most individuals. Since other causes (mostly unidentified) can give rise to the same effects, it will normally be impossible to identify those caused by radiation.

6. Typically, an accident will cause high doses to only a very few and small doses to many people. While those with the highest doses will bear the highest individual risks, most of the cancers and hereditary effects will normally occur in a larger population that receives small doses. For this reason, it would be impossible to prevent all such cancers and hereditary effects following an accident by intervention.

S1.3. Exposure routes and dose projections

7. Although accidental releases may occur to air, water, or land, those most likely to require urgent protective action are major releases to air. Following such a release people may be exposed to radiation from the airborne radioactive cloud and through inhalation of radioactive dust and gases in the cloud. As the cloud disperses particles will slowly settle on the earth's surface or be deposited rapidly by rainfall. People then may be exposed to radiation from these deposits, from inhaling resuspended dust, or from contaminated food or water.

8. Usually during an accident, government scientists will estimate potential doses to the population. However, early on, there are many uncertainties (e.g., in the amount and rate at which radioactive material is being released and in the meteorological situation). Because of these uncertainties and the need to use simple mathematical models to obtain results soon enough to be useful, there will be large uncertainties in early dose estimates.

9. Decision makers must be aware of this situation and ensure that their expert advisors provide expressions of the uncertainties in early estimates of doses. They should not rely on "most likely" estimates alone (which could lead to wrong conclusions that jeopardize the protection of the population) and must consider the uncertainties in arriving at a suitable decision on urgent protective action. Later, as the situation becomes clearer, it will be possible to modify protective actions and initiate new ones with a much firmer grasp of projected doses.

S1.4. The difference between normal conditions and emergency situations

10. Under normal conditions doses from man-made sources (e.g., from nuclear power or medical practice) are kept below specified levels. These are much lower than would prompt a need for protective action; typically their magnitude is comparable to local variations in natural background radiation. They are achieved through the use of controls on the radiation source and do not require direct constraints on people.

11. In the event of an accident radioactive material released to the environment is no longer under control; doses can only be reduced through protective actions, such as evacuation, sheltering, relocation, resettlement, prophylactic use of iodine, and restrictions on food and water, all of which impose constraints on people's activities. These actions may also incur additional risks. In choosing the level at which a protective action should be initiated, it is necessary to consider the effects of constraints on people's activities and any additional risks from the action itself.

12. For the above reasons the levels of dose for intervention following an accident and the levels for control of doses under normal conditions will be different and it is important to avoid confusion between these two different kinds of levels.

S1.5. Protective actions

There are limited major options available to protect the public following an accident. The most important are:

13. For the early, or urgent, response:

- **sheltering**, through advising people to remain indoors and to close doors and windows, usually for less than a day or so;
- **evacuation**, the urgent removal of people from a specified area for periods of the order of days; and
- **prophylactic administration of iodine**, if high intakes of radioactive iodine have occurred or are expected to occur.

14. For later phases of the response:

- **temporary relocation** of people, usually for no longer than one to two years;
- **permanent resettlement** of people into new or existing settlements for the foreseeable future; and
- **control of food and water** contaminated in excess of specified levels.

S2. PRINCIPLES FOR INTERVENTION

15. Three principles have been agreed upon internationally as a general basis for intervention. They may be paraphrased as follows:

(a) Intervention to prevent serious prompt health effects should be carried out as a first priority;

(b) Protective actions to avoid delayed health effects should be initiated when they will produce more good than harm in the affected population; and

(c) These actions should be introduced and withdrawn at levels that produce a maximum net benefit to the population.

16. The first principle is critical for response to an accident producing any high doses. It means that any immediate threat to individuals should be countered through evacuation (or, rarely, sheltering and, when appropriate, iodine prophylaxis) as a first priority, and carried out to the maximum extent of immediately available resources. The dose levels that should be avoided are presented in Table S.I. There may be rare cases when evacuation to satisfy this first principle is not appropriate because it could cause greater harm (e.g. moving people on life support systems, or in the face of a greater threat).

TABLE S.I. DOSE LEVELS FOR AVOIDING SERIOUS PROMPT HEALTH EFFECTS

Organ or Tissue	Dose in 2 days (Gy)
Whole body	0.5
Lung	6
Skin	3
Thyroid	5

17. Intervention levels for minimizing delayed health effects are based on the second and third principles. In applying these principles the terms "good," "harm," and "benefit" include, in addition to health and safety and the tangible costs of protective actions, unquantifiable factors such as reassurance, stress, and attention to societal values. These are not within the primary professional competence of the radiation protection expert. They are more appropriately the responsibility of the decision maker, who may choose to consider these factors, in addition to those covered by this radiation protection advice, in arriving at decisions that will produce the maximum benefit to the affected population.

18. Furthermore, the second and third principles address the reduction of risk of delayed effects in the population for the "common good"; they do not explicitly limit individual risks. Risks of delayed effects to a few individuals disproportionately higher than those to the rest of the population may be a significant factor in the decision process. For this reason, national authorities may choose to place extra resources into reducing the doses to these individuals below the generic levels recommended here. Whether this is possible will depend on the severity and nature of the accident, and the resources at the disposal of the country. In any case, these decisions should not be taken lightly since the extra resources needed rise rapidly with the adoption of lower targets.

S3. GENERIC INTERVENTION LEVELS

19. The generic intervention levels for urgent and longer term protective actions are based upon the above principles and the following premises:

— *national authorities will spend the same resources on radiation health risks as on other similar health risks;*

— *physical risks from the action are taken into account;*

— *disruption to individuals, such as to livelihood or to resources, is considered;*

— *'good' and 'harm' of psychological nature are excluded (although unpredictable, these are taken here to result in a null net benefit);*

— *political, cultural, and other social factors (such as societal disruption) are excluded (because they are rightly the sphere of the decision maker).*

The above relatively simple premises are considered appropriate for the selection of internationally applicable generic intervention levels.

The resulting generic intervention levels are presented in Table S.II.

S3.1. Protective actions for early, or urgent, response

20. These actions must be applied promptly in order to be effective. Delays may lead to population doses that could have been avoided and in the worst cases could lead to prompt health effects. Rapid decisions are difficult because there is usually very limited early information about an accident and large uncertainty about its consequences. For this reason pre-planning should be carried out wherever possible so that decisions can be made rapidly based on facility conditions and pre-arranged patterns for response, rather than just on measurements carried out and actions hastily organized during the early course of an accident.

TABLE S.II. GENERIC INTERVENTION LEVELS

Protective Action	Generic Intervention Level (dose[a] **avertable** by the protective action)
Sheltering	Initiate to avoid at least 3 mSv in six hours
Evacuation	Initiate to avoid at least 10 mSv in a day
Iodine prophylaxis	Initiate to avoid at least 50 mGy due to 10 days intake for children; 500 mGy due to 10 days intake for adults[b]
Temporary relocation	Initiate to avoid 30 mSv in a month; suspend if avoiding less than 10 mSv in a month and if permanent resettlement is not warranted
Permanent resettlement	If temporary relocation would last longer than one or two years, or if lifetime dose could exceed 1 Sv

Generic Intervention Levels for Withdrawal and Substitution of Foodstuffs (kBq/kg)		
Radionuclide group	Fresh milk, vegetables, grain, and fruit	Meat and milk products
$^{106}Ru, ^{131}I, ^{134}Cs, ^{137}Cs$	3	30
^{90}Sr	0.3	3
$^{238}Pu, ^{239}Pu, ^{241}Am$	0.03	0.3
	Baby and Infant Foodstuffs	
$^{134}Cs, ^{137}Cs$	1	
$^{106}Ru, ^{131}I, ^{90}Sr$	0.1	
$^{238}Pu, ^{239}Pu, ^{241}Am$	0.01	

[a] Sum of external effective dose and committed internal effective dose, unless noted.

[b] Committed dose to the thyroid.

21. **Sheltering** means staying in buildings to reduce exposure to airborne contamination and surface deposits, and closing doors and windows and turning off ventilation systems to reduce inhalation of radioactive material from outside air. Sheltering can also facilitate a subsequent evacuation and the prophylactic use of iodine. Because of the small penalties sheltering may be justified at relatively low dose levels. However, its effectiveness decreases with time for most structures (typically reducing doses only by a factor of two or so after a few hours). Further, there is a limit to the time that populations can remain indoors without undesirable complications.

The generic intervention level for sheltering is 3 mSv in six hours, i.e., sheltering is indicated if 3 mSv or more could be avoided by sheltering during any six hour period.

22. Sheltering can be effective if the exposure is of short duration and buildings are well sealed and of dense structure, as in some northern countries. In many warm countries, however, people cannot stay indoors in sealed houses for long periods, and most houses are made of light materials. These factors must be considered when choosing to instigate sheltering as opposed to evacuation.

23. **Evacuation** is the urgent moving of people from their normal housing for a *limited* period of time. Its use should be based on the dose that can be avoided by evacuation and would not be avoided by sheltering.

The generic intervention level for evacuation is 10 mSv in one day; i.e., unless exceptional circumstances (such as hazardous weather) prevails, prompt evacuation is indicated if 10 mSv or more would be avoided in a day.

24. In cases before an actual release has started, and where projected doses exceeding this level have a high probability of occurrence, preventive evacuation will be advisable.

25. Evacuation as a protective action is commonly used when people are threatened by other man-made hazards (e.g., fire or chemical spills) or by forces of nature (e.g., hurricanes, tornados, earthquakes, or floods). In most cases people return in a short period, typically 1-2 days, if their homes do not require prolonged clean-up. Because of the short time involved, primitive accommodation in schools or other public buildings is typical.

26. **Prophylactic use of iodine** is the administration of stable (non-radioactive) iodine in order to block the uptake by the thyroid of inhaled radioiodine. It must be carried out promptly to be effective (ideally several hours before and no later than a few hours following exposure). For this reason this protective measure is most commonly practical only when emergency planning has included prior distribution of stable iodine to the population at risk. It will usually be coupled with evacuation or sheltering.

27. The generic intervention levels for prophylactic use of iodine are 50 mGy for children and 500 mGy for adults. These levels apply to the dose that would be received from intakes of radioiodine over any 10 day period. Since there may be complications depending on local diet and other factors, public health authorities should be involved in implementing this measure.

S3.2. Protective actions for later phases of a response

28. Sheltering and evacuation are short term protective measures. If measurements confirm that doses warrant further action, temporary relocation or permanent resettlement, and control of food and water may be necessary.

29. For early protective actions, the greatest benefit is likely to accrue if action is taken with minimal delay, based on rough predictions of how the accident will develop. For long term protective actions, there will usually be a rather small radiological health penalty for delaying to obtain accurate measurements for projecting doses. Moreover, the social and economic penalties for imprudent decisions can be high, owing to the long period protective actions may be in force. It is important that a decision to implement these protective actions is carried out in as informed a manner as possible, using best estimates for the consequences of different options.

30. **Temporary relocation** means the organized removal of people for an *extended, but limited* period of time (e.g., several months) to avoid doses from radioactive material deposited on the ground, including resuspended materials, and in some cases from local food or water. People typically would be housed in temporary accommodation of a reasonable minimum standard of comfort and privacy.

The generic intervention levels for initiating and terminating temporary relocation are 30 mSv in a month and 10 mSv in a month, respectively; i.e., people should be temporarily relocated if the dose avertable over the next month is expected to be greater than 30 mSv. They may return when the avertable dose falls below 10 mSv in a month. If the dose accumulated in a month is not expected to fall below this level within a period of a year or two, the population should be permanently resettled.

Two levels are specified because there are relatively high penalties for initiating relocation in comparison with maintaining it. It is also necessary to specify the period of time it is reasonable to live in temporary housing.

31. **Permanent resettlement** means complete removal of people from the area *with no expectation of return for at least several years*. People typically would be resettled in accommodation comparable with that vacated. This may involve construction of new housing and infrastructure.

The generic intervention levels for permanent resettlement are 1 Sv in a lifetime or a dose exceeding 10 mSv per month that persists beyond one or two years (i.e., that does not permit return from temporary relocation within one or two years). It should be recognised that projected doses below the intervention levels for evacuation or for terminating temporary relocation could also, over a lifetime, become high enough (i.e., exceed 1 Sv) to warrant permanent resettlement.

32. **Control of food and water** may have to be considered under three different circumstances: where alternative supplies are available; where alternative supplies are scarce; and where food is for distribution in international trade.

33. The generic intervention levels for use by national authorities when alternative supplies of food are available are given in the bottom half of Table S.II. The values depend upon the type of foodstuff and the type of contaminating radionuclide. The radionuclides listed are those most likely to be of concern in foods following an accident.

34. In situations where extensive restrictions on food supplies could result in nutritional deficiencies or, in the extreme, starvation, case-by-case evaluations will be required. In most such situations relocation will be indicated, and alternative food made available. However, when this is not possible, the radiation hazard must be considered realistically in comparison with alternative competing health hazards, and higher intervention levels should invariably be adopted.

35. Following any event that may contaminate foodstuffs, a variety of countermeasures may be instituted at various stages in their production and distribution. These should be implemented to ensure that, to the maximum extent practicable, contamination of foodstuffs is maintained well below the intervention levels.

36. Guideline levels for foodstuffs distributed in international trade are given in Table V. These lower levels reflect the different considerations involved for foodstuffs to be consumed in countries unaffected by an accident.

1. INTRODUCTION

101. In recent years a number of accidents involving radioactive materials have occurred which had, or could have had, consequences for the health of the general public. These have ranged from the major accident at Chernobyl in 1986 to accidental dispersion of medical and industrial radioactive sources and the re-entry of satellites carrying radioactive material. Responses to these accidents differed between countries. It subsequently became apparent that some protective actions were taken that, in the most extreme cases, may have worsened, rather than improved, the well-being of the populations involved and their environmental surroundings. In other cases, the actions taken led to large but unproductive expenditures of national resources. Further, where the accident involved exposure of populations across national boundaries, many instances occurred of contradictory national responses either side of the national borders. This indicates that it would be desirable to use a common basis for national decisions to protect the health of the public, and, where reasonable, to employ the same numerical criteria for such decisions.

102. During the past decade considerable progress has been made in developing internationally recognized principles for decisions on protective measures following accidents involving radioactive materials, and in providing quantitative guidance for applying these principles [1-6]. However, experience shows that, in spite of these efforts, there remain large discrepancies in the application of both principles and guidance. This has been caused, in part, by the fact that these principles and guidance on their application have been in the process of evolution.

103. Three major principles have now evolved, which appear to have almost universal acceptance. In short, they provide that decisions to take actions to protect the health of the public should (1) prevent serious deterministic effects wherever possible, (2) be justified - that is, they should do more good than harm, and (3) be optimized - that is, they should do the most good. Further elaboration is provided in Section 2.

104. One of the consequences of these principles is that, in theory, there is a range of numerical values that the optimum intervention level for each type of countermeasure could take, depending firstly on the exact circumstances following an accident, and secondly on the different social, political and cultural factors that might be introduced by national authorities. Previous IAEA advice [7] has recognized this by indicating the range of values from which the optimum level should be selected. In practice this approach has caused some difficulties. Firstly, many countries need a single internationally accepted value for the appropriate level of protection. And secondly, for many countries without detailed emergency plans, there may not be time to carry out a detailed optimization exercise, and a single generically optimized value will almost certainly represent the best response that can be made in the limited time available. This report addresses these needs by recommending single **generic intervention levels** for the major protective measures.

105. The generic values for these intervention levels have been selected to broadly achieve the maximum net good. They have been chosen on a technical radiological protection basis, on the premise that the level of effort and resources allocated to protection against radiation should be broadly commensurate with the level of effort and resources allocated to protection of the public from other health risks of a similar magnitude and nature, taking due account of any limitations on personal freedom, and health risks from the protective actions themselves. In this way, they serve to assure the public that they will not be subjected to undue risks when the protective measures are properly applied. Given the uncertainties and variabilities inherent in this procedure, the generic levels are judged to provide protection that would be justified and reasonably optimized for a wide range of accident situations. It is clear that these generic levels can only be used as guidelines; any specific optimization process may lead to intervention levels either higher or lower than those recommended here.

106. Clearly, these recommendations cannot take into account unusual site or accident specific factors. For example, under severe weather conditions or for large populations, prompt evacuation

may be justified only at levels much higher than those recommended here, since the physical risk of the evacuation would exceed the radiological risk saved. Some degree of flexibility to these recommendations is therefore necessary, and national and local authorities should apply them with due care, taking proper account of any extenuating conditions. Whilst recognizing the need for flexibility, guidance is given in the text on the maximum values to which intervention levels could be raised. Not taking action above these maximum values would almost never be justifiable.

107. National authorities may also wish to consider factors of a socio-political or even cultural nature. Although the influence of such factors is discussed generally, it is clearly outside the scope of this report for quantitative considerations of socio-political issues to be incorporated in the recommended levels. In most circumstances, it is judged that the social benefits of adopting internationally agreed intervention levels will outweigh any disadvantages. It is therefore recommended that adoption of different levels from those given here should not be undertaken without careful consideration of the wider possible consequences.

108. In recommending these generic values, policies and practices of individual countries have been deliberately excluded. For example, some national authorities have established individual risk objectives for responses to accidents, in a manner analogous to (but not the same as) that for planned releases. These objectives may, of course, not be achievable for all accidents, and cannot be applied in the same way as legal dose limits. Such objectives are not addressed in this report, because they are considered to be matters for decision by national authorities.

109. Should a national authority consider it necessary to adopt different intervention levels from those recommended here, either for unusual circumstances or for socio-political reasons, information is provided in Appendix II and Section 6 to assist in this decision making process. Firstly, perspective is given on the residual risks to which a population and critical individuals might be exposed if the generic levels recommended here are used, as well as the effectiveness of each protective action. Secondly, the implications of adopting lower levels are explored in terms of the reduction achievable in individual and population risk, and the corresponding increase in the area of land and numbers of people affected by the protective action. Similarly the implications of adopting higher intervention levels are considered. In this way, it is hoped that judgements as to the need to adopt different levels will only be taken on rational and well-defined grounds.

110. In extreme situations it is conceivable that an accident may overwhelm the resources of the country in which it occurs, so that it is difficult for national authorities to provide adequate protection of the public. In that case, the recommendations set forth here may be used to guide international efforts to provide assistance.

2. BASIC PRINCIPLES FOR INTERVENTION

2.1. INTERVENTION SITUATIONS

201. Under normal operating conditions the additional doses to the nearby population from a nuclear facility are kept to strict levels that are as low as reasonably achievable and within internationally agreed dose limits and constraints. These dose constraints are set at levels much lower than those that would prompt a need for protective actions to the population or environment. They are also set with a margin to allow for possible future unknown sources of exposure [8]. Typically the values of these dose constraints to which discharges are controlled are smaller than local geographical variations in natural radiation. These low levels are achieved through the use of efficient control technology applied at the facility to limit the amount of radioactive material released and the resulting doses to members of the nearby population. This control does not impinge on the public in any way, but only on the commercial operation of the facility.

202. In the event of an accident, however, it has to be accepted that the amount of radioactive material released to the environment is no longer under control, and that, irrespective of liability for the accident, doses to individuals in the population can only be reduced by intervention - that is, through the imposition of protective measures, which will normally have considerable impacts on people and their environment. These measures may include evacuation, sheltering, taking stable iodine tablets, banning of food, modification of agricultural and industrial processes, decontamination measures, temporary relocation or permanent resettlement of the population. These protective measures are not without their own harmful effects: some have direct implications for health and well-being; they will all impose restrictions on people's freedom of action or choice; and resources may have to be diverted from other socially beneficial purposes to pay for them. Therefore, when choosing the level above which a given protective measure should be adopted, a balance needs to be struck between the benefits of the measure in terms of reducing the risk to health from radiation and the harm from the measure itself.

203. Hence, it is essential that confusion between the roles of dose limits and constraints for normal operations, and intervention levels for use following an accident, be avoided. Although similar principles apply (justification and optimization), they are applied to different quantities. In the case of control of planned releases, the benefit of the source itself is compared with the additional radiation exposure it produces. In the case of intervention, the benefit of the intervention is compared with the reduction in radiation exposure, including not only the reduction to the radiation exposure arising from the accident but also any changes in the exposures from the natural radiation environment as a result of the protective action. For these reasons, it is clear that intervention levels, and dose limits and constraints for normal conditions, have entirely different bases; their numerical values will normally be very different, and if for any reason their numerical values happen to be the same, this is entirely a matter of coincidence.

2.2. HEALTH GROUNDS FOR PROTECTIVE ACTION FOLLOWING AN ACCIDENT

204. Accidental releases of radioactive material may occur to air, to water, or onto land, and the protective measures for which numerical recommendations are provided in this report may be used, where applicable, for releases to any of these media. Accidents involving major releases to the atmosphere are the most likely to require urgent decisions for protective actions. Following any release of radioactive materials into the atmosphere, people may be exposed to radiation directly from the radioactive cloud and through inhalation of radioactive dust and gases from the cloud. As the cloud disperses, material will be deposited onto the earth's surface under dry conditions or washed out by rainfall or other forms of precipitation. Subsequently, people may be exposed to radiation directly from these radioactive deposits, by inhaling dust resuspended from the ground, or by eating contaminated foodstuffs or drinking contaminated water.

205. There are two main classes of health effect that can be caused by radiation exposure, termed "deterministic" and "stochastic" effects. Both classes of effect have been quantitatively characterized extensively elsewhere. A useful and comprehensive summary is contained in Annex I of Ref. [7]. Deterministic effects have the characteristics that they usually occur soon after exposure, their severity increases with the radiation dose received, but there is an effective threshold of dose below which they do not occur at all. Thus when faced with an intervention situation, every possible effort should be made to prevent anyone receiving doses above the thresholds for these effects. Indeed, because there will necessarily be uncertainties in the doses received, a margin of error will be introduced to seek to ensure that no-one suffers a deterministic effect.

206. Stochastic effects typically include a wide range of cancers and hereditary effects, which usually occur many years after the initial exposure. In contrast to the deterministic effects, there is no threshold of dose below which they cannot occur. However, they do not occur in every exposed individual; the **probability** of an individual or subsequent generations of an individual's descendants developing one of these effects increases with the dose received. Thus, even if the dose is very small,

he or she still has a very small chance of incurring one of these effects. For a large population, all receiving small radiation doses, it is possible to estimate, from a statistical point of view, the expected number of extra stochastic effects that would occur. However since other non-radiation related causes can give rise to similar effects, it is impossible to identify with certainty which individuals suffered the effects as a direct result of the radiation exposure.

207. Following an accident where radioactive material is released to the atmosphere, it is usually the case that the total population dose is made up of components ranging from few people receiving high doses to large numbers receiving very small doses. It is also usually the case that the most of the expected cancers will occur in a large population receiving smaller doses, and these cannot be totally prevented by any protective action. Thus the best that can be achieved by intervention will be to reduce the numbers of cancers by as many as reasonably possible. This will mean concentrating effort on those individuals who receive the higher doses, since this will achieve the maximum effect for the least number of people affected by any protective action.

208. Associated with any accident will be psychological stress and anxiety, independently of whether an actual radiation exposure has been received or not. This is more properly attributable to the perception of the risk to health, and whether there is confidence that the authorities are competent and trustworthy and have taken prompt and effective action to control the radiation doses. Because these effects are independent of the actual physical radiation dose received, they rightly do not influence the value of the intervention levels recommended here. Nevertheless, it is believed that having available clear, simple values that have been internationally recommended will do much to increase the confidence placed in the national authority, and thereby help to alleviate the inevitable psychological stresses and anxieties.

2.3. BASIC PRINCIPLES FOR INTERVENTION

209. Decisions to apply protective measures cannot be taken lightly, since all of these measures restrict people's freedom of action or choice, impose costs on society, and may cause direct harm and disruption of life to some people. The general principles that form the basis for these recommendations on intervention are derived from those contained in [7], and proceed naturally from the health grounds for protective action (Section 2.2).

210. The three general principles that form the basis for decisions on intervention are:

(a) **All possible efforts should be made to prevent serious deterministic health effects.**[4]

Serious deterministic effects can be prevented if the doses to all members of the public are kept below the thresholds for these effects. A margin of error will normally be introduced to ensure that wherever possible no-one receives doses above these thresholds.

(b) **The intervention should be *justified*, in the sense that introduction of the protective measure should achieve more good than harm.**

Intervention is justified when there is a net benefit in taking action. Since, for sufficiently low doses, the disadvantages of intervention may, for some protective

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[4] Although there has been discussion of the necessity to state the first principle explicitly (on the argument it is redundant), it has been included here because it is deemed necessary that explicit account be taken in the decision-making process of the uncertainties inherent in the dose predictions and the radiosensitivity of sub-groups in the population.

measures, outweigh the advantages achieved by avoiding the exposure, it is important to carefully consider the benefits and penalties of intervention. A detailed discussion of the factors that should be considered is provided in Ref. [7].

(c) **The levels at which the intervention is introduced and at which it is later withdrawn should be *optimized*, so that the protective measure will produce a maximum net benefit.**

Intervention is optimized when the net benefit from a protective measure is the maximum possible. An intervention level for each protective action can be chosen, above which the action is normally taken and below which the action is not normally taken. The values of the intervention levels for all the protective actions should then be derived in such a way as to produce the maximum net benefit.

211. The above approach is consistent with the view that an explicit limitation of individual risk is not appropriate as a general principle for intervention, whether the risk involved is of early or of late effects on health, because, if applied inflexibly, such a limitation could lead to decisions that are not justified.

212. Nonetheless, if not applied inflexibly, it is appropriate to consider action levels for intervention, when justified, to avoid unacceptably high risks to individuals. Since the choice of such action levels will depend on national decisions on the resources to commit, beyond those warranted by the arguments here, to reduce individual risks at the expense of the population taken as whole, they are not addressed here. These decisions are left for national authorities as an additional consideration that may modify some of the intervention levels derived here. Nevertheless, such decisions should not be taken lightly. Penalties increase rapidly with less and less dose saved for lower intervention levels (see Section 6.5).

2.4. FACTORS INFLUENCING THE CHOICE OF INTERVENTION LEVEL

213. Whilst there has been essentially a broad acceptance internationally of the three principles expressed above, when attempting to define a *net benefit*, it has not been possible to agree on the exact weightings to be attached to each of the factors influencing the decision to implement a protective action. In any case the importance of some of the factors will vary with the site and nature of the accident, thus making it hard to generalize. A detailed discussion of the factors that should be considered when setting intervention levels is provided in Ref. [7]. The dominant factors are those related to radiological protection principles, and to psychological and political factors. It is the intention that the generic intervention levels given in this document should be based on radiological protection principles alone, and that psychological and political factors will be deliberately excluded. Nevertheless a discussion of some of these factors is worthwhile at this stage.

214. As discussed in para. 207, a primary aim of protective actions is to reduce the numbers of cancers as much and as effectively as reasonably possible. It makes sense that a national authority should place as much effort and resources into avoiding a radiation induced cancer as it does in avoiding cancers from other causes, and more generally other serious illnesses and causes of premature death. If intervention levels have been set to achieve this, it can be seen that choosing lower levels would mean allocating more effort and resources to radiation protection than to other forms of health protection, and vice versa.

215. The level of individual risk of stochastic effects achieved by protective measures is often a significant concern to national authorities. Indeed when allocating resources for health protection, more are normally devoted to preventing effects to people at high risk than to people at low risk. Such individual risk considerations can be directly incorporated in the setting of intervention levels. Alternatively, the national authority can decide to adopt explicit objectives for individual risk levels whereby, if it is justified to do so, they would undertake intervention to keep risks of these effects

below these levels. The basis for setting such objectives for individual risk levels for intervention would clearly be different from that for deriving dose limits for normal operations.

216. For any protective action, there will be some probability of harmful effects, albeit in many cases small, due directly to the protective action itself. It is clear that in selecting intervention levels, the risk to health due to radiation exposure that is avoided by taking the protective action must exceed the risk to health from the protective action itself.

217. A national authority may be able to put the required resources and effort into health protection, but many protective actions additionally require restrictions to be placed on individual freedoms and impinge directly on people's lives. When selecting generic intervention levels, care should be taken that actions are not required to protect health that, because of the disruption and restrictions on personal freedoms, individuals would not normally deem to be worthwhile.

218. Most intervention is also disruptive to normal social and economic life. Change causes anxiety, which can be harmful to health and well-being. On the other hand, the absence of protective measures can also cause anxiety, which is often enhanced by a lack of objective information. These effects are non-radiological, are not readily quantifiable, will vary markedly between countries, and in any case will normally provide opposing forces on the choice of intervention levels. These considerations complicate decisions on intervention, which, in general, must involve persons and perspectives from outside the radiation protection community.

219. National authorities may sometimes wish to introduce protective measures that are not expected to impose a significant burden on the population or the national economy, even if these measures have little or no positive impact on health. This can occur when the absence of any action may lead to apprehension of inadequacy on the part of authorities, e.g. (a) that national authorities are not prepared and are unable to assess the situation and reach conclusions on the necessary protective measures; or (b) that, although national authorities and their advisers are fully aware of an assumed dangerous situation, they are reluctant to provide information to the public, are afraid of inducing or increasing panic or - even worse - are ignorant of the public anxiety, or are entering into an ignoble partnership with those responsible for the accident. In such cases, the need to gain public confidence to reduce anxiety and to gain broad acceptance for a given policy may be particularly important. Nevertheless, national authorities should always make clear to the public that such decisions are being taken for these reasons and not because they are warranted by radiological protection considerations.

2.5. APPROACH ADOPTED IN DEVELOPING GENERIC INTERVENTION LEVELS

220. If it were possible to be precise, taking a fully rigorous approach to selecting generic intervention levels would mean that for each separate site and facility and for a full spectrum of accident scenarios describing the nature and magnitude of the radioactive release, and possible meteorological and other local conditions, optimization, probably using some multiattribute technique, could be performed. These calculations would result in a set of possible intervention levels from which a value representative of the set could be selected as the generic intervention level.

221. This process would necessarily not be able to include the preferences of unknown decision makers/national authorities involved and their attitudes towards the importance of the various factors in the decision making process, some of which would be extremely difficult to quantify. Additionally, the reasoning behind the resulting generic levels would be obscured from external scrutiny, and even the decision makers themselves would find it difficult to appreciate the level of protection achieved by the use of such levels. Moreover, should they wish to consider adopting different levels, it would not be clear whether any factors had been counted twice, once in the derivation of the generic intervention level and once externally by decision makers themselves.

222. It is therefore extremely important that it be clearly stated which factors have been included in the selection of generic levels and which deliberately excluded. Should these other factors be of overriding importance, they can be readily taken into account with full knowledge of the working premises on the basis of which the levels given here are derived. In most cases the generic intervention levels will be adequate for the decision maker's use, provided they satisfy other requirements with regard to ensuring critical or radiosensitive groups are adequately protected. However, the relative importance to be attached to the various factors is ultimately a matter for the relevant authorities.

223. Nevertheless, generic intervention levels have been selected in this document for both urgent and longer term protective measures. The approach adopted is to select generic intervention levels on the basis of radiological protection principles alone, using the following working premises:

— *that, broadly speaking, under most conditions, a national authority places as much effort and resources into avoiding a radiation induced health effect as it would into avoiding risks to health of a similar magnitude and nature;*

— *that account is taken of normal physical risks from the action itself;*

— *that disruption to the individuals affected by the protective action is taken into account;*

— *that other factors of a socio-political, psychological and even cultural nature have been deliberately excluded;*

— *that the generic levels so selected form a logically consistent set of levels that are as simple to apply and understand as possible.*

It should be clearly recognized that political factors, as well as other social factors (such as disruption to society, anxiety and psychological effects), have been deliberately excluded from consideration in the development of these values. The above premises are relatively simple for a decision maker to appreciate, and to explain. It is judged that the approach represents the best technical argument that can be made on an international basis for the selection of generic intervention levels.

224. It is fully recognized that there may be important overriding reasons, such as practical difficulties, or specific site and/or accident circumstances, why levels other than those given here must be used. However, there is a restriction on the levels that may be selected, in that projected doses should, wherever possible, be maintained below the thresholds for deterministic effects. In Section 3.5 and para. 403 curbs on projected doses are discussed in detail for acute and chronic exposures, and numerical values recommended.

225. In addition, socio-political and psychological factors may well contribute to, or even dominate, some decisions. The generic guidance given here is intended to form a common baseline for decisions on protective measures, so that modifications to these intervention levels are clearly seen to be a matter of national policy, circumstances, or site-specific factors. Section 6 and Appendix II provide guidance to assist the decision maker in taking account of these factors. Nonetheless, the advantages of a common international response to radiological accidents are substantial, and reasons for such modifications should be clearly enunciated.

2.6. DOSES FOR COMPARISON WITH INTERVENTION LEVELS

226. For a typical accidental release of radioactive material to the atmosphere, the dose rate to the exposed population will initially be relatively high from the inhalation of radioactive materials in the plume and external radiation, but after the plume has passed the dose rate will fall considerably. Now the exposure will be external, from deposited material, and internal, from inhaled resuspended material and from contamination of foodstuffs. This dose rate will typically fall quite rapidly at first,

but then more slowly due to radioactive decay and other environmental processes. Figure 1 illustrates schematically a typical evolution of dose rate with time.

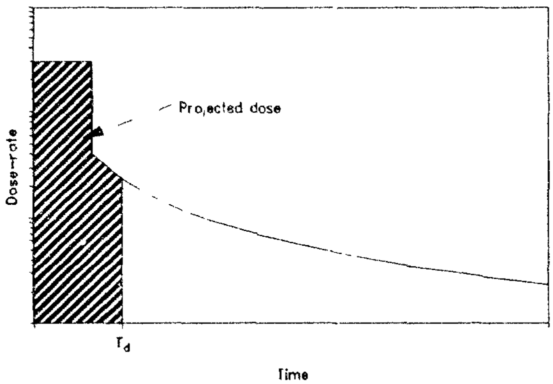

FIG. 1. Schematic diagram to illustrate concept of projected dose

227. Because of the different nature of deterministic and stochastic effects, two types of dose quantity are needed to be able to discuss the need for protective actions. The relevant quantity for expressing the risk of deterministic effects is the projected dose, i.e. the total dose received from the beginning of the accident via all pathways. This is usually limited to the dose received in a biologically significant time period, T_d (see Figure 1). To represent the risk of effects in a particular organ, the projected dose to that organ is required within a time period that depends on the organ.

228. When expressing the net benefit of a protective action to reduce the risk of stochastic effects, the dose that can be saved in the period of time, ΔT, for which the protective action lasts is the relevant quantity. Figure 2 illustrates the concept of this avertable dose. At a particular time, we suppose that a protective action is introduced such that the individuals affected subsequently have a significantly reduced dose rate. After a period of time, ΔT, the measure is withdrawn and their dose rates increase again. The dose averted by the measure is the integrated dose rate over the period ΔT that they would have in the absence of the measure, minus the integrated dose rate that they would have if the measure is taken. Only the avertable doses from those pathways that can be influenced by the protective action should normally be taken into account in judging whether to take it or not. Including doses that have already been received before a protective measure can be implemented for comparison to an intervention level expressed in terms of avertable dose is not appropriate because intervention cannot reduce doses already received.

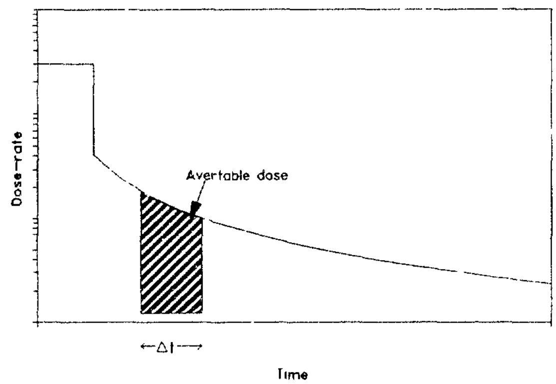

FIG. 2. Schematic diagram to illustrate concept of avertable dose.

229. For most circumstances, the second and third principles are more restrictive than the first. Hence intervention levels are more correctly expressed in terms of avertable doses. Nevertheless the optimization process is constrained by the first principle, such that there is an additional condition on the projected dose. In many practical cases, where a protective action is very effective at reducing doses, the avertable dose will be equal to the projected dose from the same pathways and over the same time period, but this will not always be the case.

230. Although the avertable dose in a given time, suitably qualified, is the most relevant quantity for judging the need for a protective action, this does not preclude the use of other quantities. Quantities such as annual dose, average annual dose over a fixed period, level of contamination, etc., can, if used judiciously, act as adequate surrogates for the avertable dose. However, these quantities will be derived from the avertable dose taking into account factors that will often be country, site, and accident specific. Thus whilst they may be used by individual countries, it is considered that the avertable dose is the best quantity to use to express generic intervention levels. On the other hand, in considering the risk from serious early health effects, quantities such as the projected dose truncated over a period of biological importance should be used (e.g. 2 days for bone marrow dose). Indeed, such quantities have been used here for expressing the upper bounds for projected dose.

231. The values for generic intervention levels recommended here, on the whole, will not lead to situations where any detectable increase in cancer rates will occur. However, should there have been delays or inefficiencies in the implementation of protective actions that led to exposures much higher than the intervention levels, then an authority may identify a concern that increases in cancer rates will be detectable and that it will be held responsible for these on the grounds of negligence or incompetence. In these circumstances, it may well be considered that past doses should be included in the decision making process for long-term intervention levels. However, this would have to be clearly recognized as a socio-political factor that national authorities are explicitly incorporating into the decision process. In this document such considerations are deliberately excluded.

2.7. REALISM IN THE DEVELOPMENT OF INTERVENTION LEVELS

232. Because of the different nature of deterministic and stochastic health effects, it is necessary to consider the population groups to which any criteria might apply. Because of the existence of thresholds for deterministic effects, the average dose to a population is not a meaningful predictor of the likelihood of these effects. Instead the projected dose to the highly exposed and radiosensitive groups of the population should be used. Because of uncertainties in any dose assessment, a margin of error will often be used to ensure that the likelihood of any deterministic effects is small.

233. However, in normal circumstances, protective actions will be dominated by the need to reduce the numbers of stochastic effects in the population. Since there is no threshold of dose for these effects, the average avertable dose for the population to whom the protective action is contemplated will represent the average avertable risk of late effects. Hence the estimate of dose, or other surrogate quantity, for comparison with the intervention level should be as realistic as possible. The assumption of extreme or unrealistic characteristics in the dose assessment would be inconsistent with the optimization used in the development of these levels for intervention.

234. The adoption of a conservative approach to the estimation of dose is often defended as being beneficial on the grounds that action will be taken at lower doses and this is in the best interests of those affected. This view, however, ignores any negative impacts of the protective measure itself, which, particularly in the case of longer term protective measures, may be considerable. The effects of using more conservative approaches are discussed in Section 6.5. The use of average values for living habits will normally remain reasonable, because the variation between extreme and average habits will not result in a significant risk variation.

235. On the other hand, it cannot be emphasized too strongly that there will be special situations or groups in the population for which intervention at levels that are normally appropriate will be clearly unreasonable. For example, evacuation at the intervention level appropriate under normal circumstances for the general population should be deferred to a higher value (a) for medical patients who are not movable, (b) in hazardous weather conditions, or (c) when there is a competing disaster, e.g. a hazardous chemical release along an evacuation route or an earthquake. Emergency response plans would have to make explicit provisions for such situations and groups, and, in the case of accidents for which there is no emergency response plan, responsible officials must take special care to assess and adjust the implementation of protective measures to accommodate such special situations.

3. URGENT PROTECTIVE MEASURES

3.1. GENERAL

301. The term "Urgent Intervention" is used to describe those actions or protective measures that must be applied promptly in order to be effective, and for which procrastination will markedly reduce their effectiveness. Unwarranted delays will lead to population exposures that could have been

avoided and, in the worst cases, could even lead to serious deterministic health effects. Thus the principal characteristic of urgent protective actions is the lack of time available in which to make a decision regarding their initiation. There will be no time in which to introduce lengthy appraisal procedures for the optimization of the application of protective measures. This lack of time is compounded by the fact that information about the magnitude and nature of the accident is usually very limited and uncertainties are correspondingly large when these decisions need to be taken.

302. This lack of time in which to take a decision on whether to invoke a protective action and to what scale, is the crucial reason for having detailed emergency plans wherever possible. Indeed, fuel cycle facilities (e.g., reactors, fuel fabrication facilities and reprocessing plants) in any case have mandatory emergency plans in force. These plans specify intervention levels for the various protective actions, and detailed considerations of site-specific and accident-specific conditions can be taken into account at the planning stage when specifying these levels. This reduces the chances that an otherwise unprepared decision maker could make seriously wrong decisions under the pressure of lack of time. Thus much of the flexibility implied in the optimization process can be built into the plans themselves; nevertheless, the final decision always rests with the decision maker at the time as to whether there are any overriding reasons why a different course of action should be taken from that specified in those plans.

303. The generic levels recommended here can in many circumstances be specified as the appropriate intervention levels in the emergency plans. They will usually not be significantly different from the range of levels that could be produced by a group of decision makers, given the level of information that would be available to such a group. There are considerable advantages in adopting them as internationally recognized levels. Nevertheless, as mentioned before, there will be identifiable situations for which they are not appropriate. In these cases, the generic levels can be used as benchmarks, and the reasons for selecting other values can be clearly and explicitly given.

3.2. PATHWAYS OF EXPOSURE AND URGENT PROTECTIVE ACTIONS

304. The risk to a population following an accident may arise from direct exposure and/or contamination from an unshielded or damaged source and/or the release and dispersion of radioactive material into the environment. Release of airborne radioactive substances into the atmosphere is the more probable source of contamination of the environment from accidents involving nuclear fuel cycle facilities (including reactors). However, the release of liquid radioactive materials to surface or ground waters cannot be ignored. This release of radioactive material can be as short as an hour or less, or can last up to several days or even weeks. For a protective action to be an urgent one, it must be effective against exposures that arise in the short term (hours and days). Members of the public may be exposed to radiation over this time period either externally or internally by various pathways. External exposure results principally from gamma-emitting radionuclides contained in the plume or deposited on the ground, but also includes exposure of the skin to beta-emitting radionuclides deposited on the skin or clothing. Internal exposure in the short term is dominated by inhaled airborne radioactive material, of which the short-lived radioiodine isotopes are of particular importance for nuclear power plant accidents. In the case of a prolonged release, exposure from the ingestion pathway may have to be considered, since contaminated locally produced/consumed foodstuffs may contribute significantly to the total exposure.

305. The radionuclides released and the exposure pathways play a key role in determining the effectiveness of protective measures. Experience shows that among the protective measures that are available in the event of a nuclear accident or major radiological emergency, those that need to be applied promptly to be most effective are:

- evacuation;
- sheltering;
- administration of stable iodine.

306. Additional protective measures that could be applied promptly may include:

- control of access and egress;
- respiratory protection;
- use of personal protective clothing.

It should be stressed that, although these secondary protective measures may bring a consequent protection, it will usually be inappropriate to recommend any related intervention levels, as the protective measures do not stand alone, but will be accompanying measures for the primary actions.

3.3. DISCUSSION OF THE URGENT PROTECTIVE MEASURES

3.3.1. Sheltering

307. Sheltering refers to staying inside or moving into dwellings or other buildings, closing doors and windows, and turning off any ventilation systems in order that individuals will inhale less radioactive material from the outside air, as well as reducing their direct exposure to the cloud and to short-lived surface deposits. Sheltering can also be used as a means of controlling the population in order to facilitate other protective measures, such as evacuation and the administration of stable iodine. However, there is a limit to the time that the population can reasonably be expected to remain sheltered indoors. In considering sheltering as a protective action, its effectiveness in averting radiation doses will need to be considered, since it can vary markedly.

308. During the early stages of an accident involving a release of relatively short duration of mixed radionuclides into the atmosphere, and while the plume is passing, the contribution of the dose from inhalation will usually be much larger than that from external radiation [9]. Most buildings will reduce potential inhalation doses by a factor of two or so [10]. External doses can be reduced by an order of magnitude or more for brick-built or large, commercial structures [11]. Many open or lightweight buildings, however, do not provide such effective protection. Judgements on the relative merits of sheltering and evacuation as protective measures strongly depend on the timing of their respective introduction relative to the accident phase and the magnitude and radionuclide composition of the release. In any case, following a period of sheltering and after the plume has passed, ventilation is advisable, to reduce the air concentrations that have risen inside the shelter to the levels of the now relatively clean air outside.

3.3.2. Administration of stable iodine

309. Taking stable iodine is a practicable measure for reducing the uptake of inhaled and ingested radioiodine into the thyroid, which otherwise could receive an unnecessarily high radiation dose. After an intake of radioiodine, the activity in the thyroid reaches 50% of the maximum within about six hours and the maximum itself in one or two days [12]. Thus, to obtain the maximum reduction of the radiation dose to the thyroid, stable iodine should be administered before any intake of radioactive iodine; otherwise, as soon as practicable thereafter. If stable iodine is administered orally within the six hours preceding the intake of radioactive iodine, the protection provided is about 98% ; it is about 90% if stable iodine is administered at the time of inhalation. Its effectiveness decreases with delay, but the uptake of radioiodine by the thyroid can still be reduced to about 50%, if it is administered within four to six hours of inhalation [12].

310. It is therefore important to administer stable iodine as soon as possible, and ideally some pre-release distribution is desirable. Whilst a generic intervention level for the administration of stable iodine is given here, it should be stressed that this is for the case where distribution prior to the release has been done. The decision as to whether and how stable iodine should be made available for the population is one that has to be taken at the stage of developing emergency plans.

One of the key factors influencing this decision is the likelihood of an accident occurring that would lead to the generic intervention level being exceeded.

311. The main potential source of radioiodine to the population would be from accidents at reactors (such as from those at Windscale in the United Kingdom in 1957 and Chernobyl in the USSR in 1986). Usually, it is expected that a release of radioactive iodine isotopes would be accompanied by a significant release of other radioisotopes. However, there could be instances, such as in the Windscale accident, when radioiodines would predominate in the release. It is in such cases that iodine prophylaxis could become an important protective measure. In most other cases, the doses to the thyroid from other radionuclides and other pathways such as external radiation could become the major contributors to thyroid exposures. In addition, Ref. [13] suggests that I-131 in the thyroid is one fourth to one third as effective as external radiation. In these cases, the decision as to whether to apply iodine prophylaxis would have to be carefully weighed, since the administration of stable iodine does entail some risk.

312. The risk of cancer (both fatal and non-fatal) to the thyroid is high for the very young, decreasing with age and becoming almost negligible (because of the latency period) for the elderly [13].

313. The risks associated with the administration of stable iodine to members of the public in a single dose of 100 mg of iodine (which is the recommended dosage for one day, the most common materials being potassium iodide or potassium iodate in quantities of 130 and 170 mg respectively) are very small in countries with high dietary iodine intake, but increase for countries and areas where there is a marked iodine deficiency in the diet [12]. The main risks from intakes of stable iodine would be in the occurrence of hypothyroidism, hyperthyroidism, thyrotoxicosis and goitre. When the correct dosage is given to the population, the risk of side effects is relatively small to the very young, whilst it increases with age, and becoming pronounced for the elderly.

314. In all cases, the risks of stable iodine prophylaxis should be weighed against the risks of the induction of hypothyroidism and benign or malignant tumours by the additional dose that would be received if stable iodine were not administered. In addition, the reduction in effectiveness with delay should also be considered.

315. The administration of stable iodine will usually not be a stand-alone protective measure, but will accompany evacuation and/or sheltering. Authorities may, for practical reasons, choose to develop emergency plans that rely on these protective actions rather than on the use of stable iodine.

316. If exposure to radioactive iodine lasts more than a few days, which is the period during which the thyroid is protected after a single administration of stable iodine, it could be advisable to repeat this medication. It should be emphasized that the risk of side effects, which is small for a single administration, will increase with the number of administrations. Therefore, this action should not be relied on as the main protection against the ingestion of radioiodine-contaminated foodstuffs (unless no uncontaminated food is available). Reference [14] recommends that the total dosage of stable iodine compounds should not exceed the equivalent of 1 gram of iodide for individuals over 1 year of age.

317. By taking into account the probable pathways of exposure to the thyroid, i.e. from inhalation and from ingestion, and the existence of the dosage limitation for stable iodine, and taking into account the half-lives of the predominant iodine isotopes, the conclusion can be reached that iodine prophylaxis should be considered as a protective measure for inhalation only, since the release phase lasts for a relatively short time, during which the limiting dosage of stable iodine would not normally be exceeded, and **not** for the ingestion pathway. For ingestion, other protective measures such as food restrictions would have to be employed.

318. In defining the national intervention level for stable iodine administration, more than for other protective measures, country-specific considerations have to be taken into account, rather than

employing the generic intervention levels presented here. These considerations will be based, inter alia, on the dietary iodine intake by the population and the prevalence of thyroid diseases. When iodine deficiency is present, the thyroid will take up more iodine (and therefore radioiodine) than the thyroid of a person with an adequate iodine intake. On the other hand, the side effects of stable iodine are also likely to be more frequent in populations with a low iodine intake [12].

3.3.3. Evacuation

319. Evacuation is the urgent moving of people from their normal place of residence, or from places of work or recreation, for a limited period of time, in order to avoid unnecessarily high exposures that would otherwise arise in the short term from the accident. This protective measure is commonly used for many other types of emergency where a population is threatened by hazards caused either by forces of nature (e.g. earthquakes, floods) or by man-made activities (e.g. fire, chemical spills). In most cases the population will be permitted to return to their places of residence within a short period of time, typically 1-2 days, if these places are habitable and do not warrant prolonged periods of clean-up operations. Because of the short period that the population is expected to stay away from their homes, they will usually be given temporary and very rough accommodation, such as in schools and other public buildings. Although relocation and resettlement are discussed in detail in Section 4, it should be noted that the provision for the comfort of the population undergoing these protective actions will necessarily entail a much higher standard, since the period of absence from the homes is much longer (if not forever), and it should be possible to better plan the conditions under which the moved population will live. Only in the case that evacuated people are forced to remain away from their homes for long periods or permanently, will the accommodation conditions in the transitional period become really unpleasant.

320. Evacuation can be implemented at various stages in the development of an accident. It is most effective (in terms of avoiding radiation exposure) if it can be taken as a precautionary measure in the pre-release phase of an accident in a nuclear facility, before there has been any significant release of radioactive material. An assessment of how the release might progress, particularly during the earlier stages of the accident, will have considerable significance for the decision whether to implement precautionary evacuation.

321. In some cases there may be insufficient warning to effect precautionary evacuation. For a release from a nuclear facility, evacuation implemented during the release phase might result in moving some people through the airborne plume, with the possibility of their receiving higher doses than they may have received had they, alternatively, been advised to shelter. The relative merits of evacuation and sheltering once a release has begun will depend critically on the efficiency of sheltering and the accident prognosis, particularly the meteorological influence, and these factors are likely to vary considerably with both the location and the characteristics of the accident. It is not, therefore, possible to generalize on the optimum course of action, as this can only be determined by consideration of the specific circumstances of interest, including practical considerations such as the type and nature of the available emergency planning resources.

322. Evacuation may still be implemented after the dispersion of the released material has terminated. In this case, it would be introduced as an urgent action to avoid exposure from deposited material (externally and also internally from resuspended material) which, in the absence of evacuation, might result in unnecessarily high doses being received in the short term (i.e. within a few days). This situation is most likely to arise in some atypical cases of radiological emergencies, e.g following a nuclear powered satellite re-entry, or after the spread of contamination from a damaged large radiation source.

3.4. GENERIC INTERVENTION LEVELS (GILs) FOR URGENT PROTECTIVE ACTIONS

323. The development of Generic Intervention Levels for Urgent Protective Measures from the working premises given in para. 223 is presented in Appendix I. On the basis of a set of sensitivity studies, the values given in Table I are recommended. In addition to satisfying the premises, these levels have other desirable features, namely (1) they observe the obligation to avoid serious deterministic effects in the population, including sub-groups more radiosensitive than the average, (2) the assumed statistical increase in the numbers of cancers in the future to the population for whom the protective action is not applied is not unnecessarily high and (3) they are sufficiently far from the thresholds for deterministic effects to allow for uncertainties in the development of the accident.

324. Evacuation is most effective if it can be taken as a precautionary measure in the pre-release phase. The recommended Generic Intervention Level given in Table I for evacuation is expressed as the average dose avertable by the evacuation. If any of the projected doses are expected to exceed the thresholds for deterministic effects, the priority for evacuating people should be such that those groups who first might exceed this threshold should be evacuated first. If all the projected doses are below the thresholds for deterministic effects but above the GIL, evacuation should also be implemented, but only if the foreseen avertable dose is higher than the GIL. If a large number of people are to be evacuated and the increased traffic volume might cause some exposure during evacuation, this should be taken into account when considering whether the measure can avert a dose exceeding the GIL.

TABLE I. RECOMMENDED GENERIC INTERVENTION LEVELS FOR URGENT PROTECTIVE ACTIONS

Protective action	Generic Intervention Level (dose **avertable** by the protective action)[a,b]
Sheltering	Initiate to avoid at least 3 mSv in six hours[c]
Iodine prophylaxis	Initiate to avert at least: 50 mGy from up to 10 days' intake for children; 500 mGy from up to 10 days' intake for adults[d]
Evacuation	Initiate to avert at least 10 mSv in one day[c,e]

[a] These levels are of avertable dose, ie the action is taken if the average dose that can be averted by the action, taking into account the loss of effectiveness due to any delays or other practical reasons, is greater than the figure given (see para. 228).

[b] The levels in all cases refer to the average population, not to the most exposed individuals (see para. 233). However, the projected doses to the critical and/or radiosensitive groups should be kept within the upper bounds (Table II).

[c] Doses are effective doses and are the sum of the doses due to the external and the committed internal doses.

[d] Committed dose to the thyroid due to radioiodine.

[e] For the dose avertable by evacuation account may well need to be taken of the fact that advice to shelter may already have been given. For example, if buildings provide a dose reduction factor of about three, and if the dose received during evacuation itself will be 5% of the outdoor dose otherwise received in the first day, an appropriate outdoor dose (external + inhalation) for which the avertable dose is 10 mSv in a day is :

$$10/(⅓-0.05) \approx 35 \text{ mSv in a day}$$

In addition, the physical risk of the countermeasure and the risk of deterministic effects must also be taken into account in the decision. The development of such operational quantities is outside the scope of this document, but guidance will be provided in a future publication.

TABLE II. THRESHOLDS OF OCCURRENCE OF DETERMINISTIC EFFECTS AND CORRESPONDING RISKS OF STOCHASTIC EFFECTS FOR ACUTE EXPOSURE

Organ or tissue	Dose[a] in 2 days (Gy)	Deterministic Effects		*Corresponding lifetime risk of stochastic effect*[b]
		Type of effect	Time of occurrence	
Whole body (bone marrow)	1	death	1 - 2 months	*1 × 10^{1} (fatal cancer)*
	0.5	vomiting	1st day	*1 × 10^{-2} (fatal cancer)*
Lung	6	death	2 - 12 months	*5 × 10^{-2} (lung cancer)*[b]
Skin	3	erythema	1 - 3 weeks	*1 × 10^{-3} (skin cancer)*[d]
Thyroid	5	hypothyroidism	1st - several years	*8 × 10^{3} (fatal thyroid cancer)*[e]
Lens of the eye[f]	2	cataract	6 months - several years	*not applicable*[f]
Gonads[f]	3	permanent sterility	weeks	*3 × 10^{-2} (genetic effects)*

[a] Projected dose delivered in a short period of time. Generally speaking, the shorter the time, the more severe the effect. As this time dependence varies between organs, it is not possible to give an exact value for the maximum period during which the dose would have to be delivered to produce the same effect; however, in all cases presented in this table, the dose would have to be delivered in less than 2 days to produce the described effect.

These levels of dose are applicable to a population characterized by a typical age distribution, and represent doses below which deterministic effects will not normally occur. For some specific conditions (eg health conditions ...) the values could be lower. Consequently, these values may not be appropriate for special radiosensitive groups.

[b] These are the average risk of stochastic effects to individuals who are exposed to the thresholds in the first column, but do not exhibit deterministic effects. The risk is appropriate only for the two days exposure considered. There will usually be additional risks from continued exposure after this period. The basic values are those recommended by the ICRP [13] but they do not take into account the DDREF (Dose and Dose Rate Effectiveness Factor), as (except for the lung) the dose is delivered in a short period of time (absorbed dose greater than 0.2 Gy or dose rate greater than 0.1 Gy h^{-1}). The use of a DDREF would underestimate the risk of stochastic effects after acute exposure of whole body, bone marrow, skin and thyroid. For lung, the DDREF has been applied since any isolated dose to the lung will be due to inhalation and will normally be committed over longer periods of time.

[c] Including a risk of 1.10^{-2} of leukemia.

[d] Expresses only the risk of fatal skin cancer, which represents only a very small fraction of the total skin cancers, since most skin cancer is curable.

[e] Since most thyroid cancers are curable, and this figure represents only the risk of fatal thyroid cancers, the value should be multiplied by about twenty to get the total risk of thyroid cancer.

[f] The lens of the eye and the gonads are listed in this table for completeness, although in practice they are often redundant: an accident which results only in irradiation of the lens of the eye or of the gonads is very unusual. Therefore, these organs are normally protected automatically against deterministic effects by the lower threshold for other organs such as bone marrow (whole body exposure). This also means that the risk of genetic effects is overestimated by this figure here, and would normally be a factor of three lower, if 1 Sv whole body were the limiting criterion.

3.5. PREVENTING DETERMINISTIC EFFECTS ON HEALTH

325. Intervention should always be introduced at levels of individual dose above which deterministic health effects would occur. The sole exception to this is if such intervention would make the situation worse.

Generally, the dose-response relationships for deterministic effects exhibit a threshold. For each deterministic effect, the two parameters to be considered are the threshold above which the given effect may occur and the severity of the effect.

The main objective for planning purposes and decision making is to identify:

(1) the organs and tissues at risk in an accident; and

(2) the levels of dose below which the deterministic effects are unlikely to occur in the exposed individuals.

It is important to emphasize here that when individual doses caused by an accident are projected, due consideration should be given to uncertainties in the doses projected which are to be compared to the threshold doses for deterministic effects.

326. The most important among the severe early health effects, against which the affected population group should be protected, is early mortality. Non-fatal, but still serious, early health consequences of radiation exposure should also be taken into consideration. These so-called morbidity effects are in most cases temporary, treatable and curable. Early mortality may be seen in some radiosensitive individuals at doses of about 1 Gy or above (acute exposure) to the whole body because of bone-marrow failure. Acute radiation effects may also occur in single organs following exposures to high doses. Most of the threshold values (acute exposure) for these single organ effects are above the threshold for bone-marrow failure. Because of this, it is not necessary to consider the effects to single organs likely to occur after acute whole body exposures. However, some organs such as the thyroid and the lung may receive preferential organ exposures due to particular metabolism of important inhaled or ingested radionuclides. Decision makers should be aware that, at doses around the thresholds for deterministic effects, the risk of stochastic effects is not negligible. Table II gives numerical values for assisting in the decision on introducing urgent countermeasures to avoid deterministic health effects that have a high degree of certainty due to safety factors in the dose projection.

327. In many emergencies, there will be people for whom the application of protective measures, especially evacuation, will be more difficult than for others. These groups would include bed-ridden people, including hospital patients, old people, prisoners, etc. In other cases, the implementation of evacuation would cause undue risk, and may even expose the evacuees more than if they had not been evacuated. The exposure to these specific populations should be considered not only according to a generic intervention level, but also according to an upper bound for projected dose based on a consideration of the levels in Table II.

4. LONGER TERM PROTECTIVE ACTIONS

4.1. INTRODUCTION

401. Whilst the protective measures of sheltering, evacuation and the distribution of stable iodine are intended to be of short duration, other protective measures may be considered that are likely to be more prolonged. Most notable among these are the temporary relocation or permanent resettlement of people away from the contaminated area, and food interdiction. Although the basic principles of justification and optimisation still apply to decisions on these longer term protective

measures, the nature of such decisions is rather different. In the case of urgent measures, the greatest benefit is likely to accrue from taking measures with little or no delay based on predictions of how the accident will develop. For longer term protective measures, there could be a rather small radiological penalty for delaying whilst measurements are undertaken to more accurately determine the impact of the accident. Moreover, the social and economic penalties for adopting imprudent criteria may be very high, owing to the relatively long time period over which the protective measures may be in force. Therefore for longer term protective measures it is important that the justification and optimisation process is carried out in as informed a manner as possible, using best estimates for the consequences of different protective options. If pessimistic estimates are used for some of the consequences (e.g. the radiological consequences) whilst other consequences are either best estimates or under-estimates, then the resulting decision cannot be optimal, and there may be significant penalties in the longer term.

402. It is recognised that for any particular accident and circumstance generic levels would be unlikely to be exactly optimum. However, even after an accident, it is difficult to predict the precise consequences that will result from a protective action, owing to the length of time over which the protective measures may be in force. This means that no optimisation study for longer term protective measures can expect to identify the theoretically true optimum. However, the benefits to be gained from adopting an internationally recognized value in advance of an accident, in terms of ease of application and increased public confidence, are large. Provided generic intervention levels adopted are not grossly non-optimum for a wide range of circumstances, and the circumstances in which alternative levels would be appropriate are clearly identified, the advantages of adopting generic levels will often outweigh any disadvantages.

403. The purpose of longer term protective measures is generally to reduce the risk of stochastic and genetic health effects in the exposed population. However, it is clearly important to ensure that the level of protection is also sufficient to prevent serious deterministic health injuries. The deterministic thresholds for protracted exposure are higher than the corresponding thresholds for acute exposure. This is because the human body has repair mechanisms that can operate if a dose is delivered over a longer period of time. The reduced harmful effect of protracted doses varies with organs and tissues; in most cases, the reduction increases rapidly as the time over which the dose is delivered is increased. For instance, while 1 Gy can be considered as a threshold for bone marrow failure when the dose is delivered in a few hours or less, 4 Gy are needed if the exposure is prolonged over a few months; for thyroid, the threshold dose needs to be increased about 5 times if the dose from iodine-131 is delivered internally over a period of about three weeks, compared with acute external exposure; for lung, factors of 10, 20 and 50 [15] are not inconceivable when the dose is delivered in 2 weeks, 6 months and 1 year respectively; prolonged exposure of the skin will result in chronic radiodermatitis, with hyperkeratosis and telangiectasia of the exposed blood vessels. Dose protraction seems less effective for the lens of the eye than for some other organs, since a dose higher by a factor of 2-3 and delivered in a few weeks results in the same effect. Another effect of dose protraction is that additional deterministic effects may arise following chronic exposure that are not observed following acute exposure. However, all these effects will only appear at levels of total dose well in excess of the typical intervention levels used in order to reduce the risk of stochastic effects. This is certainly true of the generic intervention levels recommended here.

4.2. MOVING PEOPLE IN THE LONGER TERM

404. Temporary relocation and/or permanent resettlement are two of the more extreme protective measures available to control radiation exposures to the public in the event of a major nuclear accident. Temporary relocation is the term used to indicate the organised and considered removal of people from the area affected by an accident for an extended but limited period of time (e.g., several months) to avert exposures principally from radioactive material deposited on the ground and from inhalation of any resuspended radioactive particulate materials [7]. During this period, people would typically be housed in temporary, rented accommodation. Permanent resettlement, on the other

hand, is the term to indicate the considered complete removal of people from the area with no expectation of return within their lifetimes. This would typically involve construction of new accommodation and infrastructure in an area remote from the contaminated zones.

405. It is important not to confuse temporary relocation with evacuation, which refers to the urgent removal of people from an area to avert or reduce their exposure from an airborne plume or from deposited radioactive materials [7]. Accommodation following an urgent evacuation will typically take place in local community centres and people will return to the area within a relatively short period of time (e.g., several days) provided temporary relocation is not warranted. Thus, temporary relocation may be carried out as an extension to evacuation, or could be implemented at a later stage of the accident. During the period of temporary relocation there will be time for decontamination of land and property.

406. The decision on the need for temporary relocation is usually less urgent than that for evacuation. Temporary relocation is introduced to avoid unnecessarily high doses occurring over the period of months, and limited delays whilst measurements are taken and the situation is assessed can usually be justified.

407. With the passage of time, radioactive decay and natural processes (e.g., wash-off, weathering) will reduce the contamination in the area originally designated for temporary relocation, allowing people to return and/or resume other activities in that area. Remedial measures, including forced decontamination of land and property [7], can be used to shorten the period of temporary relocation. In any case, there will be a limit to the period of time for which temporary relocation can reasonably be sustained. Two factors will affect the length of this period. Firstly, economic considerations will take into account the relative costs of continuing temporary relocation against the costs of permanent resettlement. Secondly, social considerations will take into account the fact that any uncertain, temporary situation is unsustainable. A prolonged transitory period will produce a general sense of anxiety and discontent in the population affected, all of which can result in loss of productivity, public health problems and even a possible shortening of life expectancy.

408. At the time when the decision on moving people is taken it is important to decide whether decontamination and radioactive decay will be able to reduce the contamination levels so that temporary relocation for a limited and reasonable period of time is warranted, or whether permanent resettlement is deemed to be necessary. If the relocation is temporary, the population should be notified about the approximate period of relocation, in order to allay anxieties and provide them with a target goal for returning to their old and usually more desirable way of life. Informing the population as soon as possible that the proposed move is permanent could enable them to readjust more quickly and sooner return to a more normal and productive way of life.

4.3. TEMPORARY RELOCATION

409. Provided temporary relocation is justified, intervention levels can be set for this protective action that balance the health risks of continued radiation exposure against the risks to health and well-being of temporary relocation and other direct and indirect costs. The magnitude of these direct and indirect costs may vary with the accident conditions and their relative importances may be susceptible to political and social value judgements.

410. For many cases the dominant considerations are the radiological risks, the efforts and resources used to reduce radiation exposures, and individual and social disruption, although anxiety and any resulting risks to mental well-being can also play a part. For the purposes of selecting generic intervention levels for temporary relocation, the working premises of para. 223 have been utilized. It should be noted that these premises deliberately exclude the factors of social disruption and reassurance, both of which could be of importance in the decision making process with regard to temporary relocation. The factors that are considered are discussed below.

411. The resources required for the forced movement of people, e.g. for evacuation and, specifically here, relocation, include the following categories:

- — transport of people and their belongings away from (and later back to) the affected area;
- — temporary accommodation and additional living expenses;
- — loss of income from being unable to reach the workplace;
- — lost capital values and investments on land and property;
- — maintenance and/or renovation of the empty buildings;
- — additional policing and administrative costs.

412. The resources required to transport people and their belongings from the contaminated area to a temporary residence (and back again on return) are needed only once and will entail providing transport itself and any labour needed to assist with the removals.

413. Other resources will be needed on a continuing basis whilst the protective action lasts, such as accommodation and loss of income. Accommodation of an acceptable standard and convenience will need to be provided and/or possible monetary compensation to make up for any shortfall in the standard of accommodation.

414. People who have been relocated temporarily may or may not be able to continue to attend their usual place of work. This will depend on the scale of the accident. For accidents of a smaller scale, it is likely that for many of the population only the residence would be curtailed by relocation, and that work could continue in the area. For large-scale accidents work might have to be suspended leaving people temporarily unemployed; although some people who normally travel significant distances to their workplaces could continue to work.

415. The loss of capital value on the property and the maintenance/renovation of the property go hand-in-hand, and in assessing the resources needed to cover these aspects it is important to ensure that they are not counted twice.

416. With regard to personal disruption, it is possible to estimate from other cases where households are temporarily relocated (e.g. owing to storm, flood, subsidence damage) how much value people attribute to staying in their homes, and how much compensation they would need to be forcibly moved from their homes and placed in accommodation of a comparable standard [16]. This can be expressed as a fraction of their salary and incorporated as a measure of individual disruption associated with relocation.

417. The physical risks associated with temporary relocation are relatively small compared to, say, those for evacuation, since the action can be carried out in a relatively controlled and safe manner, and the dangers of living in temporary accommodation are not significantly higher than those of living in the original accommodation. It should be noted that there will be special groups in the population for which the physical risks associated with relocation could be high (e.g. hospital patients). In addition, there may be psychological harm to relocated individuals, from the upheaval to their normal way of living. These factors are hard to quantify and, in any case, will need to be considered along with the psychological harm of not moving due to perceived radiological risk.

418. If the total resources are dominated by the continuing needs as opposed to the initial requirements, then the intervention level will be naturally expressed as the avertable dose in a period of time commensurate with typical lengths of temporary relocation. In this document, the levels are expressed as the dose in mSv that can be saved in a month of temporary relocation. In addition this criterion will be used to indicate when return to an area is warranted. Finally, it should be noted that while there is more time for the decision to be taken on temporary relocation than for urgent decisions, values for intervention levels need to be in the emergency plans, because they are also needed for the decision on whether people can return to their homes should they have been urgently evacuated.

419. Other factors that may influence the decision to relocate and hence the intervention level for relocation will include the following:

- Social disruption
- Anxiety
- Need for reassurance
- Political factors.

4.4. GENERIC INTERVENTION LEVELS FOR TEMPORARY RELOCATION

420. Because of the potential importance of socio-political factors in the establishment of intervention levels for relocation, differences are to be expected between the levels used in different countries, even where they have all been developed in accordance with the same basic radiological protection principles or objectives. Such differences should therefore not be seen as surprising but rather be recognized as almost inevitable. Nevertheless generic levels are believed to be valuable as a benchmark against which these differences can be measured, and also to provide an internationally recognized value that will give the population some confidence that authorities are acting in their best interests.

421. The working premises given in para. 223 have been realized in Appendix I and generic intervention levels have been selected on the basis of that technical analysis. The values are presented in Table III.

422. It should be emphasized that the intervention levels as presented in Table III refer specifically to (1) the avertable dose in a month; (2) the mean per caput avertable dose of the population being considered for relocation, i.e. a realistic mean dose rate to individuals living normally, allowing for the time spent inside buildings with realistic reduction factors for their shielding effects. Operational quantities can be calculated, for example, of the equivalent dose rate measurable outside that would give rise to the generic intervention level of avertable dose (Annex).

423. Although in principle the intervention level for temporary relocation will vary from country to country, Appendix I indicates that it might be much less sensitive to geographical location than to considerations of resources needed for radiological protection or health protection separately, because both quantities are likely to be similarly correlated to national wealth.

TABLE III. GENERIC INTERVENTION LEVEL FOR TEMPORARY RELOCATION

Avertable dose
30 mSv in first month 10 mSv in a subsequent month

Notes:
1. The avertable dose applies to an average population being considered for temporary relocation.
2. Month here refers to any period of about 30 days and not to a calendar month.

424. Note that there are two values given in Table III. The first indicates that temporary relocation should be initiated if the dose that could be saved in the first month is greater than 30 mSv. The return from temporary relocation could take place if the dose that can be saved by continuing the relocation is less than 10 mSv in the subsequent month, provided that permanent resettlement is not justified (see Section 4.5).

4.5. PERMANENT RESETTLEMENT

425. Whilst the intervention level for temporary relocation has been given above, it may be that for long lived radionuclides, where the dose rate does not fall quickly, the residual doses to people will be large enough that permanent resettlement is indicated.

426. The maximum length of the period of temporary relocation that is acceptable before permanent resettlement will have to be introduced is dependent on many social and economic factors. An argument based on economic grounds shows that it is necessary to evaluate the break-even point between the resources needed for continuing temporary relocation and those for permanent resettlement.

427. The resources needed for permanent resettlement would cover:

- transport of people and belongings;
- new housing and infrastructure;
- temporary loss of income while new infrastructure becomes established.

Depending on the values placed on the above, the time at which continuing temporary relocation costs will begin to exceed permanent resettlement costs is usually between about one and five years.

428. The working premises of para. 223 have been employed in Appendix I to enable the selection of a generic intervention level for permanent resettlement, which is presented in Table IV.

TABLE IV. GENERIC INTERVENTION LEVEL FOR PERMANENT RESETTLEMENT

Generic Intervention Level for Permanent Resettlement
1 Sv

4.6. DECONTAMINATION

429. Decontamination can be characterised both as a protective measure and as a recovery measure. Protective measures can be defined as those directed towards the affected population, while recovery measures are directed mainly towards the physical environment and the restoration of normal living conditions. Recovery measures include decontamination and cleanup of buildings and land and are directed towards the return, so far as possible, to pre-accident conditions.

430. Decontamination is, in general, a less disruptive protective measure than a long-term closure of areas, because after the clean-up process is completed, some activities can resume. The purpose is to reduce (a) the external irradiation from deposited activity, (b) the transfer of activity to humans, animals and foodstuffs, and (c) the potential for resuspension and spread of activity.

431. The effectiveness of decontaminating urban areas depends on a number of factors, not all of which are controllable. Generally, the effectiveness is greater the sooner the decontamination operation is started as time tends to increase the adherence of the contaminants to the surfaces by physical and chemical forces [17]. On the other hand, it could be beneficial to delay the start of decontamination operations because of the reduction of radiation levels due to radioactive decay and weathering. The collective dose to the decontamination personnel, and thus some part of the decontamination costs, could thereby be reduced. Consequently, there will be competition between the starting time of the operations and the decontamination efficiency achieved by these operations. This could also influence the time of the re-entry and return to urban areas that have been relocated [18].

432. A single intervention level for decontamination of urban environments is not clearly definable. However, a distinction can be made between areas where the population is temporarily relocated, where it is permanently resettled and where it is neither. For the first case, some decontamination might be carried out with the purpose of speeding the return of the population to their original homes.

The time when the population can return to their original homes will depend on the effective removal half-life of the deposited radionuclides and the decontamination efficiency. For the second case, some decontamination may be carried out in order to avoid permanent resettlement. For the third case, some may be carried out because it is justified and optimized so to do. In all three situations, the optimum intervention should be established by balancing the value of the collective dose to the population avoided by the decontamination against the decontamination costs, taking into account any other relevant factors.

5. FOOD INTERVENTION

5.1. INTRODUCTION

501. The remarks made in Section 4.1 also apply to food intervention, which will in general not be considered urgent, though will need to be timely. In order to select an appropriate control of food after an accident it is necessary to consider the options available for reducing the contamination in foods. Controls may be placed at different stages in the production and distribution of foods in order to reduce or prevent contamination. Treatments can be applied directly to plants and to soil that will substantially reduce the intake of radionuclides into crops and animal feed. Treatments can be applied to animals to reduce the transfer of particular radionuclides into animal products, whilst the appropriate processing of many foods prior to sale can significantly reduce their level of contamination [19]. It is also possible to reduce individual doses (although not collective doses) by mixing contaminated food with uncontaminated food before sale. Finally, foods can be completely withdrawn from sale. Conventionally, intervention levels are only developed for this last form of food intervention. However, the recommendation of the generic intervention levels for the withdrawal of foods given here should not preclude national authorities from considering the application of other protective agricultural measures to reduce food contamination still further.

502. Three distinct regimes for the control of contamination in food can be considered: controls where alternative food supplies are readily available, controls where alternative supplies are scarce, and control for international trade purposes. Different considerations apply to each of these situations and consequently different standards are relevant to each.

5.1.1. Controls where alternative food supplies are readily available

503. Intervention Levels for withdrawing and replacing foodstuffs under the jurisdiction of a national authority will be set according to the principles of justification and optimization. Where alternative food supplies are readily available, the requirement that intervention be justified is easily satisfied. The major inputs to the selection of intervention levels are the collective doses that will be averted, the value placed on the food by society, and the distribution of individual doses likely to result from the action. The premises in para. 223 can be elaborated to indicate the magnitude of the intervention levels. This approach has been used in Appendix I to select generic intervention levels for the withdrawal of foodstuffs.

504. In many cases, the generic intervention levels recommended here will be sufficient for national authorities to adopt in their emergency plans, since unless there are strong reasons for adopting very different values, there will be considerable advantages in maintaining credibility, confidence and trust in the authorities by accepting internationally recognized values. Moreover, the use of such values will help to prevent the anomalies that otherwise might exist along borders with neighbouring countries.

505. Whilst the adoption of these intervention levels will prevent food with a higher level of contamination being offered for sale, it is important that the process of optimization does not stop at this point. Consideration should always be given to other measures that could reduce levels of

contamination still further. Such measures were outlined in the Introduction and are discussed in more detail later in Section 5.4.

5.1.2. Controls where alternative supplies are scarce

506. The values of the generic intervention levels recommended in this text have been evaluated only to be appropriate in situations where alternative food supplies are readily available. In situations where extensive food bans could result in inadequate food supplies being available, then the values should be re-examined in the light of achieving commensurate protection against radiological hazards and other hazards, such as, in this case, nutritional deficiencies. Thus, a more global justification and optimization of the intervention levels are required, taking into account both the radiological and nutritional impact. In such circumstances, provided individuals were protected from receiving doses that might result in serious deterministic health effects, it is the nutritional needs of the population that will dominate the decision to ban food. The choice of the intervention levels will reflect this, and will invariably result in higher (probably much higher) levels than the generic levels given here. Such situations must necessarily be treated on a case-by-case basis; however information is given in Section 6 on the levels of individual risk of cancer associated with adopting the generic levels to assist the authorities in developing appropriate intervention levels. Again, it must be stressed that the decision to adopt higher intervention levels for withdrawal of food must not preclude the consideration of other protective agricultural measures for reducing contamination in food (Section 5.4).

5.1.3. International trade

507. The preceding situations consider controls for foods where a national authority has jurisdiction. However, when a foodstuff leaves a country, it is considered necessary that it shall meet certain standards in order that it can be exempted from any further monitoring or control by the receiving country and any other subsequent receiving countries. Thus, internationally agreed standards for minimum food quality are essential in order that international trading in food is not severely disrupted by excessive monitoring, administrative and legal requirements. It should be recognized that these levels will be a compromise between what is appropriate on radiological protection grounds and the natural wish of countries unaffected by an accident to avoid importing any contaminated produce, no matter how small the contamination. Thus levels adopted for exemption from control will be lower than those for the necessary withdrawal of foodstuffs based on radiological grounds. It is also normally possible to adopt fairly restrictive standards for this without significantly affecting international trade. It can be seen that for an agreement to be reached internationally on the values of such standards for trade, social, economic and political factors will dominate the radiological ones.

508. This situation has been addressed by the Codex Alimentarius Commission of the Food and Agricultural Organization (FAO) of the United Nations, and the World Health Organization (WHO), and Guideline Levels for Radionuclides for use in International Trade following accidental nuclear contamination have been agreed [20]. These levels are reproduced in Table V, and Member States that are signatories of the Codex Alimentarius Commission recommendations are bound by these levels.

5.2. GENERAL CONSIDERATIONS FOR FOOD INTERVENTION

5.2.1. Individual doses

509. After an accident, the levels of contamination in foods will vary markedly according to many factors, e.g.: type of food, the pattern of deposition, the physical and biological half-lives of the radionuclides, soil types, agricultural practices, etc. The distribution of contamination in foodstuffs making up the human diet after the application of any protective measures will range from zero up to the intervention level for withdrawal of foodstuff. In addition normal food preparation, including

TABLE V. CODEX ALIMENTARIUS COMMISSION GUIDELINE LEVELS FOR RADIONUCLIDES FOR USE IN INTERNATIONAL TRADE FOLLOWING ACCIDENTAL NUCLEAR CONTAMINATION [20]

FOODS DESTINED FOR GENERAL CONSUMPTION		
Dose per Unit Intake (Sv/Bq)	Representative Radionuclides	Level (Bq/kg)
10^{-6}	^{241}Am, ^{239}Pu	10
10^{-7}	^{90}Sr	100
10^{-8}	^{131}I, ^{134}Cs, ^{137}Cs	1000
MILK AND INFANT FOODS		
10^{-5}	^{241}Am, ^{239}Pu	1
10^{-7}	^{90}Sr, ^{131}I	100
10^{-8}	^{134}Cs, ^{137}Cs	1000

Notes:

These levels are intended only for radionuclide contamination in food moving in international trade following an accident and not to naturally occurring radionuclides which are normally present in the diet. The Guideline Levels remain applicable for one year following a nuclear accident. By an accident, a situation is meant where the uncontrolled release of radionuclides to the environment results in the contamination of food offered in international trade.

As the proposed levels were derived using extensive conservative assumptions, there is no need to add contributions, and from each of the three groups; each group should be treated independently. However, if more than one radionuclide is present, the activities of the different accidentally contaminating radionuclides within a group should be added together. Thus the 1000 Bq/kg value is assigned to that group. For example, following a power reactor accident, ^{134}Cs and ^{137}Cs could be contaminants of food and the 1000 Bq/kg refers to the summed activity of both these radionuclides.

These levels are intended to be applied to food prepared for consumption, and would be unnecessarily restrictive if applied to dried or concentrated food prior to dilution or reconstitution.

Both FAO and WHO have called attention in the expert meeting reports to special consideration that might apply to certain classes of food which are consumed in small quantities, such as spices. Some of the foods grown in the areas affected by the Chernobyl accident fallout contained very high levels of radionuclides following the accident. Because they represent a very small percentage of total diets and hence would make very small additions to the total dose, application of the Guideline Levels to products of this type may be unnecessarily restrictive. FAO and WHO are aware that policies vary at present in different countries regarding such classes of food.

washing and cooking, can substantially reduce the radionuclide concentrations in foods, often by as much as a factor of ten [21]. Generally, the average level of contamination of the diet will be much lower than the intervention level, and therefore the actual doses received by individuals is substantially lower than those that would be estimated on the assumption that all food was contaminated at the intervention level. This has been demonstrated in many countries following the

Chernobyl accident, where direct whole body measurements have consistently shown lower doses than those predicted by models [22]. Clearly where population groups are entirely dependent on a single source for their food, the above discussion may not hold. In this case, the situation is one in which alternative food supplies are scarce (Section 5.1.2), and a careful balance needs to be struck between the nutritional needs of the population and the desire to keep doses low.

5.2.2. Protection of radiosensitive individuals

510. Optimization of protection necessarily requires a trade-off between the competing needs of different groups within a population. It is not reasonable that intervention levels be made overly restrictive in order to protect a single individual with unusual dietary habits. For example, when considering the maximum individual doses implied by an intervention level, it is in general appropriate to consider normal ranges of dietary habits. If additional protection is required for individuals with less common dietary habits, then it is normally more appropriate to advise these individuals about modification of their habits than to introduce a substantially lower intervention level for the withdrawal of foods. On the other hand, intervention levels should not be set without regard to the doses that might reasonably be expected to be received by more radiosensitive population sub-groups, such as young children and infants. Intervention levels should always take due account of these age-groups.

5.2.3. Intervention levels for different foods

511. Provided that socio-political factors can be excluded, the most efficient method of reducing the population dose from food will be to select generic intervention levels according to the results of a cost-benefit analysis. Applying this technique will automatically mean that foods consumed infrequently will have higher intervention levels.

5.2.4. Practical considerations

512. Clearly, a balance needs to be struck between the theoretical 'correctness' of determining separate intervention levels for every radionuclide, food and type of accident, and the need for a system straightforward to administer consisting of categories of foodstuffs and radionuclides. The number of categories should be kept to a minimum commensurate with the inherent uncertainties associated with the doses saved and the costs. Moreover, it is desirable to develop numbers for generic application after any accident.

513. It is important that any intervention criteria can readily be implemented. For food, this means that the criteria should be expressed in directly measurable quantities (i.e. in units of Bq/kg). Measurable quantities indirectly related to the criteria, such as concentrations on the ground, in fodder, or in other foods, may also be helpful in some circumstances, although these will not normally be the intervention levels themselves. Guidance on the development and use of these operational quantities are planned for a later document.

5.2.5. Timing in the introduction of food interdiction

514. Food restrictions are, in general, not classified as "urgent" countermeasures in the way that evacuation or sheltering are, since it takes time for radionuclides to enter the foodchain. For example, milk does not become significantly contaminated until about a day following an initial deposition of Cs-137 onto pasture whilst concentrations in meat may build up over a week or so [23]. Nevertheless, over the short term it is essential for emergency plans to specify the intervention levels to be applied for foodstuffs. The generic intervention levels recommended here can in many circumstances be specified as the appropriate levels in the emergency plans, and there are considerable advantages in adopting them as internationally recognized levels. In the longer term

(say about a month after any actual accident) there will have been time to reconsider the situation and on the basis of detailed information make an informed decision as to whether different levels are appropriate.

5.2.6. Delineating the area for food restrictions

515. Because it is impractical to monitor every item of produce offered for sale, it is usually necessary, on the basis of the intervention levels, to delineate areas where agricultural production is interdicted. This delineation will normally be carried out by using combining sampling and applying some statistical criterion, with models that infer ground concentrations from the intervention levels. On radiological protection grounds, any assumptions made in employing these methods should be realistic. Pessimistic assumptions aimed at ensuring no single item of food is ever offered for sale above the intervention criteria will result in large quantities of food below these criteria being banned. If a few individuals occasionally consume produce contaminated above the intervention level, then the overall risk to those individuals will not be significantly increased. Nevertheless it is recognized that a decision may be taken to implement intervention criteria in a very restrictive way for socio-political reasons. It must be clearly understood that there is strictly no need to do this on radiological protection grounds.

5.3. GENERIC INTERVENTION LEVELS FOR WITHDRAWING FOODS

516. As discussed earlier, it is both useful and possible to develop generic intervention levels for withdrawal of foods where alternative supplies are readily available. These levels are not relevant for application to international trade nor to situations where alternative food supplies are scarce. It is judged that national considerations would normally result in intervention levels that differ from the generic levels by less than a factor of a few, i.e. by such a comparatively small factor compared with other uncertainties that the advantages of adhering to internationally accepted generic levels would in many cases outweigh any perceived advantages of different national levels. Nevertheless national authorities may have overriding reasons to justify the adoption of levels different from those recommended.

517. Only a few radionuclides have been explicitly considered for providing generic intervention levels for food. These were chosen from source terms characteristic of facilities in the nuclear fuel cycle and industrial radiography, and nuclear power and heat sources used in satellites. Only those that might pose a significant contamination problem in food have been assessed, namely strontium-90, ruthenium-106, iodine-131, caesium-134 and caesium-137, plutonium-238, plutonium-239 and americium-241.

518. The premises given in para. 223 have been employed in Appendix I to derive ranges of intervention levels and generic values have been selected, which are listed in Table VI. For reasons of practicability, only six radionuclide/food categories have been defined. These are divided into two broad food groups based on the value associated with the foodstuff and three radionuclide groups based on their radiological hazard, and baby foods are considered separately. Specific values for water or for the consumption of minor foods are not given. However, guidance on the control of these is given below.

519. It is intended that these intervention levels be applied independently of one another; a food containing half the permitted concentration of iodine-131 and three-quarters of the permitted concentration of strontium-90 would be considered to satisfy the criteria. However, within a single group, the radionuclide concentrations are additive; a food containing half the permitted concentration of iodine-131 and three-quarters of the permitted concentration of radiocaesium would be considered to have failed the criteria.

TABLE VI. RECOMMENDED GENERIC INTERVENTION LEVELS (kBq/kg) FOR WITHDRAWAL OF FOODSTUFFS WHERE ALTERNATIVE SUPPLIES ARE READILY AVAILABLE[a,b]

Radionuclide[c]	Fresh Milk, Vegetables, Grain, Fruit[d]	Meat, Milk Products
^{106}Ru, ^{131}I, ^{134}Cs, ^{137}Cs	3	30
^{90}Sr	0.3	3
^{238}Pu, ^{239}Pu, ^{241}Am	0.03	0.3

Radionuclide[c]	Baby and Infant Foodstuffs
^{134}Cs, ^{137}Cs	1
^{106}Ru, ^{131}I, ^{90}Sr	0.1
^{238}Pu, ^{239}Pu, ^{241}Am	0.01

a These levels apply to national control where alternative food supplies are readily available. Where food supplies are scarce, higher levels will apply (see Section 5.1.2).

b These levels are not intended to apply to minor foodstuffs (ie those that contribute less than about 3% to the total diet). For these foodstuffs, levels a factor of ten higher are appropriate (see Section 5.3.2).

c For practical reasons, the criteria for separate groups should be applied independently to the sum of activities of the radionuclides in each group.

d Contamination of drinking water is normally an insignificant hazard following atmospheric releases of radioactive material. Whilst no specific levels are recommended for drinking water, it is not unreasonable to adopt the levels for fresh milk, vegetables etc. (see Section 5.3.1). It is often the case that for lakes, rivers and reservoirs, consumption of contaminated fish will dominate any need for protective actions.

5.3.1. Drinking water

520. The analyses carried out in Appendix I do not explicitly consider drinking water, because it is extremely difficult, on a generic basis, to enumerate the resources put into protecting water supplies. The issue is complicated by several factors. In some parts of the world, water is extremely plentiful and substitute supplies can be easily found. In other parts of the world, it is a very precious commodity that could not easily be withdrawn without major and immediate repercussions for health and even survival. Moreover, water as a resource provides many more functions than those of just drinking water, ranging from fisheries and irrigation to industrial needs. The World Health Organization is updating its guidelines for radioactive contamination of drinking water for normal situations [24]. However, these guidelines are not appropriate for application following accidents, and, if it were deemed life-threatening to withdraw water supplies, much higher levels could be tolerated.

521. Fortunately, in general, from most airborne radioactive releases, it is extremely unlikely that drinking water supplies will become significantly contaminated. In view of this fact, for pragmatic reasons, the approach used here is to recommend generic intervention levels for drinking water that are the same as for foodstuffs that have the same average dietary intake. In this case, the highest radiation dose would be to those individuals who collect and use rainwater directly for drinking. If levels higher than these generic levels might occur in rainwater, it would be reasonable to give warnings to the public about drinking fresh rainwater.

522. If significant contamination of surface or ground water supplies occurs, then the options for providing clean supplies would have to be carefully evaluated. Priority should be given to measures that achieve the greatest dose saving, including all pathways, such as fisheries and industrial products. Moreover, the monetary cost of averting one man-sievert should be calculated and compared with the expenditure committed for averting unit collective dose from other foods. It would not constitute an optimal use of resources if these values were substantially different.

5.3.2. Minor foodstuffs

523. Some foodstuffs constitute only an infrequent or small part of the normal diet. This category would include, among others, spices and herbs. Since foods falling into this category will vary from country to country, they have not been treated explicitly here. On average, the value placed on these foods per unit mass is higher than for those constituting major components of the normal diet. It is therefore appropriate to apply higher intervention levels (e.g. by one order of magnitude or higher) than those given here for commonly consumed foods. This automatically ensures that doses from minor foods do not contribute significantly to the dose from the total diet.

5.4. FOOD COUNTERMEASURES OTHER THAN BANNING

524. The generic levels recommended here for foods represent levels above which it is expected that food would not normally be consumed by members of the public. It does not, however, preclude the use of agro-technical measures to reduce the levels in food still further, and these methods should be used in any case if they are justified. However the strategy for introducing these other countermeasures needs to be optimized, and account taken of the cost-effectiveness of the measures, social impact and any other possible side effects.

525. Simple but potentially very effective techniques include the washing of fruit and leafy vegetables and the removal of outer leaves and surfaces of crops, to remove surface contamination. Other techniques include the alteration of agricultural practices [19, 25, pages 430 - 433 of Ref. 26], e.g. administering Prussian Blue to reduce caesium in animal products, the feeding of livestock with uncontaminated feed for a few weeks before slaughter, changes in the crops grown on contaminated soil, and altering the source of water used for irrigation. Storage of suitable foods can significantly reduce contamination by short lived radionuclides. Finally, food processing techniques, such as blanching, dehydrating and chemical separation (e.g. cheese making) can also reduce contamination substantially [21]. It is strongly recommended that the application of such techniques is considered before decisions to ban food are taken.

526. In applying these additional countermeasures, there will be a need to develop practical operational quantities that will trigger the use of a particular countermeasure, such as a concentration in pasture grass that will trigger the removal of cattle grazing that grass, or the concentration in manure above which it should not be used as fertilizer. The development of such operational quantities is outside the scope of this document, but guidance will be provided in a future publication.

6. APPLICATION OF GENERIC INTERVENTION LEVELS

6.1. INITIATION AND IMPLEMENTATION OF PROTECTIVE ACTIONS

601. For cases in which pre-planning is possible, such as for most fixed facilities, emergency response plans should incorporate pre-determined intervention levels for urgent protective measures. These levels may take account of known site-specific and foreseeable accident-specific conditions and in some cases will therefore differ from the generic values recommended here.

602. Wherever it is possible to do so, emergency response plans should prescribe action to implement urgent measures on the basis of facility conditions that carry a reasonable expectation of an accidental release, rather then relying on confirmation of an actual release and/or a quantitative determination of its magnitude and its environmental consequences through measurements. Such measurements may be used to refine the scope of the protective response, but should generally not be a pre-condition to initiating it.

603. For situations where pre-planning has not been possible, the generic intervention levels given here should provide a useful basis for decisions by national authorities. In most cases they will represent the best course of action, given the lack of the time, information and possibly experience that would allow for a more sophisticated response.

604. On the other hand, longer term protective measures, such as the relocation of populations, address lower dose rate exposures of long duration. Decisions to implement them are generally made after the source of exposure is brought under some measure of control and can rely on more precise assessments of the levels of contamination. Long-term protective measures are generally expensive, and may in themselves produce considerable socio-economic harm to the affected population. For these reasons it is important to choose the level of interdiction carefully, so that it is at least reasonably well justified and optimized. The decision, although it should not be unduly delayed, because that in itself creates harm, should be made deliberately and on the basis of full knowledge of the relevant factors. The guidance given on these longer term protective measures should thus serve as a basis for further study and refinement, taking into account local conditions.

605. The following sections provide information on how the generic levels may be used and, if necessary, modified either when developing site- and/or accident-specific plans, or if it is deemed necessary to refine levels being used following an actual accident.

6.2. SCHEME OF INTERVENTION LEVELS FOR DIRECT PROTECTION OF THE PUBLIC

606. A summary of the scheme of intervention levels for direct protection of the population is presented schematically in Figure 3. The first consideration of the decision maker is whether the dose that can be saved by advising sheltering is larger than the specified intervention level for sheltering, IL_{shelt}. If it is, sheltering will normally be advised. This dose should be evaluated taking into account the dose reduction provided by buildings against inhalation of activity in the air, and against cloud and deposited radioactive material (on outdoor and indoor surfaces, skin and clothing). No pessimism should be incorporated into the evaluation. If there is no need for further action (e.g. evacuation - para. 607; relocation - para. 608), then people can normally be advised to open doors and windows when the release from the facility has stopped and the levels are consistently below the intervention level for sheltering, IL_{shelt}.

607. Urgent evacuation would normally be implemented if the projected dose to any group of the population could exceed the upper bounds for projected dose (Table II), IL_{det}. This group of people would be given the highest priority when carrying out the evacuation plans. Urgent evacuation would also be implemented if the average dose that could be saved by evacuation is greater than the intervention level for evacuation, IL_{evac}. In evaluating the average dose that can be saved by evacuation, due allowance should be made for any exposures that might occur during transportation to the emergency centre and for any protection that could already be received from sheltering. No pessimism should be normally built into the assessment of the dose that can be saved. In both cases, due account should be taken of any special groups of people (e.g. hospital patients) or environmental conditions (e.g. extreme weather conditions), and ensure that the radiological risk avoided by evacuation is larger than the physical risk of taking the measure itself. Return to the area that has been evacuated can normally take place when the radioactive release from the facility has stopped, provided that temporary relocation is not indicated (para. 608).

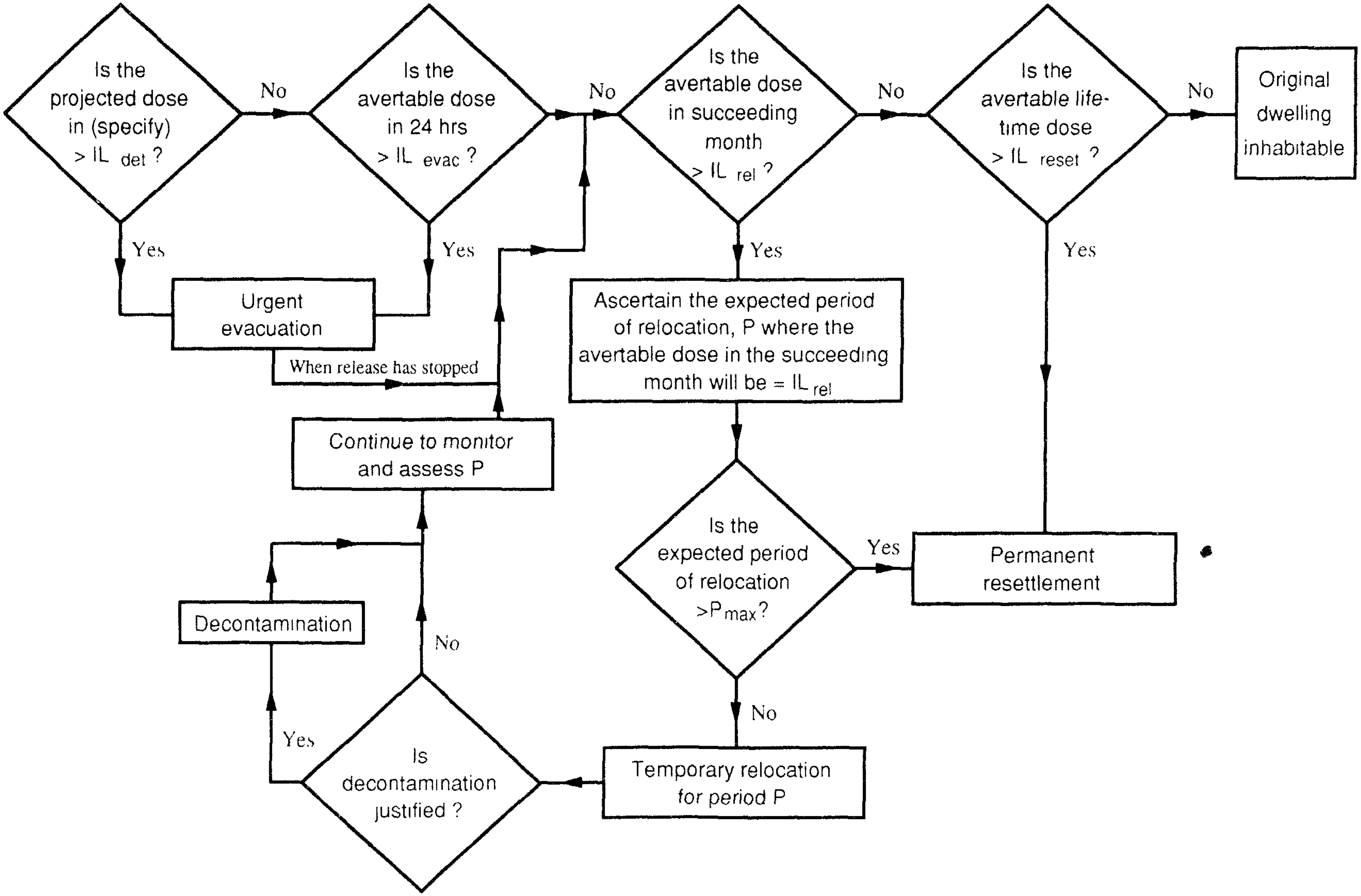

FIG. 3. Flow chart indicating the scheme of criteria for evacuation, temporary relocation and return, and for permanent resettlement.

608. The decision on temporary relocation will usually be based on measurements of dose rate and nuclide composition of the activity deposited on ground and structure surfaces. The average doses that could be saved by temporary relocation can be calculated from these measurements and assumptions on the shielding effect of buildings and time spent indoors and outdoors (time-averaged location factors). Pessimisms should not normally be built into the calculation of the average avertable dose. If the avertable dose exceeds the intervention level, IL_{rel}, temporary relocation is indicated. This criterion may apply both to people who have been evacuated and to people who were not evacuated. People would normally be able to return to their homes when the avertable dose has fallen below IL_{rel} provided that permanent resettlement is not warranted (para. 610).

609. It will be important at the time of relocation to estimate the period of time, P, within which people cannot return home and to inform them of it. If this period is greater than a maximum socially acceptable period, P_{max}, then permanent resettlement will be indicated, unless forced decontamination can decrease the dose rate to a level that will reduce the time period P to a value less than P_{max}. The establishment of a value for P_{max} would be based on social conditions and other factors not directly related to radiation protection. Prescribing such a value, which might be of the order of a year or so depending on the actual circumstances, is the responsibility of the decision maker, probably taking into account the preferences of the people affected.

610. Even if temporary relocation were implemented according to the above scheme, the total residual doses to the population could be up to the order of a sievert over the following 70 years should nuclides with long effective half-lives be prevalent. The same situation might exist even if temporary relocation is not introduced. The decision maker would in these situations have to decide in any case whether the residual doses would call for permanent resettlement, i.e. the residual doses were greater than IL_{reset}.

611. A single intervention level for decontamination is not definable. However, forced decontamination plays an important role in the overall scheme of intervention. It can reduce the time period, P, for which people may have to be temporarily relocated; it can obviate the necessity to permanently resettle people if the residual doses can be reduced to less than IL_{reset}, and if P can be reduced to a period less than P_{max}. The basic principles for intervention should be emplyed to ensure that decontamination is justified and optimized. This process will take into account factors such as the strategic, financial and industrial importance of a contaminated area, as well as the need to protect the public.

6.3. SCHEME OF LEVELS FOR FOODSTUFFS

612. A summary of the scheme of intervention levels for withdrawal of foodstuffs, Codex Alimentarius Commission guideline levels for use in international trade, and operational quantities for determining the need for agricultural countermeasures is presented schematically in Figure 4.

613. Foodstuffs should not normally be consumed with contamination above the Generic Intervention Levels (Table VI). Agricultural countermeasures should be taken as a minimum to reduce the contamination to a level below the Generic Intervention Level, else the food should be disposed of. The sole exception to this is if such action would make the situation worse, such as under famine conditions.

614. Foodstuffs with contamination above the Codex Alimentarius Commission Guideline Levels may not be automatically traded internationally. They must be monitored and controlled, but the contamination does not preclude their consumption.

615. Agricultural countermeasures should be taken wherever their use is justified and optimized to reduce the doses to members of the public to as low as reasonably achievable. Operational quantities will be derived to assist in the implementation of these countermeasures.

Foodstuffs should not normally be consumed. Countermeasures must be taken, else food must be destroyed. The sole exception to this is if it would make the situation worse.

Generic Intervention Levels for withdrawal of foodstuffs where alternative supplies are readily available (Table VI)

Foodstuff must be monitored and controlled. It cannot be automatically traded internationally. Can be consumed nationally. Agricultural countermeasures should be taken where justified and optimized.

Operational quantities to assist in the implementation of agricultural countermeasures

Codex Alimentarius Commission guideline levels for use in international trade (Table V)

Foodstuff can be traded freely. Normally no further action warranted.

FIG. 4. Scheme of intervention levels for foodstuffs.

6.4. USE OF THE GENERIC INTERVENTION LEVELS

616. In the preceding chapters, generic intervention levels have been given that are intended to be applicable in many situations. They have been derived from only technical radiological protection factors, according to the premises set out in para. 223.

617. It is recognized, however, that there may be good reasons for adopting intervention levels other than those recommended here. These may be for technical reasons, to allow flexibility in evacuating populations according to weather conditions. More likely they will be to consider social and/or political factors. Taking account of these other factors in the decision making process can be achieved in several ways: intuitively, or using some more formal decision-aiding tool [27]. ICRP has described a number of techniques that may be used as decision aids for optimization in radiological protection [28]. These range from simple cost-benefit analysis (CBA), in which the benefits and costs are quantified solely in monetary terms, to the more general multi-attribute techniques, which assist the inclusion of factors which cannot be readily quantified (e.g. some social factors). The advantage of CBA is that, by balancing the monetary costs of a protective measure against the population doses avertable, it provides a straightforward indication of how resources can be divided most cost effectively between different protective measures. This is particularly important for planning, since other factors which may influence decisions following an accident (e.g. socio-political factors) are very difficult (or impossible) to quantify in advance of the accident occurring. Multi-attribute techniques are most suited for application some time after an accident, when specific decisions are required for response to a unique situation. They are particularly relevant to decisions on longer term protective measures, since the ability of these techniques to incorporate subjective concerns as well as objectively quantifiable factors is then of prime importance.

618. In any case, where there is a departure from the generic guidance given here, it is important that the responsible decision maker fully understands the basis of the original generic levels, that they appreciate the magnitude and nature of the risks associated with the use of these levels, and that they fully recognize the implications of adopting other levels. Additional technical information is given in Appendix II that will assist the decision maker in gaining a perspective on the residual risks associated with adopting the generic levels. The next section provides a discussion on the implications of adopting other levels.

6.5. SENSITIVITY OF THE ACCIDENT CONSEQUENCES TO THE ADOPTION OF DIFFERENT INTERVENTION LEVELS

619. One can visualize the implementation of a protective measure as applying to an area Y at any given time (Figure 5). As time passes, the area Y will be reduced in size as the levels of contamination decay away. The size of this area Y is related to the choice of the intervention level for the particular action. If a more restrictive intervention level is selected, by making pessimistic assumptions, then the area affected by the measure will be larger, with associated higher costs, and in some cases the measure will be applied to many people for whom there is a net penalty rather than benefit. On the other hand, relaxation of the intervention level would reduce the area of land affected and associated costs. There is therefore a close relationship between the intervention level for any particular measure, the maximum individual doses received, the individual and collective dose averted, and the number of people and the area of land affected by the measure and associated costs. Before adopting other intervention levels the decision maker would be wise to assess the likely impact of such changes on these key variables.

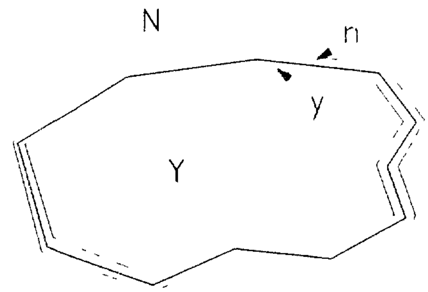

FIG. 5. Schematic plan illustrating areas for which a protective measure is applied.

TABLE VII. SENSITIVITY OF CONSEQUENCES TO CHANGES IN THE INTERVENTION LEVEL

Consequence	Change to Intervention Level		
	3 times higher	3 times lower	10 times lower
Residual individual radiation risk from this pathway alone	Risk 3 times higher	Risk 3 times lower	Risk 10 times lower
Residual individual radiation risk if the pathway concerned contributes 50% of the total dose	Total risk 2 times higher	Total risk reduced by one third	Total risk reduced by 45%
Population radiation risk saved by the countermeasure	30% less saved	40% more saved	90% more saved
Area of land; number of people; economic losses associated with this countermeasure[a]	4 times lower	4 times higher	20 times higher

[a] These economic losses assume only that costs are proportional to the area of land and/or number of people affected. If the area or number become large, the unit marginal cost of resources will normally increase due to scarcities, and the economic losses will increase faster still.

620. Whilst every accident will be different in this respect it is possible to make broad generalizations on the relationship between these variables on the basis of our knowledge of the atmospheric dispersion and subsequent distribution of radioactive material [29]. Table VII presents the influence a change to the intervention level for a protective action would typically have on maximum individual doses, collective doses, and semi-economic measures such as the area of land or number of people affected by the measures [30]. For example, the table shows that reducing, say, the intervention level for temporary relocation by a factor of three would reduce the maximum residual individual doses (that would otherwise have been averted) also by a factor of three. However the total collective dose saved (and therefore the numbers of statistical health effects avoided) would only be some 40% higher than implied by the original GIL. Moreover this would be achieved at a cost of relocating people from an area some four times greater than that implied by the original GIL. Similar arguments will apply to the areas of agricultural land affected by changing the intervention levels for food. Whilst this table is only indicative, and local hot-spots of activity or distribution of towns and agricultural land will affect the conclusions, it does show that the costs of reducing an intervention level increase far more rapidly than either the individual dose saved or even more the collective dose saved. Decision makers should therefore be convinced of the need and desirability before changing intervention levels.

7. DISCUSSION

701. Recently, the ICRP has revised its Publication 40 dealing with protection of the public in the event of a major radiation accident [31]. The revision of both ICRP 40 and the present publication were prompted by the issue in 1991 of revised fundamental principles for intervention by the ICRP in Publication 60 [13], and because previous international advice from these organisations had failed to address adequately some of the difficult problems which can arise following a serious nuclear accident. In particular, the experience gained since the Chernobyl accident indicates that the difference between the concept of dose avertable by intervention and dose limits for practices has not fully been recognised [26]. The relationship between the numerical conclusions of this document and those in reference [31] are considered in the following.

702. **Sheltering** and **evacuation** are expected to be implemented for typical time periods of several hours and a week, respectively. For such typical applications, the generic intervention levels of **3 mSv in 6 hours** for sheltering and **10 mSv in a day** for evacuation fall below the levels judged by the ICRP to be almost always justified (50 mSv and 500 mSv, respectively) and consistent with the ranges of optimised intervention levels anticipated by the ICRP for these protective actions [31].

703. For relocation the recommendations are a little more differentiated than the conclusions of the ICRP; this document divides relocation into temporary relocation and permanent resettlement, and further differentiates initiating relocation from continuing it. The ICRP example of an optimised level is identical to this document's recommended level (although this document recommends a somewhat higher level for initiating relocation). This document's recommended level for permanent resettlement (1 Sv) is identical to the ICRP level at which relocation is almost always justified.

704. For foodstuff restrictions the ICRP concludes that at an averted dose of 10 mSv in a year, for any single foodstuff, restrictions are judged to be almost certainly justified. Optimised intervention levels are anticipated to lie in the range 1 to 10 kBq/kg for β-/γ-emitting radionuclides and a factor of 100 lower for α-emitting radionuclides. Generic intervention levels are recommended in this document for three different groups of radionuclides and two different food categories (as well as baby food). The generic intervention levels for restricting meat and milk products (30 kBq/kg for β-/γ-emitting radionuclides like ^{137}Cs and ^{131}I, a factor of ten lower for ^{90}Sr and a factor of 100 lower for α-emitting radionuclides) are somewhat higher in most cases than those anticipated by Ref. [31]. However, for foodstuffs of fresh milk, vegetables, grain and fruits the generic intervention levels (a factor of 10 lower than those for meat and milk products) are consistent (or, in the case of ^{90}Sr,

lower). The implied residual committed doses from the intervention levels of **3 to 30 kBq/kg** for β-/γ-emitters like ^{137}Cs and ^{131}I would be of the order of **3 mSv/a** if 10% of the whole food basket were contaminated at these levels constantly for a whole year of consumption (Appendix II).

705. Since the administration of stable iodine involves different risks to different population groups, generic intervention levels are given for both infants and adults (50 mSv and 500 mSv, respectively). These values, which are consistent with those of Ref. [31], have been derived from a risk-risk balance of side effects of intake of stable iodine and the risk from the radioiodine exposure. The intervention levels are expressed as committed doses to the thyroid that could be averted by intake of stable iodine over a period of up to 10 days. This time period emerged from a maximum reasonably tolerable intake of 1 g of stable iodine, i.e. 10 tablets with a stable iodine content of 100 mg/tablet, each 24 hours.

706. In conclusion, the guidance in the present document is consistent with the latest recommendations of ICRP [31] for all the protective actions for which generic intervention levels have been derived.

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Appendix I

TECHNICAL ANALYSIS TO ASSIST IN THE SELECTION OF GENERIC INTERVENTION LEVELS

I.1. INTRODUCTION

I.1. A variety of decision aiding techniques are available to help in questions of social risk management. Merkhofer [1] has described three distinct, internally consistent theories of decision making; cost-benefit theory, decision theory, and social choice theory, which serve as philosophical rationales for adopting particular approaches and/or techniques. Cost-benefit theory takes an objective view that alternative strategies should be selected according to a systematic comparison of the advantages (benefits) and disadvantages (costs) that result from the estimated consequences of the choice Decision theory involves the concept of a social decision maker with special responsibility for the decision, and attempts to analyze and rationalize his subjective views. Social choice theory takes the perspective that the appropriate criterion for social decision is a rational synthesis of the preferences of all those individuals who will be affected by the decision.

I.2. Each of these philosophical approaches may have their part to play in the planning of a course of action after an accident. Clearly in making plans with regard to evacuation in the early phase of an accident, the decision will be that of a single decision maker (or small group of people) for which decision theory may be the best rationale. In the longer term, the decision to resettle could be based on synthesizing the preferences of those people potentially affected. The selection of an appropriate rationale is thus linked to the political, legal and judicial system of the country affected. However, since the aim of generic intervention levels is to provide the decision maker (or people potentially affected) with a technically based benchmark against which other alternatives can be measured, cost-benefit theory has been adopted as the rationale for selecting these values. Nevertheless some information is given in Appendix II and in Section 6 that can provide additional input for using any of the three rationales.

I.3. Having selected an appropriate philosophy for developing generic intervention levels, it remains to select a suitable procedure and to clarify which factors have been included, and which deliberately excluded. The problem can be conceptualized in cost-benefit terms where the total benefit of a particular action compared with taking no action can be expressed as [2]:

$$B = Y_0 - (Y + R + X + A_i + A_s - B_c) \qquad (I.1)$$

where:

B	is the net benefit associated with any course of action,
Y_0	is an expression of the radiation detriment (both stochastic and deterministic) associated with taking no action,
Y	is an expression of the residual radiation detriment (both stochastic and deterministic) when the action *is* taken,
R	is an expression of the physical risks of any protective measure itself,
X	is an expression of the resources and effort needed to implement the protective measure,
A_i	is an expression of individual anxiety and disruption caused by the protective measure,
A_s	is an expression of social disruption caused by the protective measure,
B_c	is an expression of the reassurance benefit from the protective measure

All of these terms are presumed to be functions of the number of people affected and the time for which a protective action is carried out, and all with varying degrees of associated uncertainty.

I.4. The equation can be applied to a specified group of people where the net benefit is evaluated for all possible protective actions, for combinations of actions, and for different times of implementation. There will be many courses of action for which the net benefit is positive: these will be *justifiable* courses of action. However, the course of action that produces the maximum net benefit will be the *optimum* one. Any other action will produce less net benefit. When this is extended to the entire population, there will be an additional trade-off that can occur between individuals, some taking slightly less benefit in order that others may take much larger benefits (for example, some members of the population might be asked to stay sheltered and not be evacuated, thereby receiving higher risk, in order that people who might otherwise suffer deterministic effects can be more efficiently evacuated). One of the key results of a cost-benefit approach is that such trade-offs can be made.

I.5. Each of the terms in Eq. (I.1) naturally have to be expressed in the same units. These units can be dimensionless quantities (such as used in multi-attribute utility analysis), or values could be expressed in "equivalent years of life lost". Conventionally in cost-benefit approaches they are expressed in monetary terms. Whilst there may be large differences in the absolute costs for the various terms in Eq. (I.1) between countries, the ratio between these costs are much less sensitive to geographical location. Thus the use of a particular currency unit is relatively unimportant; all terms could be evaluated as fractions of a country's GNP (Gross National Product) per head to allow for differences in GNP per head between countries [2]. This is assuming that costs represent true "value" of the term to individuals and society. Throughout the text here, costs have been based on those existing in "highly-developed" countries and expressed in US dollars ($).

I.6. The quantification of the various terms in Eq. (I.1) is often not straightforward. In a free market with no externalities the aggregate value of a commodity to individuals in that market is represented by the market price [1], and this has been used to evaluate the costs of effort and resources needed to implement a particular course of action. With more intangible factors, it is generally recognized that the concept of "willingness-to-pay" or "willingness-to-accept" is an appropriate methodology to ascertain value. For the components of radiological detriment, resource needs, physical risks and individual disruption, adequate estimates can be made for the purpose of selecting generic intervention levels. Since the factors relating to societal disruption, and reassurance benefit, will vary greatly between situations and countries, it is much more difficult to generalize on these. It is judged that these socio-political-psychological factors cannot be taken into account when providing generic international advice on intervention levels; the responsibility for these factors remain with the decision maker. Such considerations, including such questions as societal disruption, reassurance of the public, the acceptability of residual risks etc, will often have an important or even overriding influence on the decision. These factors will in many cases act in opposite directions. But, in any case, it is only possible here to point out how sensitive intervention levels are to these factors.

I.7. The working premises adopted to guide the analysis and to communicate the outcome of the analysis to the decision maker (and to people potentially affected) can be expressed as follows (see para. 223) :

— *that, broadly speaking, under most conditions, a national authority places as much effort and resources into avoiding a radiation induced health effect as it would into avoiding risks to health of a similar magnitude and nature;*

— *that account is taken of normal physical risks from the action itself;*

— *that disruption to the individuals affected by the protective action is taken into account;*

— *that other factors of a socio-political, psychological and even cultural nature have been deliberately excluded;*

— *that the generic levels so selected form a logically consistent set of levels that are as simple to apply and understand as possible.*

METHODS FOR ESTIMATION OF OPTIMISED INTERVENTION LEVELS FOR THE MOVEMENT OF PEOPLE

Intervention will be justified whenever the value of B is positive and the optimum will be achieved when B is a maximum provided that the terms are defined broadly enough to encompass all the radiological protection factors For illustrative purposes we consider explicitly only the averted collective dose and the financial cost of the protective measure In many cases, the cost equivalent of the averted radiation detriment can be considered to be proportional to the averted collective dose and can be written as

$$\Delta Y = \alpha \cdot \Delta S \qquad \text{(I 2)}$$

where α is the cost assigned to averting unit collective dose and ΔS is the avertable collective dose The cost of the protective measure, X, may have a significant component that is largely independent of the intervention level, I, at which the measure is introduced, and another that is dependent on this level It can be expressed as

$$X = X_0 + X(I) \qquad \text{(I 3)}$$

If intervention is contemplated, then the proper selection of the intervention level may optimise the situation, in the sense of maximising the net benefit The intervention level is a value of dose, dose rate, or other quantity which, if foreseen to be exceeded in a particular situation, would trigger the introduction of a specified protective measure The optimised level for intervention is obtained when

$$\frac{d(\Delta Y - X)}{dI} = 0 \qquad \text{(I 4)}$$

Any protective action is justified whenever the net benefit, B, is positive The optimum protection would be achieved when B was maximum The net benefit of moving people from their homes as a function of time can be expressed as

$$B(t) = \Delta Y(t) - X(t) = \alpha \cdot \Delta E(t) - X(t) \qquad \text{(I 5)}$$

where ΔE is the avertable effective dose per capita and X is the cost per capita of moving people from their homes which could be expressed as

$$X(t) = X_0 + a \quad t \qquad \text{(I 6)}$$

X_0 is the initial costs and a is the continuing cost per unit time of accommodating them elsewhere The net benefit is the difference between the value of the averted dose and the costs of moving and keeping people elsewhere

$$B(t) = \alpha \cdot \Delta E(t) - (X_0 + a \quad t) \qquad \text{(I 7)}$$

From Eq (I 7) it can be found that moving people is justified when $B > 0$, i e when the averted dose over the time period of movement, t, is greater than

$$\Delta E(t) > \frac{X_0 + a \cdot t}{\alpha} \qquad \text{(I 8)}$$

which is the intervention level for the initial movement for a time period of t The optimum return time is when the averted dose per unit time, $\Delta \dot{E}(t)$, equals the continuing costs per unit time At this time, the net benefit per unit time equals zero

$$B(t) = \alpha \cdot \Delta E(t) - a = 0 \qquad \text{(I 9)}$$

The averted dose per unit time of return can be found from Eq (I 9) as

$$\Delta \dot{E}(t) = \frac{a}{\alpha} \qquad \text{(I 10)}$$

which is the intervention level for return, IL_{ret}

I.8. The approach adopted to develop generic intervention levels has been to evaluate terms in Eq. (I.1) using realistic estimates for parameters, and thereby to identify intervention levels that produce the maximum benefit for the default set of parameter values. A set of sensitivity analyses have then been performed [3] to assess the relative influence of the parameters and the robustness of the intervention levels, and on the basis of these studies to select an appropriate intervention level for each protective action that can be applied generically to a large set of situations and accident scenarios. Simplified versions of these sensitivity studies are presented here in order to illustrate the nature of the exercise performed and results obtained and the importance of the various contributing factors. The next sections describe the various models, parameters and numerical values for each term in Eq. (I.1) for the simplified studies performed for each protective action.

I.2. VALUE ASSIGNED TO AVOIDING HEALTH DETRIMENT

I.9. Whilst a value for physical resources needed to implement a protective action can be readily assigned on the basis of market values and in monetary terms, attaching such a value on loss of life is especially difficult; under nearly all conceivable situations, no sum of money would induce individuals to give up their lives voluntarily. Some would argue that length and quality of life are more fundamental measures of value than monetary terms, contending that the true value of market commodities should be measured against how much they improve the quality of life. Nevertheless, individuals do implicitly value their own and other people's lives, in a way that can be expressed in monetary terms, when they make everyday decisions that involve risk. For example, when considering making a journey by car, train or aeroplane, some implicit trade-off is made between, amongst other factors, the financial costs and to some degree the risk. It is also clear that from an economic point of view, there are limits to the proportion of a society's economy that can be spent on health and safety. In the course of this appendix, an expression is derived for a value, in monetary terms, of averting both stochastic and deterministic effects, and hence for the level of resources to be allocated to reducing radiation exposures.

I.10. Several methods have been developed for assessing how much value is placed by both individuals and society on avoiding health detriment [4]. These include human capital approach, legal compensation approach, insurance premium analogies, public-implied or revealed preference approach, and willingness-to-pay approaches. In some way, there are flaws in all of these methods and a useful review of the pros and cons of these approaches in valuing the cost of avoiding unit collective dose, α , is given in Stokell et al. [5]. Nevertheless, it is possible to arrive at a credible range for the level of resources allocated to avoiding health detriment, and thus at a range of values for α.

I.11. A rough evaluation of typical resources allocated to avoiding radiation health detriment is now given using a simplified version of the human capital approach. The method was recommended by the IAEA in a Safety Guide outlining the assessment of a minimum international value of unit collective dose for application to transboundary radioactive emissions [6]. This method has been modified here to take account of the 1990 recommendations of the ICRP [7]. The following four assumptions are made to reflect the impact of the loss-of-life-expectancy resulting from a collective dose of 1 man·Sv :

(i) average loss of healthy life associated with one case of radiation-induced lethal cancer is of the order of 13 years;

(ii) nominal probability coefficient for fatal cancer is 5.0×10^{-2} Sv^{-1};

(iii) the detriment coefficient[1] for non-fatal cancers is 1.0×10^{-2} Sv^{-1};

[1] The detriment coefficients for non-fatal cancers and hereditary effects are comprised of two terms, one representing the frequency of occurrence of an effect, and one weighting them in some way according to their severity.

(iv) the detriment coefficient[1] for induction of severe hereditary damage in all generations is 1.3×10^{-2} per man·Sv.

From these assumptions, the statistical loss of life expectancy (with some allowance for loss of quality of life for non-fatal cancers and severe hereditary effects) associated with 1 man·Sv can be evaluated as being the probability of occurrence of a somatic or genetic effect, weighted by the average loss of life expectancy associated with each of these effects:

$$(5 \times 10^{-2} + 1 \times 10^{-2} + 1.3 \times 10^{-2}) \times 13 \text{ years} \approx 1 \text{ year} \qquad \text{(I.11)}$$

Because of the uncertainties associated with the risk coefficients for the effects of radiation, this value can only be considered to be accurate to within about a factor of two (see, for example, p. 137 and Table 14B of Ref. [7]).

I.12. It can be shown that as a first approximation the level of health care in any country is proportional to the country's annual average GNP per head. From a purely economic basis, a minimum value to be associated with a statistical year of life lost is the annual GNP per head. For highly developed countries, the value of GNP per head is approximately \$ 20 000 a^{-1}. A value of α for such countries can therefore be calculated to be:

$$\begin{aligned} \alpha &= 1 \text{ year per Sv} \times \$\,20\,000 \text{ a}^{-1} \text{ per man} \\ &\approx \$\,20\,000 \text{ per man·Sv saved} \end{aligned} \qquad \text{(I.12)}$$

I.13. Several objections are raised and subsequently modifications are often made to this basic value of α [1]. Firstly, it takes no account of pain, grief and suffering associated with a premature death. Secondly, because there is a natural aversion of people to higher risks, and because society is normally willing to allocate more resources to protect people at higher risks, a modification is often used whereby α is increased according to the level of risk. Thirdly, an argument is made that because there is an inherent social time preference to speed up the receipt of desirable outcomes and postpone undesirable ones, a reduction factor should be applied to account for the delay between exposure and appearance of the effect. Reduction factors range from zero (an argument for which is that, whilst the social time preference discounts future harm, this harm is likely to become more valuable relative to other goods in society as the standard of living improves) up to 10% per annum. Since the typical delay between exposure and occurrence of a cancer is of the order of twenty years, the discount factor can range from one to as much as eight times. These three factors, which in some way counteract each other, could be directly assessed by willingness-to-pay methods, and could lead to a considerable range of values [8, 9]. In the complete set of sensitivity studies [3] the influence of these factors are considered in more detail.

I.14. However, there will always be other competing health demands in a society, and the allocation of resources to protecting health after a large radiation accident ought not to be significantly different from that to protecting against other hazards. Otherwise, a significant fraction of a country's economy could be diverted into saving relatively few health effects, out of all proportion to how the money could have been better spent on general health care. In extreme cases, it could have disastrous effects on a country's economy, and even place severe economic burdens on future generations. Clearly, these decisions are of a political nature, and cannot be addressed generically. The ranges of values adopted in this analysis do not take into account such political considerations. Some discussion on how these considerations may place limits on the value of α selected is given in an Annex to Ref. [6].

I.15. The factors outlined in para. I.13 also influence the expression of the detriment associated with early death from radiation exposure, and with death due to the physical risk of the protective action. In both cases, the *average* loss of life per early death is some thirty to forty years in highly developed countries; this occurs immediately and at levels of radiation dose where deterministic effects can occur, the probability of death is relatively high. This implies a much higher weighting being given to the avoidance of early death, either from radiation or from the side-effects of the protective action, compared with that for cancer death. This would appear to be intuitively reasonable.

I.3. PROTECTIVE ACTIONS AFFECTING FREEDOM OF MOVEMENT

I.16. There are four levels of protective action considered here, where the freedom of the population to carry out their normal lives is restricted to varying degrees by either keeping them at home or removing them. They are Sheltering, Urgent Evacuation, Temporary Relocation and Permanent Resettlement. Each action has associated with it a different level, nature and timescale for the terms in Eq. (I.1), and they are discussed in the following sections.

I.3.1. Sheltering

I.17. Sheltering would involve informing the population such that they would remain indoors with the doors and windows closed, essentially to avoid the direct radiation from the plume and inhalation of radioactive material. Such a measure would be continued for twenty-four hours or so, after which conditions, in many cases, could become intolerable.

I.18. The financial penalties involved in sheltering are essentially just due to loss of income. These may be estimated from the GNP per head as \$20 000 ÷ 365 ≈ \$55 per head per day to within a factor of three, i.e. within a range of about \$20 to \$160 per day. By applying the equations expounded in the box on page 59, sheltering would be justified if the avertable dose were of the order of:

$$\frac{\$3 \text{ to } \$20 \text{ per hour}}{\$10\,000 \text{ to } \$40\,000 \text{ per Sv}} \approx \text{a few hundred } \mu\text{Sv to a few mSv per hour}$$

I.19. The length of time over which to express the avertable dose for sheltering is to some extent arbitrary, because the period over which the sheltering will be maintained is unknown. However, it must be long enough that the decision to shelter must be based on a relatively stable assessment of the avertable dose, and it must be long enough compared with the time between the decision and the implementation of sheltering; on the other hand it should not be so long that dose projections for comparison with the intervention level are too unreliable or that it extends into a period of sheltering that would be intolerable. Taking these considerations into account, a period of 6 h has been selected. Thus the intervention level for sheltering, IL_{shel}, is expressed as an avertable dose of:

$$6 \times \frac{\$3 \text{ to } \$20 \text{ per hour}}{\$10\,000 \text{ to } \$40\,000 \text{ per Sv}} \approx \text{one to ten mSv in 6 hours}$$

I.3.2. Urgent evacuation

I.20. An urgent evacuation involves moving a population to an emergency centre (such as local school, community centre, etc.), where facilities would be expected to be uncomfortable but adequate for a short period. A maximum period of stay under such conditions might be as long as a week, before conditions became intolerable. Such a period would be long enough to allow a decision to be made on whether to allow the population to return or for them to be moved to temporary but longer term accommodation.

I.21. The total financial cost accrued over the evacuation period can be expressed as the sum of three main cost components: transportation costs, loss of income costs and accommodation costs. By selecting typical values for each of these component costs as follows for a "highly developed" country:

— transportation out and later return:		a few tens of $
— loss of income	$20 000 ÷ 365 =	$55 per day within a factor of three
— accommodation/food		a few tens of $ per day

It is clear that the cost of transportation is small compared with the cost of maintaining the evacuation; and that the **average** cost per person could be evaluated as between about $50 and $250 per day (depending on the number of days evacuated).

I.22. Taking into account the discussion in the box on page 59, the evacuation of people will be justified if the avertable dose by the evacuation exceeds:

$$\frac{\$50 \text{ to } \$250 \text{ per day}}{\$10\,000 \text{ to } \$40\,000 \text{ per Sv}} \approx \text{a few to a few tens of mSv in a day}$$

I.23. The length of time over which to express the avertable dose for evacuation is to some extent arbitrary, because the period over which evacuation will be maintained is unknown. However, it must be long enough that any initial one-off costs and risks from the evacuation itself are overcome, and it must be long compared with the time between the decision and the implementation of evacuation; on the other hand it should not be so long that dose projections for comparison with the intervention level are too unreliable. These considerations having been taken into account, the period of a day has been selected.

I.3.3. Temporary relocation

I.24. Temporary relocation is here used to mean the movement of people from their homes (or from emergency evacuation centres) to live in temporary accommodation for a period of several months or more. In this time, people will live in rented accommodation of an acceptable standard in the full expectation of being able to return to their original homes. The measure would be taken to avoid radiation exposures from deposited radioactive materials, the dose rate being expected to fall over the period, either naturally or due to forced decontamination measures.

I.25. The total relocation cost accrued over the relocation period can be determined as the sum of three main cost components: accommodation costs, loss of income costs and loss of capital costs. To these, the costs of the initial move and the final return to the homes have to be added. Typical values for each of these component costs for a "highly developed" country are as follows:

— transportation out and later return:	a few hundreds of $ [10]
— loss of income:	several tens to a few hundreds of $ per month
— rental of substitute accommodation:	a hundred [11] to two hundred [12] $ per month
— depreciation/maintenance:	a few tens to several tens of $ per month[13]

The **average** cost per person can be evaluated as between about $400 and $900 for the first month including transport costs and between about $200 and $500 for subsequent months.

I.26. Taking into account the discussion in the box on page 59, the temporary relocation of people will be justified for the first month if the avertable dose in that month exceeds IL_{rel} :

$$\frac{\$400 \text{ to } \$900 \text{ in first month}}{\$10\,000 \text{ to } \$40\,000 \text{ per Sv}} \approx \text{ten to several tens of mSv in the first month}$$

The optimum time for return is when the averted dose in a following month drops below IL_{ret} :

$$\frac{\$200 \text{ to } \$500 \text{ in the month}}{\$10\,000 \text{ to } \$40\,000 \text{ per Sv}} \approx \text{a few to a few tens of mSv in the month}$$

I.27. The length of the period over which to express the avertable dose for relocation must be long enough that any initial one-off costs and risks from the relocation itself are overcome; on the other hand it should not be so long that dose projections for comparison with the intervention level are too unreliable, and that the decision on return cannot respond to changes as they arise. Taking these considerations into account, the period of a month has been selected, and because of the significant transportation costs, a distinction is made between the first month and subsequent months.

I.3.4. Permanent resettlement

I.28. Permanent resettlement here is taken to mean the movement of people from their homes or from temporary accommodation into permanent new homes, with no expectation of being able to return to their original homes in the foreseeable future. Such a decision would be taken within a few months of the accident.

I.29. The cost of permanent resettlement will be dominated by the one-off costs of transportation of people and their belongings, and of the construction and furnishing of new accommodation. There would be some loss of income over the short term, but this would be small compared to the other initial costs. No long term continuing costs are to be expected. On the basis of housing values [11] and expected income losses in highly developed countries, a range of costs for resettlement can be proposed of $10 000 - $30 000 per head.

I.30. The intervention level for permanent resettlement, IL_{reset}, on the assumptions made would lie in the range of:

$$\frac{\$10\,000 \text{ to } \$30\,000 \text{ per person}}{\$10\,000 \text{ to } \$40\,000 \text{ per Sv}} \approx \text{a few hundred mSv to a few Sv}$$

This level will also be a constraint on the return from temporary relocation, i.e. in order to return from temporary relocation, the dose in the subsequent month must be less than IL_{ret} and the residual dose must also be less than IL_{reset} .

I.4. IODINE PROPHYLAXIS

I.31. Because of the relatively low cost of administering iodine to the population (probably on the order of less than ten US dollars/day/person) the only factors which should be taken into consideration in determining the generic intervention levels for iodine prophylaxis are the risk of thyroid cancer and the risk from the intake of stable iodine.

I.32. The ICRP [7] estimates the risk of all thyroid cancers (both fatal and non-fatal) to be 7.5×10^{-3} Gy^{-1}. It does not distinguish between the different age groups. It should be noted that the risks from radioiodine intakes will be significantly higher for infants than for adults.

I.33. There are several numbers quoted in the literature for the risk involved in the intake of stable iodine. These numbers differ widely, mainly because of the differences in the dietary intakes of iodine, and the prevalence of thyroid diseases, which make the effect of the administration of stable iodine potentially more serious. It should be noted that these risks are much higher for adults than for infants and young persons. The US FDA [14] estimated that the risk to the population is between 1-10 x 10^{-7} for a daily therapeutic dose of 300 mg, and is, of course, a third of this for the recommended 100 mg/day prophylactic recommended intake. On the other hand, a large possible range of risk values between 3×10^{-4} and 2×10^{-2} were reported for hypothyroidism [15] depending on whether the country had large or small dietary intakes of iodine. In another report [16] the risk of thyrotoxicosis was reported as 1×10^{-5}, as compared with a risk of hypothyroidism of 2×10^{-2}.

I.34. It should be noted that hypothyroidism, hyperthyroidism, thyrotoxicosis and goitre (which side-effects are the main risks associated with stable iodine) are often conceived to be less "serious" illnesses than non-fatal thyroid cancers and are almost always curable. However, in some cases the cure is surgical, and they are here considered to be of comparable seriousness.

I.35. The above large variation in the risk factors makes it difficult to develop a single risk factor that will be applicable to all countries and to all age groups. The generic intervention level is therefore selected to represent a more central value, but is presented for two distinct age groups. It would be advisable to have country specific intervention levels, and to use the generic levels presented here only in the absence of any other national guidance.

I.36. In order to arrive at a generic intervention level, the ratio between the risk from taking the daily dosage of stable iodine and the risk of incurring thyroid cancer has to be calculated. Assuming the average risk from the total intake of stable iodine to be 10^{-3} and taking the ICRP risk factor for thyroid cancer of 7.5×10^{-3}, one arrives at a generic intervention level of:

$$IL_{thyr} = 10^{-3} \,/\, 7.5 \times 10^{-3} \approx 150 \text{ mGy}$$

However, for reasons already mentioned, distinction can be made between infants and adults. Taking the radiological risk for infants from the intake of radioiodine to be about an order of magnitude higher than that for adults, and the risk from side effects from the prophylaxis somewhat lower, and assuming that the younger age group constitute only a fraction (between a fourth and a fifth) of the population, the generic intervention level for infants can be set to be 50 mGy. By the same token, the generic intervention level for adults can be set at 500 mGy.

I.37. As already presented in para. 316, the further constraint of not exceeding an accumulated dosage of 1 g, and assuming a daily equivalent intake of 100 mg iodide sets the additional condition that the maximum period of the application of stable iodine prophylaxis shall not exceed 10 days. Moreover, because of the potential side-effects of iodine prophylaxis this period should be reduced as much as possible.

I.38. Thus, the generic intervention levels for iodine prophylaxis against an **intake** of radioiodine are selected as :

For adults:	**500 mGy committed thyroid dose from up to 10 days' exposure**
For infants:	**50 mGy committed thyroid dose from up to 10 days' exposure**

I.39. Although, strictly speaking, these intervention levels have been calculated for projected doses, they can be assumed to be the values of avertable doses, for the case when the iodine prophylaxis is administered in a timely manner. In the case that there has been a delay in the administration, the efficiency of the prophylaxis will be reduced, as already discussed (para. 309). In this case, the intervention level should be adjusted, taking into account the reduction in efficiency. This will result in higher intervention levels, in order to retain the same level of protection by the application of stable iodine prophylaxis.

METHODS FOR ESTIMATION OF OPTIMISED INTERVENTION LEVELS FOR FOODSTUFF RESTRICTIONS

Commonly, situations involving food and water contamination will arise where uncontaminated food and water can be substituted at approximately the same cost, and utilized without major disruption of lifestyles. In this case the requirement that intervention be justified is readily satisfied, and it will be possible to apply simple cost-benefit optimisation to derive Intervention Levels for food countermeasures.

The cost of the food countermeasure per unit time can be derived from the cost of the considered foodstuff per kg, ***b***, and the consumption rate, *V*, of that foodstuff as:

$$a = b \cdot V \tag{I.13}$$

The rate at which the dose is committed from consumption of foodstuffs with concentration of activity, *C*, can, for radionuclides with a given committed effective dose per unit intake, ***e(50)***, be calculated as:

$$\dot{E} = C \cdot V \cdot e(50) \tag{I.14}$$

Food restrictions are justified whenever the cost per unit time of the restriction, ***a***, is less than the cost of the averted dose per unit time, $\alpha \cdot \dot{E}$.

The optimised intervention level expressed as the concentration of a given group of radionuclides having the same committed effective dose per unit intake, ***e(50)***, can be calculated when the net benefit per unit time equals zero:

$$\begin{gathered} \alpha \cdot \dot{E} - b \cdot V = 0 \\ \alpha \cdot C \cdot V \cdot e(50) - b \cdot V = 0 \end{gathered} \tag{I.15}$$

The optimised concentration, C_{food}, is given by:

$$C_{opt} = \frac{b}{\alpha \cdot e(50)} \tag{I.16}$$

The optimum intervention concentration depends, for specific categories of foodstuffs (cost categories) and specific groups of radionuclides, on the ratio b/α, which will be less sensitive to geographical location than either ***b*** or α alone.

I.5. FOOD COUNTERMEASURES

I.40. Radionuclides characteristic of accidents in the nuclear fuel cycle, industrial radiography and nuclear power and heat sources in satellites, and which are relevant for general problems of food contamination, can be divided into three main groups, according to their doses per unit activity ingested for adults:

Group 1:	e(50) ≈ 10^{-8} Sv/Bq	^{106}Ru, ^{131}I, ^{134}Cs, ^{137}Cs
Group 2:	e(50) ≈ 10^{-7} Sv/Bq	^{90}Sr
Group 3:	e(50) ≈ 10^{-6} Sv/Bq	^{238}Pu, ^{239}Pu, ^{241}Am

I.41. For specific problems of baby and infant food contamination, the nuclides can be re-grouped according to their doses per unit activity ingested for infants:

Group 1:	e(50) ≈ 10^{-8} Sv/Bq	^{134}Cs, ^{137}Cs
Group 2:	e(50) ≈ 10^{-7} Sv/Bq	^{106}Ru, ^{131}I, ^{90}Sr
Group 3:	e(50) ≈ 10^{-6} Sv/Bq	^{238}Pu, ^{239}Pu, ^{241}Am

I.42. Based on the principles outlined in the box on page 66, foodstuffs can be divided into two categories with broadly the same value per kg:

Category 1: a fraction up to about a dollar per kg	Fresh milk, vegetables, grain, fruit
Category 2: a few up to about ten dollars per kg	Meat, milk products

The ranges of the cost for the two food categories are valid for "highly developed" countries. The annual consumption rates are approximately 430 kg for category 1 and 60 kg for category 2 [17]. The consumption rates and the prices are consistent with the basic law of economics relating to indifference between two goods. The ratio of prices between the two categories are also consistent with the ratio of production of meat and milk products to fresh milk. This means that although the intervention levels for food are derived primarily on the basis of the worth of the food to the population, they also implicitly curb high total intakes.

I.43. A range of the optimised intervention levels, C_{food}, for the two food categories and the three radionuclide groups have been calculated for the specified values of b and $e(50)$ and for the range of monetary values for saving unit collective dose. As an example, considering Group 1 nuclides and Category 1 foodstuffs, the intervention level for withdrawing foodstuffs from human consumption is:

$$\frac{\$0.4 \text{ to} \$1 \text{ per kg}}{\$10\,000 \text{ to } \$40\,000 \text{ per Sv} \times \sim 10^{-8} \text{ Sv per Bq}} \approx \text{one to ten kBq per kg}$$

In a similar manner, ranges for intervention levels for the other groups and category have been evaluated and the results are shown in Table VIII.

TABLE VIII. RANGES OF INTERVENTION LEVELS (kBq/kg) FOR WITHDRAWAL OF FOODSTUFFS FROM GENERAL CONSUMPTION WHERE ALTERNATIVE SUPPLIES ARE READILY AVAILABLE

Radionuclide Group	Food category 1	Food category 2
Group 1	one to ten	ten to a hundred
Group 2	a few hundred to a thousand Bq/kg	one to ten
Group 3	a few tens to a hundred Bq/kg	a few hundred to a thousand Bq/kg

Note: Baby foods are considered separately in para. I.44.

I.44. Because of the higher risk per unit dose for infants, the optimized intervention levels for withdrawal of infant foodstuffs would be lower than the values in Table VIII. The risk factor might be up to a factor of three higher, and therefore the optimized values could correspondingly be a factor of three lower than in the table. In addition, because of the higher dose per unit ingested for infants, the nuclides are re-grouped as discussed in Para I.41.

TABLE IX. GENERIC INTERVENTION LEVELS SELECTED FROM THE RANGE OF OPTIMIZED VALUES

Protective Measure	Symbol	Range	Selected Value
Sheltering	IL_{shelt}	one to ten mSv in six hours	3 mSv in 6 hrs
Evacuation	IL_{evac}	a few to a few tens of mSv in a day	10 mSv in a day
Thyroid Prophylaxis	IL_{thy} (committed thyroid dose from up to 10 days' intake)	—	50 mGy for infants
		—	500 mGy for adults
Temporary Relocation	IL_{rel}	ten to several tens of mSv in the first month	30 mSv in first month
Return from Relocation	IL_{ret}	a few to a few tens of mSv in the month	10 mSv in subsequent month
Permanent Resettlement	IL_{reset}	a few hundred mSv to a few Sv	1 Sv
Withdrawal of foodstuffs from general consumption, IL_{food}	Radionuclide Group	Food Category 1	Food Category 2
	Group 1	(one to ten kBq/kg) **3 kBq/kg**	(ten to a hundred kBq/kg) **30 kBq/kg**
	Group 2	(a few hundred to a thousand Bq/kg) **0.3 kBq/kg**	(one to ten kBq/kg) **3 kBq/kg**
	Group 3	(a few tens to a hundred Bq/kg) **0.03 kBq/kg**	(a few hundred to a thousand Bq/kg) **0.3 kBq/kg**

I.6. SELECTION OF GENERIC INTERVENTION LEVELS

I.45. The ranges for intervention levels arrived at in the preceding sections have been assessed on the basis of ranges for the financial costs of the protective action, the physical risk of side effects in the case of iodine prophylaxis and the benefit of averting the radiation doses. They are not intended to express the full range of variability in the optimized intervention levels, but more the confidence the authors have in the range within which the generic intervention level should lie. In the more extensive sensitivity studies [3] underpinning the simpler presentation here, the influence of personal disruption and the more subjective elements of the value of averting unit collective dose on the ranges for the intervention levels have been examined. These considerations do not significantly alter the confidence the authors have in the ranges within which they expect the generic intervention levels to lie.

I.46. Based on these considerations a single set of internally consistent intervention levels has been selected from within the ranges of optimized intervention levels, and is presented in Table IX. The values have been chosen, in general, towards the middle of each range since it is judged that this will lead to the least divergence from any specific situation. However, it must always be recognized that accident and site-specific conditions, as well as political considerations, might lead to different numbers, even outside the ranges.

I.47. In particular, where the numbers of people and area of land potentially affected by a protective action become extremely large, the cost of resources and societal disruption become more and more important, and relaxation of the intervention levels will be justified. On the other hand, when the numbers of people and area of land potentially affected are very small, additional costs can be readily absorbed by society in order to gain public confidence. Nevertheless, these considerations have been excluded from the analyses performed here.

I.48. As a check, several comparisons have been made between the values selected and other levels of risk (Appendix II), and an intercomparison of the values with each other has been used to check internal consistency (para. I.49). These comparisons provide additional confidence that the set of intervention levels selected are internally consistent and are intuitively reasonable.

I.49. By comparing the value of resources and effort for the various protective actions, some conclusions may be drawn as to their internal consistency. Table X presents, for each protective action, how long another protective action would be needed to last in order to be worth roughly the same. Clearly there is some uncertainty in such comparisons, since the generic levels selected are not dependent completely on each other. On the other hand there is some degree of correlation between the values selected. Thus the values have not only been selected from the ranges presented in the analyses, they have been selected so that there are no inconsistencies in the ratios between the values.

TABLE X. CONSISTENCY BETWEEN INTERVENTION LEVELS

Protective Action	Cost-equivalent Protective Action
Urgent Evacuation for 1 day	Sheltering for 20 h
Temporary Relocation for 1 month	Urgent Evacuation for 3 days
Permanent Resettlement	Temporary Relocation for 100 months

I.50. Indeed the comparisons would also appear to be intuitively consistent from the perspective of how much social disruption and anxiety they cause. If the associated costs of anxiety and disruption were significantly out-of-line with the penalties compared here, the inclusion of such factors in the analysis would affect the existing internal consistency. For example, if the family unit were split during an evacuation, but not during relocation, the anxiety and disruption factors for evacuation would be more significant and one would expect the intervention level for evacuation to be relatively higher.

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Appendix II

RISK PERSPECTIVES

II.1. INTRODUCTION

II.1. In this section several perspectives are given on the risks associated with the generic intervention levels recommended here. For the protective actions of sheltering, evacuation, temporary relocation and permanent resettlement, where the intervention levels are quoted in terms of avertable doses, comparisons are made with variations in natural background radiation. For protective actions involving food, comparisons are made of the radiological risk with other risks associated with eating common foodstuffs. Finally for all protective actions a perspective is provided on the magnitude and nature of the health risk in comparison with other risks taken in everyday life.

II.2. Figure 6 illustrates schematically an area of land where a particular protective action has been taken, *Area Y*. Outside this area, in *Area N* the particular action has not been taken, although other actions may have been. At the border between the two zones, the dose to population *y* averted by taking the action will be received by population *n*, along with other contributions to dose. Thus it will be appreciated that the populations that receive the highest radiation exposures are the group just outside an area where a protective measure is taken. This group is normally relatively small compared to the numbers of people undergoing the protective action and to the numbers outside of the zone of control. Nevertheless we estimate here the risks to this group of most highly exposed individuals.

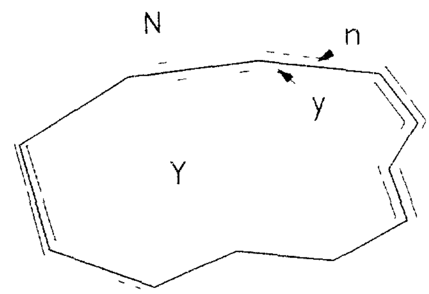

FIG 6 Schematic plan illustrating areas for which a protective measure is applied

II.3. Building in conservatisms in the selection of the intervention levels can lead to action being applied that does considerably more harm than good. However, despite the fact that the generic intervention levels are based primarily on realistic assumptions and should theoretically be applied to the average population, in practice there is inevitably some conservatism that will be applied by control officers. This is in the nature of human reaction to an accident. Thus the individual doses implied by the intervention levels will almost certainly be greater than the average individual doses received, though not necessarily higher than the dose to the most exposed individual.

II.2. COMPARISON WITH NATURAL BACKGROUND RADIATION

II.4. Throughout history people have lived in an environment with radiation as a constituent element, and natural sources deliver the highest radiation dose that people normally receive. The main sources of exposure include cosmic rays, gamma rays from terrestrial materials either indoors or outdoors, exposure to the radioactive gas radon, and exposure from natural radionuclides in foods. Globally, the average annual dose due to natural sources is some 2.4 mSv [1]. Within this statistical average are typical individual doses that range from less than one to several millisieverts a year and in extreme cases, to a sievert or more.

II.5. As an example of the variability of the human exposures to natural radiation, Figure 7 presents the annual and lifetime doses from natural radiation sources for seventeen different countries in Europe [2]. It can be seen that radon exposures are responsible for the wide variation between

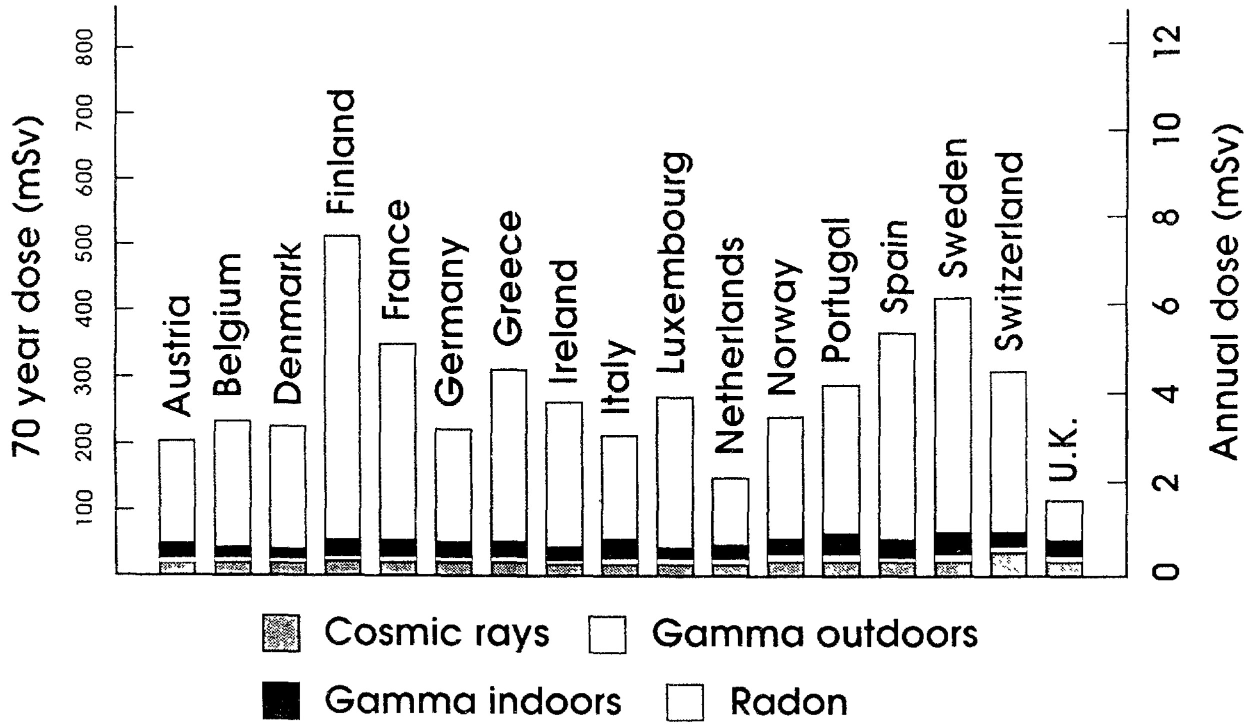

FIG 7. The annual and lifetime doses from natural radiation sources for different European countries.

TABLE XI. LENGTH OF TIME SPENT IN A COUNTRY WITH HIGHER NATURAL BACKGROUND THAT GIVES RISE TO A DOSE THAT COULD BE AVERTED BY INTERVENTION AT THE GENERIC INTERVENTION LEVELS

Protective Action	Generic Intervention Level (averted dose)	If action lasts for	the dose averted is	equivalent to the **additional natural background** dose received by staying in country A rather than country B for
Sheltering	3 mSv in 6 hours	**6 h**	3 mSv	**7 months**
		48 h	24 mSv	**≈ 5 years**
Evacuation	10 mSv in a day	**1 day**	10 mSv	**2 years**
		7 days	70 mSv	**14 years**
Temporary Relocation	30 mSv in 1st month, then 10 mSv in a month	**1 month**	30 mSv	**6 years**
		1 year	< 140 mSv	**<28 years**
Permanent Resettlement	1 Sv in a lifetime	**70 years**	1 Sv	**200 years**

the natural radiation doses in these countries. For example, the annual average dose from natural sources is about 5 mSv higher in Finland (country A) than it is in the United Kingdom (country B), and the total average lifetime dose[1] is therefore some 0.35 Sv higher. This variation in natural background exposure may be used to give some perspective on the generic intervention levels recommended here by indicating the length of stay in country A by a person normally resident in country B that would lead to the same additional radiation exposure (Table XI).

II.6. It should be borne in mind that the annual and lifetime doses used for countries A and B are averages for their populations, and that we have compared them with the dose to the maximum individuals **just** not affected by the relevant protective action. The averages themselves conceal a considerable degree of local variation. Whilst this does not arise for the cosmic ray component, nor is it pronounced for gamma rays, radon concentrations can vary appreciably from one locality to the next - by a factor of ten - and dramatically from one house to another - perhaps by a factor of one hundred. For some illustration of this, the map in Figure 8 indicates that within each country there is considerable variation between regions [2].

II.7. On the basis of the above comparisons with variations in natural background, there appear to be no major grounds to suggest that the values of generic intervention levels chosen are unreasonable. However, should decision makers choose to select alternative intervention levels, they would find it rewarding to look at the variations in natural background as one perspective on their decision.

II.3. COMPARISON WITH OTHER RISKS

II.8. As discussed in the main text, the health effects associated with exposure to radiation fall into two main categories, deterministic and stochastic. Using the generic intervention levels recommended here will ensure that no deterministic effects will occur in the exposed population. However, it is assumed that exposure will result in some additional risk of cancer to the exposed individuals, and hence a statistical increase in the cancer incidence in the population. The magnitude and nature of these risks are discussed in this section.

II.9. The main source for the estimation of cancer risks is the continuing follow-up studies of the survivors of the Hiroshima and Nagasaki atomic bombs, where some 80 000 people were exposed to high and acute levels of radiation [1]. On the basis of extrapolations from these data, and supported by other smaller study groups, animal and laboratory experiments, risk factors for exposure to radiation have been proposed by ICRP [3]. The risks are dependent on sex, age at exposure to the radiation and time since exposure as well as on the normal underlying risks of contracting cancer. Although a considerable uncertainty in the risk factors inevitably remains, it is probably fair to say that the use of these factors is unlikely to underestimate the true risks.

II.10. In comparing risks from radiation with those from other sources, in many cases it is clear that there are considerable uncertainties associated with estimating the risks from these other sources. Thus, such comparisons should be treated with caution, since they indicate only the possible magnitude of the risks involved. The quality of these risk comparisons thus is less than that of the comparison with natural radiation, where physical measurable quantities were being compared.

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[1] Taken here to be a 70-year dose.

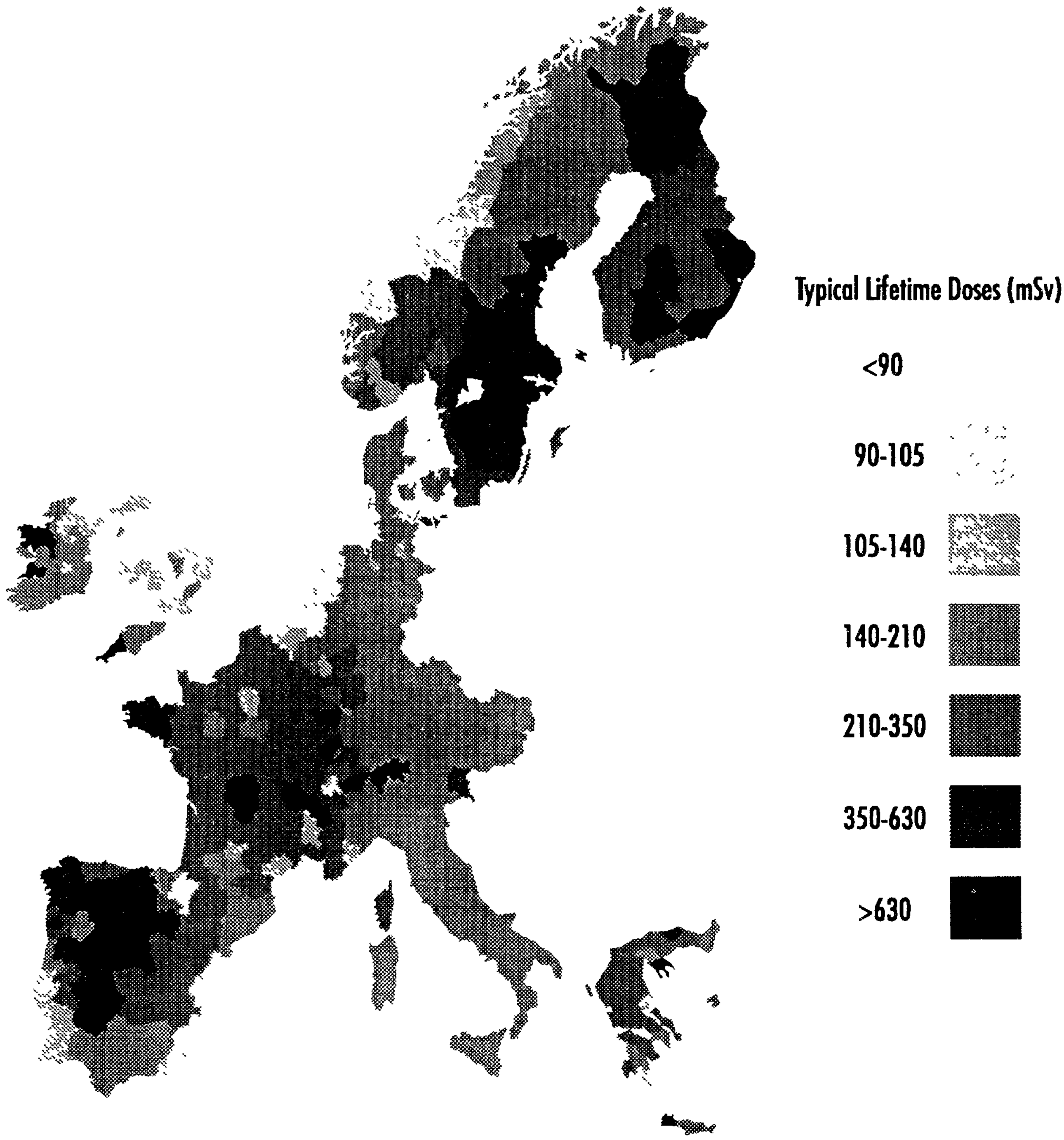

FIG 8 Map indicating regional variation in natural background exposure (Europe)

II.11. A perspective on the nature of the cancer risk will necessarily involve considering when in life the cancer occurs. Most of the predicted cancers induced by radiation appear a relatively long time after the exposure to radiation. In many cases the most likely time for radiation-induced cancers to appear is when the exposed individual reaches his or her seventies. Figure 9 illustrates the risk of death from radiation-induced cancer following a single exposure at various ages [4, 5]. Two sets of curves are given; one set for the total lifetime risk of death, and secondly, one for the risk of dying before age 65. It is clear that children are more at risk than adults (about a factor of three), and that about two-thirds of the risk is expressed after age 65 years.

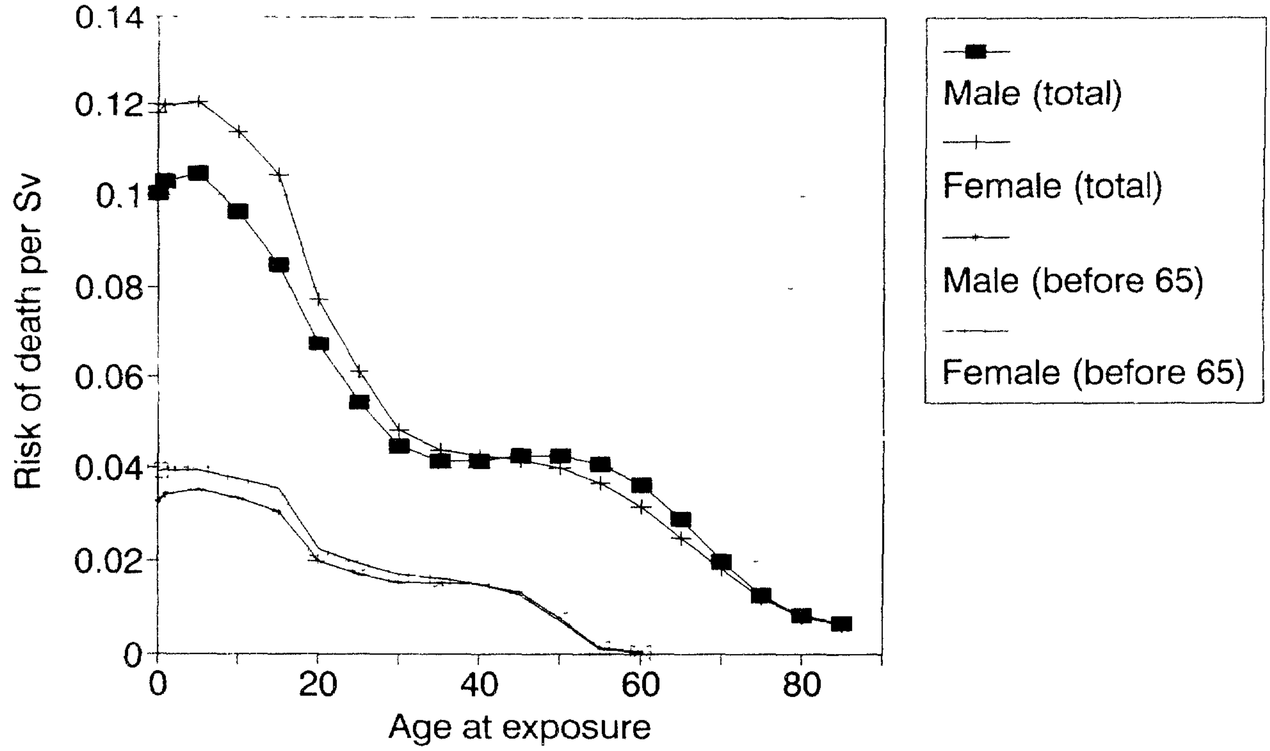

FIG. 9. Probability of death from a radiation-induced cancer following a single exposure at various ages

TABLE XII. RISKS OF HEALTH EFFECTS AVERTED BY IMPLEMENTING PROTECTIVE ACTIONS AT THE GENERIC INTERVENTION LEVELS

Protective Action	Generic Intervention Level	Time for which action is assumed to last	Dose averted over that period (mSv)	Risk[a] averted to population at the edge of the protective action boundary		
				Average	Children	Pensioners
Sheltering	3 mSv in 6 hours	6 hrs	3	1 in 4600	1 in 1900	1 in 19000
		48 hrs	12	1 in 1200	1 in 500	1 in 5000
Evacuation	10 mSv in a day	1 day	10	1 in 1400	1 in 600	1 in 6000
		7 days	70	1 in 200	1 in 80	1 in 800
Temporary Relocation	30 mSv in 1st month; then 10 mSv a month	1 month	30	1 in 450	1 in 200	1 in 2000
		1 year	< 140	< 1 in 60	< 1 in 25	< 1 in 250
Permanent Resettlement	1 Sv[b]	Lifetime	1000	1 in 30	1 in 13	1 in 130

[a] Risk of fatal cancer and weighted non-fatal cancers and hereditary effects, with a mean nominal probability coefficient of 7.2% per Sv.

[b] Taking into account that the lifetime dose is protracted in time.

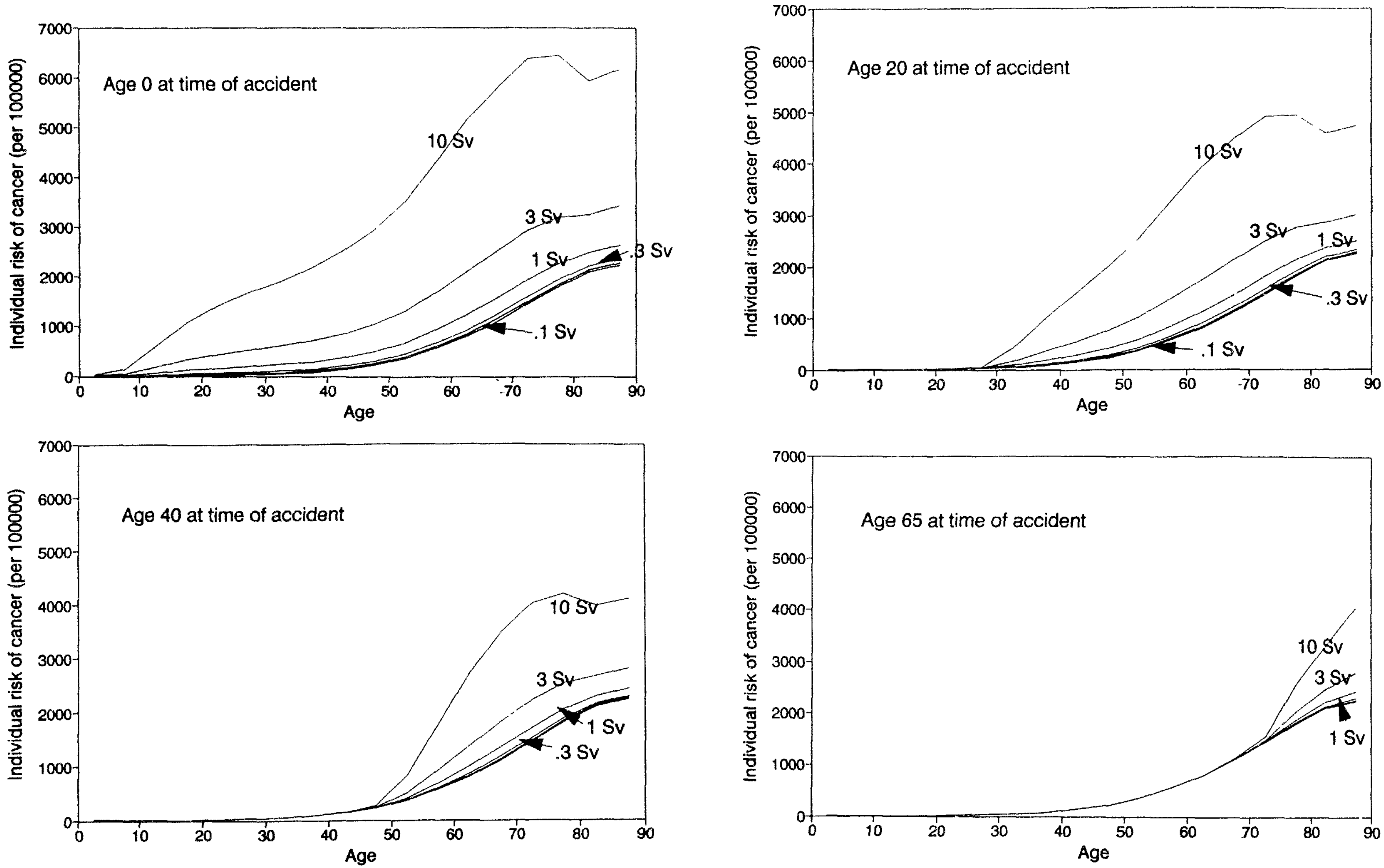

FIG. 10. Statistical increase in cancer incidence for various lifetime exposures.

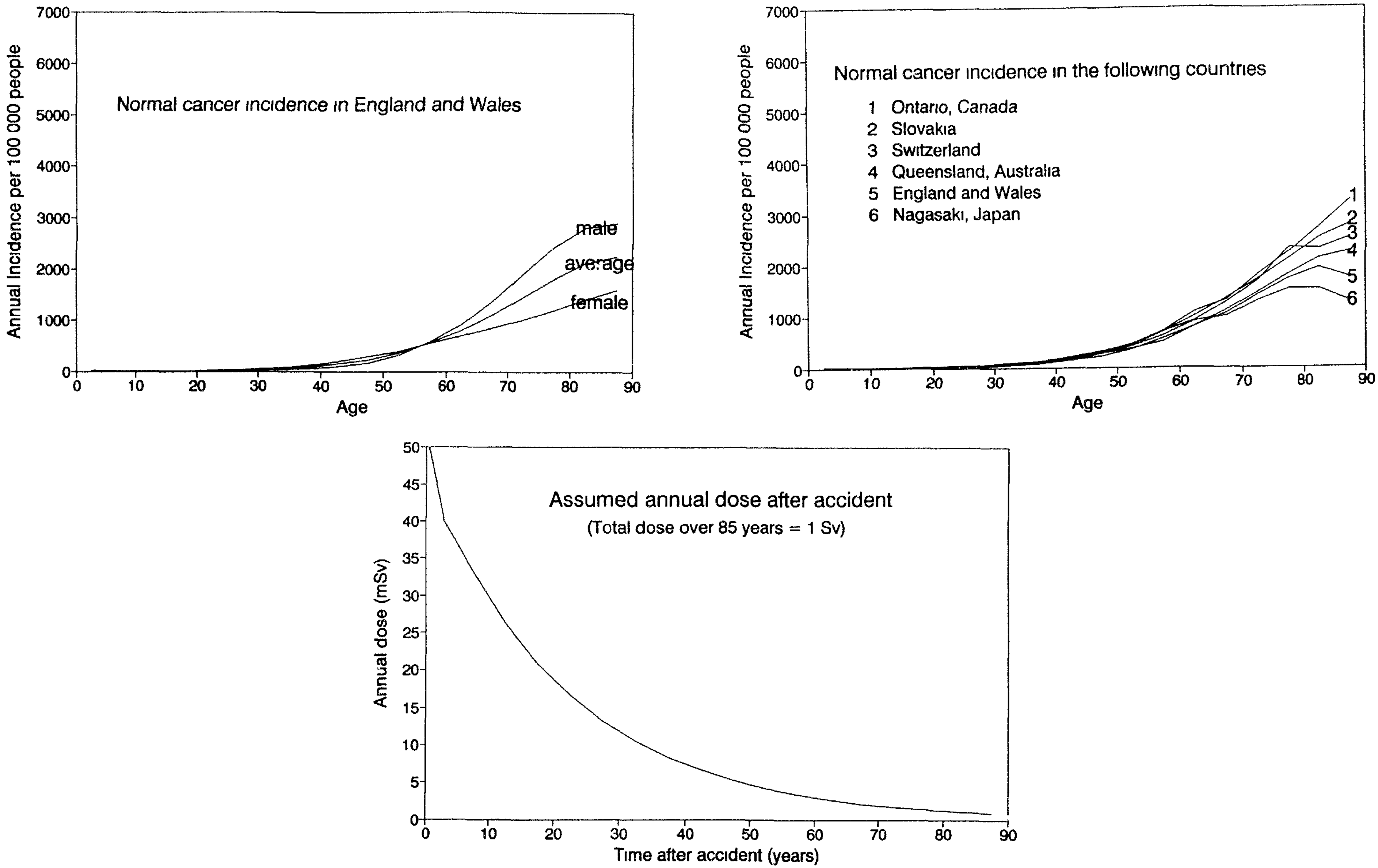

FIG 11 Underlying rates of cancer incidence in various countries

II.12. Additionally, there will be other attributes that affect the perspective on the radiation-induced risks, such as uncertainty, inequity between individuals, the degree of voluntariness, and public perception. These factors and others will make additional distinctions in comparisons of radiation-induced risks with other risks that should always be borne in mind.

II.13. Table XII presents the risk to the population averted by implementing the protective actions for various lengths of time at the recommended generic intervention levels. Additionally the risks are presented for the average population, children and pensioners. The strong dependence of radiological risk with age is a factor that a decision maker will need to consider in developing his response, as well as the different physical risks to these population groups from the measure itself. Clearly this illustrates the possibility of developing flexibility into the emergency plans to allow for radiosensitivities of different groups within the population. However, this will involve careful social judgements that can only be made by national responsible authorities. Consideration of the information presented here should be rewarding in developing any specific plans to address these needs.

II.14. An additional perspective on the implied risks of permanent resettlement can be obtained from the graphs in Figure 10, where the increased risk of cancer (both fatal and non-fatal) are shown as a function of age for four age-groups (infants, 20-year olds, 40-year olds and 65-year olds) for several lifetime dose criteria [4, 5]. These increased risks are shown on top of an underlying cancer

TABLE XIII. TYPICAL MAXIMUM INDIVIDUAL DOSES AND RISKS ASSOCIATED WITH GENERIC INTERVENTION LEVELS FOR FOOD

Radionuclide Group	Intervention Level (kBq/kg)	Maximum total dose in one year (mSv)[a]	Total risk of fatal cancer
Group 1 : Caesiums etc.	3	a few[b]	10^{-4}
	30	about ten	$5\ 10^{-4}$
Group 2 : Sr-90	0.3	about ten[c]	$5\ 10^{-4}$
	3	a few	10^{-4}
Group 3 : Actinides	0.03	a few[d]	10^{-4}
	0.3	a few tens	10^{-3}

[a] Assuming 30% of diet is contaminated at IL for one year. Dose calculations are most restrictive of assuming critical group intake of a single food, or average consumption of all foods within a category specified in Table VI.

[b] Infant: assuming I-131 contamination for 2 months, or Cs-134 for 1 year.

[c] Infant.

[d] Assuming effective dose per unit intake, *e(50)*, of 10^{-6} Sv/Bq for foods as (a) actinides do not transfer to milk, and (b) an infant-specific *e(50)* only applies to the first few months.

The intervention levels for foodstuffs shown in Table IX have been established to be independent of the contamination of other foodstuffs and other exposure pathways. If only 10% of all the foodstuffs were contaminated up to the intervention level in all three nuclide groups the committed effective dose from consumption of these would be about 3 mSv.

incidence curve. The risks for a lifetime criterion of 1 Sv again illustrate the nature of the trade-off between the risks to children compared with those to elderly people. Once again, the social difficulties that might be involved in having differential policies must be examined by the regulatory authorities. Also presented in Figure 11 are graphs showing the variability of the normal cancer incidence rates between various countries and between the sexes in order to get a perspective on the magnitude of the increased cancer risks associated with the generic intervention level for permanent resettlement [6].

II.4. RISK PERSPECTIVE ON GENERIC INTERVENTION LEVELS FOR FOOD

II.15. Table XIII presents indicative maximum individual doses resulting from application of the GILS for food withdrawal. In deriving these doses, account has been taken of the wide range of concentration levels in marketed food, as discussed in Section 5.2.1. It can be seen that, in general, individual doses are most unlikely to exceed 10 mSv during the first year (and would be expected to reduce substantially in subsequent years). This represents a total risk of fatal cancer of approximately 5×10^{-4}; the average risk per year over a lifetime of 50 years then is of the order of 10^{-5}/a.

II.16. Many items of our normal diet have in themselves side effects that pose some hazard to us. These hazards are generally small, are not very well appreciated or are considered acceptable risks. In order to provide some perspective on the generic intervention levels for food given above, Table XIV gives the radiocaesium concentrations that would have to exist in these foods to give a risk

TABLE XIV. CONCENTRATION OF ^{137}Cs IN FOODSTUFFS THAT WOULD GIVE RISE TO COMPARABLE LOSS OF LIFE EXPECTANCY RESULTING FROM CONSUMPTION OF 1 kg OF THE GIVEN FOODSTUFF

Foodstuff	Concentration of ^{137}Cs giving rise to comparable risk (kBq/kg)
Bottled mineral water[a], broiled meat[b], milk[c]	up to 0.03
Fish[d]	0.03
Diet soft drink[e]	0.07
Coffee drinking[f]	0.25
Peanut butter[c]	0.8
Mollusca[d]	0.3 - 1
Non-diet soft drink[g]	7
High calorie dessert[g]	40

[a] Considering only the radiological risk from Ra-226
[b] Considering only the carcinogenic risk from organics by pyrolysis
[c] Considering only the carcinogenic risk from aflotoxins
[d] Considering only the radiological risk from Po-210
[e] Considering only risk of bladder cancer from saccharin
[f] Considering only the risk of bladder cancer, neglecting mutagenic effects of caffeine, effects on nervous system and weight control
[g] Considering only the effects of unused extra calorific intake - reversible by exercise and diet

equal to that from the inherent hazard of eating the food under normal circumstances. For example, the Codex Alimentarius Commission level for food moving in international trade, 1 kBq/kg for radiocaesium, is in line with other risks from many foods, and generally much lower than the risk associated with high calorific foods. The generic intervention level recommended here for the withdrawal of meat, etc. of 30 kBq/kg has a risk associated with it similar to that of eating a high calorie dessert [7]. These comparisons are very imprecise in nature and should be treated with caution. Nevertheless, they indicate that radiation risks controlled to the generic intervention levels in food are not significantly out-of-line with some other risks from food.

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Annex

EXAMPLE CALCULATIONS OF OPERATIONAL QUANTITIES FOR RELOCATION

A-1. INTRODUCTION

Quantities such as dose rate and surface contamination density would be needed as operational intervention levels (OILs) as these quantities could be easily measured and applied as surrogates for the intervention level of averted dose. However, such operational quantities should be carefully derived from the intervention level, the local conditions and the circumstances of the accident which include environmental half-lives of the deposited radionuclides and shielding factors for housing conditions in the affected areas.

As the operational intervention levels are derived from the intervention levels they have also been called derived intervention levels (DILs) [1]. However, the DILs have often been derived from intervention levels that were indistinguishable from dose limits or were even considered as dose limits. To avoid misunderstanding, the derived quantities are therefore called OILs; this is merely a change in terminology rather than a change in concept.

A-2. DOSE RATE

A-2.1. Single radionuclides

The ratio of the accumulated external dose over a given time period, (t_1, t_2), to the external dose accumulated per unit time at time t_3 after the plume passage can be calculated for a given radionuclide as:

$$\frac{E(t_1, t_2)}{E(t_3)} = \frac{\int_{t_1}^{t_2} \dot{E}_0 \cdot e^{-\lambda t} \mathrm{d}t}{\dot{E}_0 \cdot e^{-\lambda t_3}} = \frac{e^{-\lambda t_1} - e^{-\lambda t_2}}{\lambda \cdot e^{-\lambda t_3}} \qquad \text{(A-1)}$$

Values of $E(t_1, t_2)/E(t_3 = 1$ day) are shown in Table A-I for radionuclides having an effective removal half-life in the range 0.2 - 10 years and for (t_1, t_2) in the range 1 - 6 months.

The operational intervention level, OIL_{rel}, corresponding to the intervention level for relocation, IL_{rel}, can be calculated from the values in Table A-I as:

$$OIL_{rel} = \frac{IL_{rel}}{\overline{L}_t \cdot E(t_1, t_2)/E(t_3 = 1 \text{ day})} \qquad \text{(A-2)}$$

where $\overline{L}_t$ is the time-averaged location factor for the area.

TABLE A-I. FRACTION OF PROJECTED DOSE $E(t_1, t_2)$ IN mSv ACCUMULATED OVER THE TIME INTERVAL (t_1, t_2) TO THE DOSE ACCUMULATED PER UNIT TIME $E(t_3=1$ DAY) IN mSv/h

Effective removal half-life $T_{1/2}$ (years)	$E(t_1, t_2)/E(t_3=1$ day) External accumulated dose per dose per unit time (mSv/(mSv/h))					
	(t_1, t_2) (days)					
	(1,31)	(30,60)	(60,90)	(90,120)	(120,150)	(150,180)
0.2	621	471	354	267	200	151
0.5	678	607	542	483	431	385
1	700	661	625	590	557	526
2	709	690	671	652	633	616
3	713	700	687	674	661	649
5	716	708	700	692	684	676
10	718	714	710	706	702	698

Relocation of the area for at least 1 month at an intervention level of 10 mSv/month should be introduced if the outdoor reference dose rate, $\dot{E}_{ref}$, from a radionuclide on the assumption that the time-averaged location factor for the area is 0.2 with an effective removal half-life of 0.2 year, measured at day 1 after the accident, is greater than:

$$OIL_{rel} = \frac{10}{0.2 \cdot 621} = 0.08 \text{ mSv/h} \qquad \text{(A-3)}$$

Relocation should continue for at least 6 months if the outdoor reference dose rate at day 1 exceeds:

$$OIL_{rel} = \frac{10}{0.2 \cdot 151} = 0.33 \text{ mSv/h} \qquad \text{(A-4)}$$

A-2.2. Mixture of fission products

Another approach is to consider a release of a mixture of fission products. The dose rate from a mixture of fission products has a time dependence typically of the type t^{a}, where a is in the range of 0.2 - 0.8 for the first few months after the release, depending on the nuclide composition. The ratio of the accumulated dose over a given time interval, (t_1, t_2), to the dose accumulated per unit time at different times, t_3, after the plume passage can be calculated from:

$$\frac{E(t_1, t_2)}{E(t_3)} = (t_3)^a \cdot \int_{t_1}^{t_2} t^{-a} dt = (t_3)^a \cdot \frac{(t_2)^{1-a} - (t_1)^{1-a}}{1 - a} \qquad \text{(A-5)}$$

Values of $E(t_1, t_2)/E(t_3)$ are shown in Table A-II for a range of t_3 up to 4 weeks and a range of monthly periods up to 6 months after the release. The value of the parameter a is here assumed to be 0.8, which is valid for a mixture of all the iodine and caesium radionuclides in the same proportion as in a reactor core. For the total activity in a reactor core the value of the parameter a is about 0.3.

TABLE A-II. FRACTION OF PROJECTED DOSE $E(t_1, t_2)$ IN mSv ACCUMULATED OVER THE TIME INTERVAL (t_1, t_2) TO THE DOSE ACCUMULATED PER UNIT TIME $E(t_3)$ IN mSv/h AT TIME t_3 AFTER THE ACCIDENT (t IN DAYS)

Time after accident t_3 (days)	$E(t_1, t_2)/E(t_3)$ External accumulated dose per dose per unit time (mSv/(mSv/h))				
	(t_1, t_2) (days)				
	(1,31)	(30,60)	(60,90)	(90,120)	(150,180)
1	120	35	23	17	12
3	290	85	55	42	29
5	430	130	83	63	44
7	560	170	110	83	58
14	980	290	190	140	100
28	1700	510	330	250	175

The operational intervention level, OIL_{rel}, corresponding to the intervention level for relocation, IL_{rel}, can be calculated from the values in Table A-II as:

$$OIL_{rel} = \frac{IL_{rel}}{\overline{L}_t \cdot E(t_1, t_2)/E(t_3)} \qquad \text{(A-6)}$$

Relocation of an area for at least 1 month at an intervention level of 10 mSv/month should be introduced if the outdoor reference dose rate, $\dot{E}_{ref}$, measured at day 1 after the accident, is greater than:

$$OIL_{rel} = \frac{10}{0.2 \cdot 120} = 0.4 \text{ mSv/h} \qquad \text{(A-7)}$$

Similarly, relocation should continue for at least 4 months if the measured outdoor reference dose rate at day 1 exceeds:

$$OIL_{rel} = \frac{10}{0.2 \cdot 17} = 3 \text{ mSv/h} \qquad \text{(A-8)}$$

Furthermore, if the intervention level for relocation, IL_{rel}, is set at 40 mSv over the first 4 months after the accident, corresponding to 10 mSv/month on average, relocation should be introduced for at least 4 months if the outdoor dose rate at day 1 exceeds:

$$\begin{aligned} OIL_{rel} &= \frac{IL_{rel}}{\overline{L}_t \cdot \sum E_i(t_1, t_2)/E_i(t_3)} \\ &= \frac{40}{0.2 \cdot (120 + 35 + 23 + 17)} \qquad \text{(A-9)} \\ &\approx 1 \text{ mSv/h} \end{aligned}$$

A-3. SURFACE CONTAMINATION DENSITY

The outdoor external reference dose rate, $\dot{E}_{ref}$, will depend on the contamination density, Q, of the deposited radionuclides. At an unshielded outdoor position, i.e. with no buildings within about 100 metres around the measuring position, the surface contamination density can be expressed as:

$$Q = q \cdot \dot{E}_{ref} \tag{A-10}$$

where q is the surface contamination density per unit dose rate.

This conversion factor is nuclide specific and also depending on the roughness of the surface on which the radionuclides are deposited. Normally, the surface roughness of a lawn is used as reference for the calculation of conversion factors for deposited nuclides. Values of the conversion factor, q, are shown as illustration in Table A-III for the radionuclides of ^{134}Cs, ^{137}Cs and ^{106}Ru.

TABLE A-III. SURFACE CONTAMINATION DENSITY PER UNIT EXTERNAL OUTDOOR DOSE RATE 1 METRE ABOVE AN INFINITE PLANE SURFACE SOURCE WITH A SURFACE ROUGHNESS CORRESPONDING TO AN EFFECTIVE DEPTH OF THE SOURCE IN THE SOIL OF 3 mm

Nuclide	q (MBq·m^{-2})/(mSv/h)
^{106}Ru	2 000
^{134}Cs	280
^{137}Cs	710

An accumulated external dose of 10 mSv over one month corresponds to an accumulated dose per unit time of 10/30·24 = 14 μSv/h for long-lived radionuclides. With a time-averaged location factor for the area of 0.2 this is equivalent to an outdoor **dose rate** of 14/0.2 = 70 μSv/h. From the figures in Table A-III it can be seen that an external dose rate of 70 μSv/h would result from a surface contamination density with ^{137}Cs of 50 MBq/m^2. A surface contamination density of 50 MBq/m^2 ^{137}Cs is therefore the operational intervention level for relocation of that area. For ^{106}Ru the corresponding OIL_{rel} would be 140 MBq/m^2.

For comparison with the external dose factors shown in Table A-III the corresponding dose factors have been calculated for resuspension and ingestion doses to small children playing outside for 8 hours a day. These calculations have been made with the assumptions that the resuspension factor is 10^{-5} m^{-1}, that 0.2 g soil is ingested per day and that the inhalation/ingestion dose conversion factor is 10^{-8} Sv/Bq (radionuclides of cesium, iodine etc.). The results are shown in Table A-IV.

TABLE A-IV. SURFACE CONTAMINATION DENSITY PER UNIT RESUSPENSION AND INGESTION DOSES PER UNIT TIME FOR SMALL CHILDREN: THE RESUSPENSION AND INGESTION DOSES ARE REPRESENTATIVE FOR RADIONUCLIDES HAVING DOSE CONVERSION FACTORS OF THE ORDER OF 10^{-8} Sv/Bq

Exposure pathway	q (MBq·m^{-2}/mSv·h^{-1})
Resuspension	40 000
Ingestion of soil	400 000

Examples on operational intervention levels for temporary relocation corresponding to an intervention level of averted external dose of 10 mSv/month are given in Table A-V for different radionuclides, expressed as outdoor external dose rate and surface contamination density.

TABLE A-V. OPERATIONAL INTERVENTION LEVELS, OIL_{rel}, FOR TEMPORARY RELOCATION CORRESPONDING TO AN INTERVENTION LEVEL, IL_{rel}, OF AVERTED EXTERNAL DOSE OF 10 mSv/month: THE TIME-AVERAGED LOCATION FACTOR FOR THE AREA IS $\bar{L}_t$

Operational Intervention Level for temporary relocation, OIL_{rel}		
Radionuclide	Outdoor external dose rate at time of relocation (μSv/h)	Surface contamination density at time of relocation (MBq/m^2)
^{106}Ru	$14/\bar{L}_t$	$28/\bar{L}_t$
^{134}Cs	$14/\bar{L}_t$	$3.9/\bar{L}_t$
^{137}Cs	$14/\bar{L}_t$	$10/\bar{L}_t$

Examples of operational intervention levels, OIL_{per}, for permanent relocation, corresponding to an intervention level, IL_{rel}, of averted external dose of either 10 mSv/month beyond a time period of 1 year or an averted external dose of 1 Sv are shown in Table A-VI. It is assumed that the environmental half-life for the deposited material is 15 years, which will give an effective removal half-life for ^{137}Cs of 10 years.

The OIL_{per} for permanent relocation elsewhere based on an averted external dose of 1 Sv can generally be expressed as an outdoor external dose rate:

$$OIL_{per} = \frac{80\ \mu Sv/h}{\bar{L}_t \cdot T_{1/2}} \qquad (A\text{-}11)$$

where $T_{1/2}$ is the effective removal half-life in **years**.

TABLE A-VI. OPERATIONAL INTERVENTION LEVELS, OIL_{per}, FOR PERMANENT RELOCATION ELSEWHERE CORRESPONDING TO AN INTERVENTION LEVEL, IL_{rel}, OF AVERTED EXTERNAL DOSE OF EITHER 10 mSv/month BEYOND 1 YEAR OR AN AVERTED EXTERNAL DOSE OF 1 Sv

Operational Intervention Levels for permanent relocation, OIL_{per}				
Radionuclide	Outdoor external dose rate at time of relocation (μSv/h)		Surface contamination density at time of relocation (MBq/m^2)	
	10 mSv/month	1 Sv	10 mSv/month	1 Sv
^{106}Ru	$30/\bar{L}_t$	$80/\bar{L}_t$	$60/\bar{L}_t$	$160/\bar{L}_t$
^{134}Cs	$20/\bar{L}_t$	$40/\bar{L}_t$	$5.6/\bar{L}_t$	$11/\bar{L}_t$
^{137}Cs	$15/\bar{L}_t$	$8/\bar{L}_t$	$11/\bar{L}_t$	$5.7/\bar{L}_t$

If the outdoor external dose rate from a contamination with ^{106}Ru at the time of decision for relocation is above $30/\bar{L}_t$ μSv/h, the averted external dose after 1 year would still be greater then 10 mSv/month and permanent relocation elsewhere is therefore mandatory. Similarly, for ^{137}Cs, permanent relocation should be introduced if the outdoor dose rate is greater than $15/\bar{L}_t$ μSv/h.

It appears from Table A-VI, that for a ^{137}Cs-contamination with an effective removal half-life of about 10 years, corresponding to an environmental half-life of 15 years, the criterion for permanent relocation of 1 Sv will be the most restrictive of the two criteria. The value of the effective removal half-life that would make the two criteria equally restrictive is about 7 years. For an effective removal half-life lower than this, the criterion of 10 mSv/month will be the most restrictive, i.e. the averted external dose from a permanent relocation at this Intervention Level would be less than 1 Sv.

REFERENCE TO ANNEX

[1] INTERNATIONAL ATOMIC ENERGY AGENCY, Derived Intervention Levels for Application in Controlling Radiation Doses to the public in the Event of a Nuclear Accident or Radiological Emergency, Safety Series No. 81, IAEA, Vienna (1986).

GLOSSARY

Avertable dose	The dose that would be saved if a protective measure is applied (see para. 228).
Derived intervention level	A term used to describe a reference level (see below) above which a decision on intervention was required.
Deterministic health effect	Health effects of which the probability of occurrence rises rapidly from zero to unity as the dose increases above some threshold of dose. The severity also rises with the dose above the threshold.
Dose constraint	A dose constraint is placed on the doses to individuals so as to limit the inequity that otherwise might result from unconstrained optimization.
Effective dose	The effective dose is the sum of the weighted equivalent doses in all the tissues and organs of the body. It is given by the expression $E = \sum_T w_T \cdot H_T$ where H_T is the equivalent dose in tissue or organ T and w_T is the weighting factor for tissue T.
Effective removal half-life	When considering the natural reduction in the radiation dose from activity deposited on the ground or urban surfaces, the combination of the removal rate λ_r and the radioactive decay rate λ_d can be expressed as an effective removal half-life, $t_{½}$, thus $t_{1/2} = \frac{1}{\lambda_r + \lambda_d}$
Evacuation	The urgent moving of people from their normal place of residence, or from places of work or recreation, for a limited period of time, in order to avoid unnecessarily high exposures that would otherwise arise in the short term from the accident. Because of the short time involved, primitive accommodation in schools or other public buildings is typical.
Generic intervention level	Intervention Levels for protective actions that have been selected to be generically applicable to a wide range of accident situations in the absence of more specifically derived values.
Operational quantity	Term given to a reference level used to assist in the implementation of protective measures.
Permanent resettlement	Removal of people from an area with no expectation of their return in the foreseeable future. People would typically be resettled in accommodation comparable with that vacated.

Precautionary evacuation Evacuation of people on the basis of serious plant conditions before a release has occurred.

Projected dose The integral of the dose rate to an individual up to a given time, i.e. the total dose received or to be received (see para. 227).

Reference level Values of measured quantities established to held in the management of a situation above which some specified action or decision should be taken. They include intervention levels.

Residual dose The dose remaining after a protective action has been taken.

Risk Risk is used in both the sense of a hazard, but also in the specific sense for radiation protection; namely, the probability that a given individual will incur any given deleterious stochastic effect as a result of radiation exposure.

Sheltering Staying or moving indoors, closing doors and windows, and possibly turning off ventilation systems in order primarily to reduce the dose from inhalation of and external dose from radioactive material in a passing plume, and to reduce the external dose from radioactive deposits.

Stable iodine In the context of the present document: a chemical compound containing a non-radioactive form of iodine, to be administered as a protective measure for the population in the case of a release of radioactive isotopes of iodine.

Stochastic health effect Stochastic health effects typically include a wide range of cancers and hereditary effects. The probability of an individual or subsequent generations of an individual's descendants developing one of these effects increases with the dose received.

Temporary relocation The organized removal of people from an area for an extended, but limited period of time (e.g. several months) to avoid doses from radioactive material on the ground. People would typically be housed in temporary accommodation of a reasonable minimum standard of comfort and privacy.

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Consultants Meetings

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