5.10. Dose limits

(238) Dose limits apply only in planned situations but not to medical exposures of patients. The Commission has concluded that the existing dose limits that it recommended in *Publication 60* continue to provide an appropriate level of protection (ICRP, 1991b). The nominal detriment coefficients for both a workforce and the general public are consistent with, although numerically somewhat lower than, those given in 1990. These slight differences are of no practical significance (see Annex A). Within a category of exposure, occupational or public, dose limits apply to the sum of exposures from sources related to practices that are already justified.

(239) For occupational exposure in planned situations, the Commission continues to recommend that the limit should be expressed as an effective dose of 20 mSv per year, averaged over defined 5 year periods (100 mSv in 5 years), with the further provision that the effective dose should not exceed 50 mSv in any single year.

(240) For public exposure in planned situations, the Commission continues to recommend that the limit should be expressed as an effective dose of 1 mSv in a year. However, in special circumstances a higher value of effective dose could be allowed in a single year, provided that the average over 5 years does not exceed 1 mSv per year.

(241) The limit on effective dose applies to the sum of external exposures and internal exposures due to intakes of radionuclides. In *Publication 60* (ICRP, 1991), the Commission stated that intakes may be averaged over a period of 5 years to provide some flexibility, and the Commission maintains this view.

(242) Dose limits do not apply in situations where an informed, exposed individual is engaged in volunteered life-saving actions or is attempting to prevent a catastrophic situation. For informed volunteers undertaking urgent rescue operations, the normal dose restriction may be relaxed. However, responders undertaking recovery and restoration operations in emergency exposure situations should be considered occupationally exposed workers and should be protected according to normal occupational radiological protection standards, and their exposures should not exceed the occupational dose limits recommended by the Commission. Since the Commission recommends specific protection measures for female workers who may be pregnant or are nursing an infant (see Section 5.4.1) , and taking account of the unavoidable uncertainties surrounding early response measures in the event of an emergency exposure situations, female workers in those conditions should not be employed as first responders undertaking life-saving or other urgent actions.

(243) The recommended limits are summarised in Table 6. In addition to the limits on effective dose, limits were set in *Publication 60* for the lens of the eye and localised areas of skin because these tissues will not necessarily be protected against tissue reactions by the limit on effective dose. The relevant values were set out in terms of the equivalent dose. These dose limits remain unchanged and are reproduced in the present Table 6. However, new data on the radiosensitivity of the eye with regard to visual impairment are expected. The Commission will consider these data and their possible significance for the equivalent dose limit for the lens of the eye when they become available.

(244) The dose limits for tissues are given in equivalent dose. The reason for this is that the Commission assumes that the relevant RBE values for the deterministic effects are always lower than w_R values for stochastic effects. It is, thus, safely inferred that the dose limits provide at least as much protection against high-LET radiation as against low-LET radiation. The Commission, therefore, believes that it is sufficiently conservative to use w_R with regard to deterministic effects. In special situations where high-LET radiation is the critical factor and where it predominantly exposes a single tissue (such as the skin), it will be more appropriate to express the exposure in terms of the absorbed dose and to take into account the appropriate RBE (see Annex B). To avoid confusion, it is necessary to clearly mention whenever an RBE-weighted absorbed dose in Gy is used.

(245) The Commission's multi-attribute approach to the selection of dose limits necessarily includes societal judgements applied to the many attributes of risk. These judgements would not necessarily be the same in all contexts and, in particular, might be different in different societies. It is for this reason that the Commission intends its guidance to be sufficiently flexible to allow for national or regional variations. In the Commission's view, however, any such variations in the protection of the most highly exposed individuals are best introduced by the use of source-related dose constraints selected by the national authorities and applied in the process of optimisation of protection.

Table 6. Recommended dose limits in planned exposure situations[1]

Type of limit	Occupational	Public
Effective dose	**20 mSv per year**, averaged over defined periods of 5 years[4]	**1 mSv in a year** [5]
Annual equivalent dose in:		
Lens of the eye	150 mSv	15 mSv
Skin [2,3]	500 mSv	50 mSv
Hands and feet	500 mSv	-

[1] Limits on effective dose are for the sum of the relevant effective doses from external exposure in the specified time period and the committed effective dose from intakes of radionuclides in the same period. For adults, the committed effective dose is computed for a 50-year period after intake, whereas for children it is computed for the period up to age 70 years.
[2] The limitation on effective dose provides sufficient protection for the skin against stochastic effects.
[3] Averaged over 1 cm^2 area of skin regardless of the area exposed (see also ICRP 1991a).
[4] With the further provision that the effective dose should not exceed 50 mSv in any single year. Additional restrictions apply to the occupational exposure of pregnant women.
[5] In special circumstances, a higher value of effective dose could be allowed in a single year, provided that the average over 5 years does not exceed 1 mSv per year

6. IMPLEMENTATION OF THE COMMISSION'S RECOMMENDATIONS

(246) The previous chapter describes the Commission's system of protection to be applied in all situations requiring a decision on the control of radiation exposures. This chapter addresses the implementation of the system in the three types of exposure situations: planned exposure situations, emergency exposure situations, and existing exposure situations. Particular attention is focused on areas where implementation of the recommendations may not be immediately straightforward. In a number of these areas, there is further guidance from the Commission as indicated in the text. A section comparing the radiological protection criteria in these recommendations with those in the previous recommendations, *Publication 60* (ICRP, 1991b) and derivative publications, is included. The last section of this chapter addresses common aspects of the implementation of the Commission's recommendations, notably the responsibilities of the users and regulators.

6.1. Planned exposure situations

(247) Planned exposure situations are where radiological protection can be planned in advance, before exposures occur, and where the magnitude and extent of the exposures can be reasonably predicted. The term encompasses sources and situations that have been appropriately managed within the Commission's previous recommendations for practices. In introducing a planned exposure situation all aspects relevant to radiological protection should be considered. These aspects will include, as appropriate, design, construction, operation, decommissioning, waste management and rehabilitation of previously occupied land. Planned exposure situations also cover the medical exposure of patients, including their comforters and carers. The principles of protection for planned situations also apply to planned work in connection with existing and emergency exposure situations. Recommendations for planned situations are substantially unchanged from those provided in *Publication 60* (ICRP, 1991) and subsequent publications for the normal operation of practices and protection in medicine. Because of its specific characteristics, medical exposure is discussed separately in Chapter 7.

(248) All categories of exposure can occur in planned exposure situations, i.e. occupational exposure, public exposure and medical exposure of patients. Planned situations are therefore of interest for the protection of workers (Section 6.1.1), members of the public (Section 6.1.2) and of patients, including their comforters and carers (Chapter 7). The design and development of planned situations should have proper regard for potential exposures that may result from deviations from normal operating conditions. Due attention is paid to the assessment of potential exposures and to the growing issue of the safety and security of radiation sources (Section 6.1.3).

6.1.1. Occupational exposure

(249) The Commission continues to recommend that occupational exposure in planned exposure situations be controlled by the procedures of optimisation below a source-related constraint (see Section 5.7) and the use of prescriptive dose limits (see Section 5.9). A constraint should be defined at the design stage of a planned exposure situation for its operation. For many types of work in planned exposure situations, it is possible to reach conclusions about the level of individual doses likely to be incurred in well-managed operations. This information can then be used

to establish a dose constraint for that type of work. This work should be specified in fairly broad terms, such as work in industrial radiography, the routine operation of nuclear power plants, or work in medical establishments. It will usually be appropriate for such dose constraints to be set at the operational level. When using a dose constraint, a designer should specify the sources to which the constraint is linked so as to avoid confusion with other sources to which the workforce might be concurrently exposed. The source-related dose constraint for occupational exposure in planned situations should be set for each source (or group of sources) to ensure that the dose limit is not exceeded (see Section 5.9). Experience gained in managing workers exposed to radiation will inform the choice of a value for a constraint for occupational exposure. For this reason, large established organisations, having a comprehensive radiological protection infrastructure, will often set their own constraints for occupational exposure. Smaller organisations with less relevant experience may require further guidance on this topic from the appropriate expert bodies or authorities.

(250) Protection of transient or itinerant workers requires particular attention because of the shared responsibility of several employers and sometimes several regulatory authorities. Such workers include contractors for maintenance operations in nuclear power plants and industrial radiographers, who are not on the staff of the operator. In order to provide for their protection, adequate consideration needs to be given to the previous exposures of these workers so as to ensure that dose limits are also respected, and specific follow-up of their exposure must be implemented. Thus there should be an adequate degree of co-operation between the employer of the itinerant worker and the operators of the plants for whom contracts are being undertaken. Regulatory authorities should ensure that regulations are adequate is this respect.

(251) The Commission has previously recommended general principles for the radiological protection of workers (*Publication 75*, ICRP 1997a). These principles remain valid.

6.1.2. Public exposure

(252) In planned exposure situations, the Commission continues to recommend that public exposure be controlled by the procedures of optimisation below the source-related constraint and by the use of dose limits. In general, especially for public exposure, each source will cause a distribution of doses over many individuals, so the concept of a *representative person* should be used to represent the more highly exposed individuals (ICRP, 2006). Constraints for members of the public in planned situations should be smaller than public dose limits, and would typically be set by the national regulatory authorities.

(253) For the control of public exposure from waste disposal, the Commission has previously recommended that a value for the dose constraint for members of the public of no more than about 0.3 mSv in a year would be appropriate (ICRP, 1998a). These recommendations were further elaborated for the planned disposal of long-lived radioactive waste in *Publication 81* (ICRP, 1998c). The Commission has also issued guidance that in circumstances where there are planned discharges of long-lived radionuclides to the environment, planning assessments should consider whether build up in the environment would result in the constraint being exceeded. Where such verification considerations are not possible or are too uncertain, it would

be prudent to apply a dose constraint of the order of 0.1 mSv in a year to the prolonged component of the dose (ICRP; 1999b). These recommendations remain valid.

6.1.3. Potential exposures

(254) In planned exposure situations, a certain level of exposure is reasonably expected to occur. However, higher exposures may arise following deviations from planned operating procedures, accidents including the loss of control of radiation sources and malevolent events. These exposures are referred to by the Commission as *potential exposures*. Deviations from planned operating procedures and accidents can often be foreseen and their probability of occurrence estimated, but they cannot be predicted in detail. Loss of control of radiation sources and malevolent events are less predictable and call for a specific approach.

(255) There is usually an interaction between potential exposures and the exposures arising from planned operations in normal operation; for example, actions taken to reduce the exposure from during normal operations may increase the probability of potential exposures. Thus, the storage of waste rather than its dispersal could reduce the exposures from discharges but would increase potential exposures.

(256) Potential exposures should be considered at the planning stage of the introduction of a planned exposure situation. It should be recognised that the potential for exposures may lead to actions both to reduce the probability of the events occurring, and limit and reduce the exposure (mitigation) if any event were to occur (ICRP, 1991; 1997). Due consideration should be afforded to potential exposures during application of the principles of justification and optimisation.

(257) Potential exposure broadly covers three types of events:

- Events where the potential exposures would primarily affect individuals who are also subject to planned exposures. The number of individuals is usually small, and the detriment involved is the health risk to the directly exposed persons. The processes by which such exposures occur are relatively simple, e.g., the potential unsafe entry into an irradiation room. The Commission has given specific guidance for the protection from potential exposures in *Publication 76* (ICRP; 1997). This guidance remains valid.
- Events where the potential exposures could affect larger number of people and not only involve health risks but also other detriments, such as contaminated land and the need to control food consumption. The mechanisms involved are complicated and an example is the potential for a major accident in a nuclear reactor or the malicious use of radioactive material. The Commission has provided a conceptual framework for the protection from such type of events in *Publication 64* (ICRP; 1993). This framework remains valid. In *Publication 96* (2005a), the Commission provides some additional advice concerning radiological protection after events involving malicious intent.
- Events in which the potential exposures could occur far in the future, and the doses be delivered over long time periods, e.g., in the case of solid waste disposal in deep repositories. Considerable uncertainties surround exposures taking place far in the far future. Thus dose estimates should not be regarded as measures of health detriment beyond times of around several hundreds of

years into the future. Rather, they represent indicators of the protection afforded by the disposal system. The Commission has given specific guidance for the disposal of long-lived solid radioactive waste in *Publication 81* (ICRP, 1998c). This guidance remains valid.

Assessment of potential exposures

(258) The evaluation of potential exposures, for the purpose of planning or judging protection measures, is usually based on: a) the construction of scenarios which are intended typically to represent the sequence of events leading to the exposures; b) the assessment of probabilities of each of these sequences; c) the assessment of the resulting dose; d) the evaluation of detriment associated with that dose; e) comparison of the results with some criterion of acceptability; and f) optimisation of protection which may require several reiterations of the previous steps.

(259) The principles of scenario construction and analysis are well known and are often used in engineering. Their application was discussed in *Publication 76* (ICRP, 1997). Decisions on the acceptability of potential exposures should take account of both the probability of occurrence of the exposure and its magnitude. In some circumstances, decisions can be made by separate consideration of these two factors. In other circumstances, it is useful to consider the individual probability of radiation-related death, rather than the effective dose (ICRP, 1997). For this purpose, the probability is defined as the product of the probability of incurring the dose in a year and the lifetime probability of radiation-related death from the dose conditional on the dose being incurred. The resulting probability can then be compared with a risk constraint. Both of these approaches are discussed in the Commission's recommendations for the disposal of long-lived solid radioactive waste in *Publication 81* (ICRP, 1998c).

(260) Risk constraints, like dose constraints, are source-related and in principle should equate to a similar health risk to that implied by the corresponding dose constraints for the same source. However, there can be large uncertainties in estimations of the probability of an unsafe situation and the resulting dose. Thus, it will often be sufficient, at least for regulatory purposes, to use a generic value for a risk constraint based on generalisations about normal occupational exposures, rather than a more specific study of the particular operation. Where the Commission's system of dose limitation has been applied and protection is optimised, annual occupational effective doses to an average individual may be as high as about 5 mSv in certain selected types of operation (UNSCEAR, 2000). For potential exposures of workers, the Commission therefore continues to recommend a generic risk constraint of $2\ 10^{-4}$ per year which is similar to the probability of fatal cancer associated with an average occupational annual dose of 5 mSv (ICRP, 1997). For potential exposures of the public, the Commission continues to recommend a risk constraint of $1\ 10^{-5}$ per year, corresponding to the probability of fatal cancer associated with the generic dose constraint of 0.3 mSv applied e.g. in the case of disposal of long-lived radioactive waste (ICRP, 1998c).

(261) The use of probability assessment is limited by the extent that unlikely events can be forecast. In circumstances where accidents can occur as a result of a wide spectrum of initiating events, caution should be exercised over any estimate of overall probabilities because of the serious uncertainty of predicting the existence of all the unlikely initiating events. In many circumstances, more information can be

obtained for decision making purposes by considering the probability of occurrence and the resultant doses, separately.

Safety and security of radiation sources and malevolent events

(262) Potential exposures associated with planned exposure situations may result from the loss of control of radiation sources. This situation has received a growing attention over recent years and deserves a special consideration from the Commission. The recommendations of the Commission presume that, as a precondition for adequate radiological protection, radiation sources are subject to proper security measures (ICRP, 1991b). The control of radiation exposure in all planned situations is exercised by the application of controls at the source rather than in the environment. The Commission's view is reflected in the International Basic Safety Standards (BSS), which require that the control of sources shall not be relinquished under any circumstances (IAEA, 1996a). The BSS also requires that sources be kept secure so as to prevent theft or damage. In addition, the Code of Conduct on the Safety and Security of Radioactive Sources establishes basic principles applicable to the security of radioactive sources (IAEA, 2004). The Commission supports the initiative of IAEA in this area.

(263) Security of radioactive sources is a necessary, but not sufficient, condition to ensure source safety. Radioactive sources can be secure, i.e. under proper control, and still not safe. Thus the Commission has historically included aspects of security in its system of protection (ICRP, 1991b). In the context of safety, security provisions are generally limited to general controls necessary to prevent loss, access, unauthorised possession or transfer and use of the material, devices or installations. Essential to safety are measures to ensure that control of radioactive material and access to radiation devices and installations are not relinquished.

(264) When the Commission's 1990 recommendations were developed measures specifically to protect against terrorism or other malicious acts were not afforded prominence. However, it has become evident that radiation safety must also include the potential for such scenarios. Past experience with unintentional breaches in source security or because a discarded, or orphan, source was found indicates what might occur if radioactive materials are used intentionally to cause harm, e.g., by deliberate dispersion of radioactive material in a public area. Such events have the potential of exposing people to radiation and causing significant environmental contamination, which would require specific radiological protection measures (ICRP, 2005a).

6.2. Emergency exposure situations

(265) Even if all reasonable steps have been taken during the design stage to reduce the probability and consequences of potential exposures, such exposures may become actual and need to be considered in relation to emergency preparedness and response. Emergency exposure situations are unexpected situations that may require urgent protective actions to be implemented. Exposure of members of the public or of workers, as well as environmental contamination can occur in these situations. Exposures can be complex in the sense that they may result from several independent pathways, perhaps acting simultaneously. Response actions can be planned because potential emergency situations can be assessed in advance, to a greater or lesser accuracy depending upon the type of facility or situation being considered. However, because actual emergency situations are inherently

unpredictable, the exact nature of necessary protection measures cannot be known in advance but must flexibly evolve to meet actual circumstances. The complexity and variability of these situations give them a unique character that merits their specific treatment by the Commission in its recommendations.

(266) The Commission has set out general principles for planning intervention in the case of a radiation emergency in *Publications 60* and *63* (1991b; 1993b). Additional relevant advice is given in *Publications 86, 96, 97,* and *98* (ICRP 2000d; 2005a, 2005b, 2005c). While the general principles and additional advice remain valid, the Commission is now extending its guidance on the application of protective measures on the basis of recent developments in emergency preparedness and of experience since publication of its previous advice.

(267) Now, the Commission emphasises the importance of justifying and optimising protection strategies for application in emergency exposure situations, the optimisation process being restricted by reference levels (see Section 5.9). The possibility of multiple, independent, simultaneous, and time-varying exposure pathways makes it important to focus on the overall exposures that may occur from all pathways when developing and implementing protective measures. As such, an overall protection strategy is necessary, generally including the implementation of different protective measures. These measures may well vary with time, as the emergency situation evolves, and with place, as the emergency situation may affect distinct geographic areas differently. The overall exposure, which is projected to occur as a result of the emergency exposure situation, should no protective actions be employed, is called the *projected dose*. The dose that would result should a protection strategy be implemented is called the *residual dose*. In addition, each protective measure will avert a certain amount of exposure. This is referred to as *averted dose*, and is a useful concept for the optimisation of the individual protective measures that will make up the overall protection strategy.

(268) In emergency exposure situations particular attention should be given to the prevention of severe deterministic health effects as doses could reach high levels in short period of time. Moreover, in case of major events an assessment based on health effects would be insufficient and due considerations must be given to social, economic and other consequences. Another important objective is to prepare, to the extent practicable, for the resumption of social and economic activity considered as 'normal'.

(269) In emergency situations, reference levels should be applied in the process of optimisation. Reference levels for emergency situations are typically in the 20 mSv to 100 mSv band of projected dose as presented in Section 5.8.2. Projected and residual doses are compared with reference levels in initially assessing the need for invoking any pre-planned protection strategies, and in assessing the need for additional specific measures, that might be necessary to address actual circumstances.

(270) A protection strategy that does not reduce residual doses to below the reference level should be rejected at the planning stage. Once an emergency situation has occurred the reference level acts as a benchmark for assessing the effectiveness of protection strategies. Although particular attention should be given to exposures above the reference level, all exposures above or below the reference level, are subject to optimisation. Optimisation of protection in emergency exposure

situations should consider benefits and detriments beyond those associated with doses, for example the social detriment of permanent relocation, or the social benefit of reassurance measures. The use of reference levels in emergency exposure situations is illustrated in Figure 3.

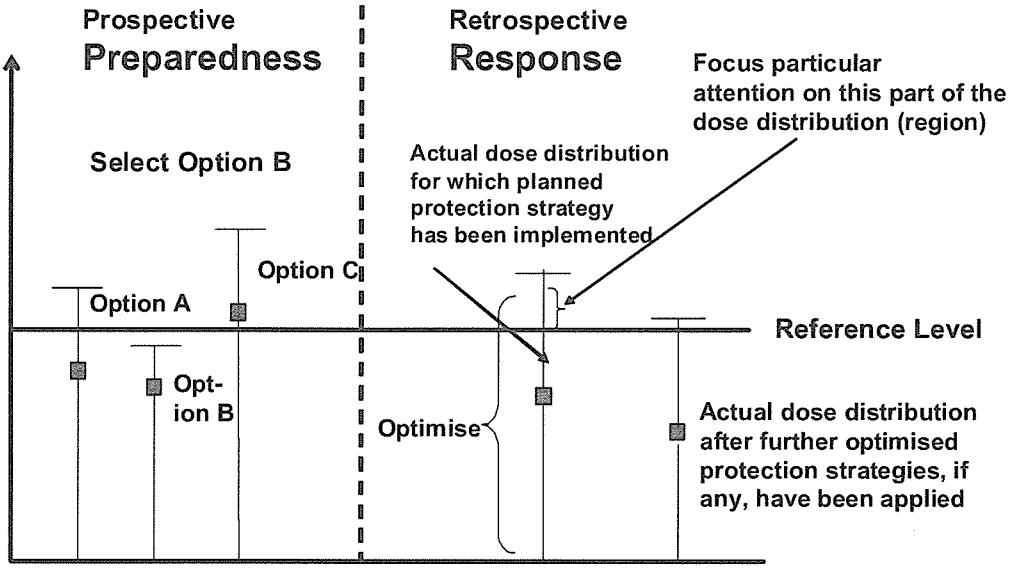

Figure 3. The application of reference levels in emergency preparedness and emergency response situations.

(271) Emergency plans should be developed (in more or less detail, as appropriate) for all possible scenarios. The development of an emergency plan (national, local or facility specific) is a multi-step iterative process that includes assessment, planning, resource allocation, training, exercises, audit, and revision. The radiation emergency response plans should be integrated into all-hazards emergency management programmes.

(272) When preparing a protection strategy for a particular emergency exposure situation, a number of different populations, each needing specific protective measures, may be identified. For example, the distance from the origin of an emergency situation (e.g., a facility, an emergency site) may be important in terms of identifying the magnitude of exposures to be considered, and thus the types and urgency of protective measures. With this diversity of exposed populations in mind, the planning of protective measures should be based on exposures to the representative persons, as described in *Publication 101* (ICRP, 2006), from the various populations that have been identified. After an emergency situation has occurred, planned protection measures should evolve to best address the actual conditions of all exposed populations being considered.

(273) In the event that an emergency exposure situation occurs, the first issue is to recognise its onset. The initial response should be to follow the emergency plan in a consistent but flexible way. The protection strategy initially implemented will be that described in the emergency plan for the relevant event scenario. Once the measures in the emergency plan have been initiated, emergency response can be characterised by an iterative cycle of review, planning, and execution. Three phases of an emergency exposure situation are considered: the early phase (which may be

divided into a warning and release phase), the intermediate phase (which starts with the cessation of the release when decisions are taken on the lifting of early phase countermeasures and initial longer term protective actions are implemented), and the late phase (the long term rehabilitation phase).

(274) Emergency response is inevitably a process that develops in time from a situation of little information to one of potentially overwhelming information, with the expectations for protection and involvement by those affected similarly increasing rapidly with time. At any stage, decision makers will necessarily have incomplete understanding of the situation regarding the future impact, the effectiveness of protective measures, the concerns of those directly and indirectly affected, amongst other factors. An effective response must therefore be developed flexibly with regular review of its impact. The reference level provides an important input to this review, providing a benchmark against which what is known about the situation and the protection afforded by implemented measures can be compared.

(275) Dialogue with stakeholders is an essential component of emergency preparedness and response. The stakeholders involved and the nature of their involvement will vary with circumstances and with time. However, with the possible exception of the urgent implementation of protective measures, stakeholder input and involvement will be necessary in the case of an emergency exposure situation, and for all exposed populations.

(276) The Commission is currently developing more detailed guidance on the protection of individuals during nuclear or radiological emergencies.

6.3. Existing exposure situations

(277) Existing exposure situations are those that already exist when a decision on control has to be taken. There are many types of existing exposure situations that may cause exposures high enough to warrant radiological protective actions, or at least their consideration. Among those of natural origin, radon in dwellings or the workplace, and naturally occurring radioactive material (NORM) are well-known examples. It may be also necessary to take radiological protection decisions concerning existing man-made exposure situations such as residues in the environment resulting from radiological emissions from operations that were not conducted within the Commission's system of protection, or contaminated territories resulting from an accident or a radiological event. There are also existing exposure situations for which it will be obvious that action to reduce exposures is not warranted. An example is exposure to cosmic rays at ground level, which is impractical to control. The decision as to what components of existing exposure are not amenable to control requires a judgment by the regulatory authority that will depend on the controllability of the source or exposure and also on the prevailing economic, societal and cultural circumstances. Principles for exclusion and exemption of radiation sources are presented and discussed in Section 2.3.

(278) Existing exposure situations can be complex in that they may involve several exposure pathways and they generally give rise to wide distributions of annual individual doses ranging from the very low to, possibly, several tens of millisieverts. Such situations often involve dwellings, for example in the case of

radon, and in many cases the behaviour of the exposed individuals determines the level of exposure. For example the distribution of individual exposures in a long-term contaminated territory directly reflects the diversity of the individual dietary habits of the affected inhabitants. The multiplicity of exposure pathways and the importance of individual behaviour may result in exposure situations that are difficult to control.

(279) The Commission's principles of justification and optimisation apply to all existing exposure situations. Furthermore, for equity considerations, every effort should be made to try to keep individual exposures below relevant reference levels expressed in term of individual dose. Because de facto exposures cannot be managed in an a priori fashion, the individual limit for planned exposure situations do not apply to existing exposure situations.

(280) A key parameter for the control of existing situation is time. The process will generally be iterative with the objective of reducing the doses to the individuals in a progressive manner. Such processes may take years or even decades according the situation. Authorities may decide to develop implementation plans including the characterisation of the exposure situation, the definition of priorities for reducing exposures and of protection strategies, as well as the requirements for information, monitoring, assessment, education and training and provision for regular progress reviews to assess the effectiveness of the implemented strategies.

(281) Application of the justification principle to existing situations requires a thorough evaluation of the exposure situation and of the means for potential control, keeping in mind that any action to reduce existing exposure will always have some disadvantages. Key considerations to justify reducing existing exposures are the level of exposure, the number of affected individuals, whether residences or daily life are affected, and the level of controllability of the exposure taking into account potential disruption of the living conditions by the available protection actions. The responsibility for judging the justification for reducing doses associated with an existing exposure situation usually falls on governments or national authorities.

(282) In applying the optimisation principle, the possibility of multiple, independent, simultaneous, and time-varying exposure pathways makes it important to focus on the overall exposures that may occur from all pathways when developing and implementing protection actions. Generally it is necessary to develop a protection strategy which includes the implementation of different protection actions.

(283) The Commission recommends that reference levels, set in terms of individual dose, should be used in conjunction with the implementation of the optimisation process in all existing exposure situations. The objective is to implement optimised protection strategies, or a progressive range of such strategies, which will reduce individual doses to below the reference level. However, exposures below the reference level should not be ignored; the process of optimisation of protection should be applied to establish whether a reduction in these doses should be undertaken. An endpoint for the optimisation process must not be fixed a priori and the optimised level of protection will depend on the situation. It is the responsibility of national authorities to decide on the legal status of the reference level, which is implemented to control a given situation. Retrospectively, when protection actions have been implemented, reference levels may also be used as benchmarks for assessing the effectiveness of the protection strategies. The use of

reference levels in existing situation is illustrated in Figure 4, which shows the evolution of the distribution of individual doses with time as a result of the optimisation process.

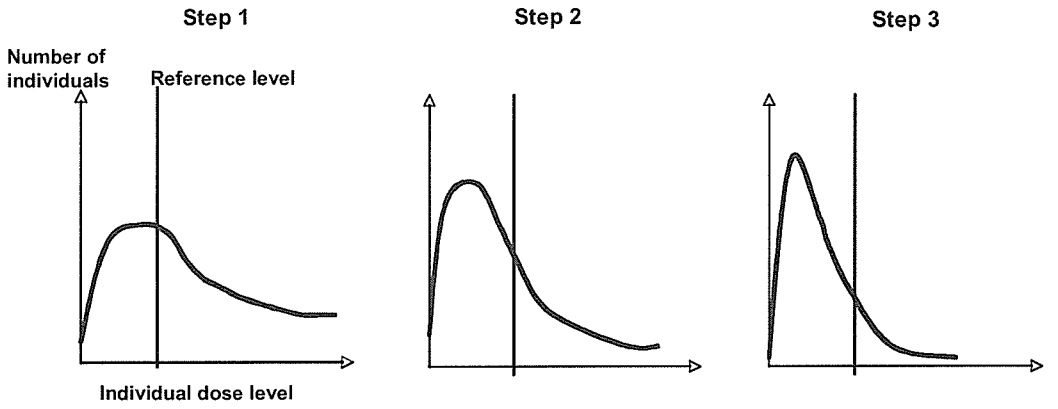

Fig. 4.. The use of a reference levels in existing situation and the evolution of the distribution of individual doses with time as a result of the optimisation process.

(284) Reference levels for existing situations should be set typically in the 1 to 20 mSv band of projected dose as presented in Section 5.8.2. They correspond to situations where individuals and/or the society will receive a benefit from the situation that outweighs the radiological detriment. It will often be important to make available to the concerned individuals general information on the exposure situation and the means to reduce doses. In situations where individual behaviours are key drivers of the exposures, individual monitoring or assessment as well as education and training may be important requirements. Living in contaminated territories after a nuclear accident or a radiological event is a typical situation of that sort.

(285) The main factors to be considered for setting the reference levels for existing situations are the feasibility of controlling the situation, and the past experience with the management of similar situations. In most existing situations, there is a desire from the exposed individual as well as from the authorities to reduce exposures to levels that are close or similar to situations considered as 'normal'. The Commission therefore recommends that, whenever practicable, values for the reference levels should be set at the lower end of the 1 to 20 mSv band. This is particularly relevant in situations of exposures from material resulting from human activities, e.g. NORM residues and contamination from accidents. In such cases, reference levels may ideally be set at values similar to those used in planned exposure situations. The Commission recognises, however, that there will be circumstances in which the setting of reference levels at such values would not be feasible and there will be other circumstances where resumption to a situation considered as 'normal' can be achieved only following a program of progressive protective actions lasting years. It is generally the role and responsibility of the national authorities to establish the reference levels in consultation with the relevant stakeholders.

(286) Stakeholder involvement is an essential component of developing and implementing protection strategies for existing exposure situations. Past experience with the control of this type of exposure has demonstrated that stakeholder involvement enhances the quality of the decisions relating to protection. The role of stakeholders in the development of the justification and the optimisation processes

and the nature of their involvement in the actual control of exposures will largely depend on the circumstances. More detailed recommendations on stakeholder involvement in the optimisation of radiological protection are given in *Publication 101* (ICRP, 2006).

(287) The Commission is currently developing more detailed recommendations on the protection of individuals living in contaminated territories after a nuclear accident or a radiological event.

6.3.1. Indoor radon in dwellings and workplaces

(288) Exposure to radon in dwellings and workplaces is an existing exposure situation of general concern and one where the Commission has previously made specific recommendations (ICRP, 1994a). Since then, several epidemiological studies have confirmed the risk of radon-222 exposure even at relatively moderate concentrations (UNSCEAR, 2006). European and North American and Chinese residential case-control studies also demonstrate a significant association between the risk of lung cancer and exposure to residential radon-222 (Darby et al 2005, 2006; Krewski et al. 2005, 2006; Lubin et al. 2004). These studies have generally provided support for the Commission's recommendations on protection against radon.

(289) There is now a remarkable coherence between the risk estimates developed from epidemiological studies of miners and residential case-control radon studies. While the miner studies provide a strong basis for evaluating risks from radon exposure and for investigating the effects of modifiers to the dose response relation, the results of the recent pooled residential studies now provide a direct method of estimating risks to people at home without the need for (downward) extrapolation from miner studies (UNSCEAR, 2006). Notwithstanding the wide range of results from residential case-control studies and the important effects of confounding by smoking and other factors, overall the pooled European and North America case-control studies clearly demonstrate an association between risk of lung cancer and residential radon-222 exposure.

(290) The Commission's view on radon risk assessment has, up till now, been that it should be based on epidemiological studies of miners. Given the wealth of data now available on domestic exposure to radon, the Commission recommends that the estimation of risk from domestic radon exposure should be based on the results of pooled residential case control radon-222 studies. However, there is still great value in the miner epidemiology studies for investigating dose response relationships and confounding effects of smoking and exposure to other agents. The currently available epidemiological evidence indicates that risks other than lung cancer from exposure to radon-222 (and decay products) are likely to be small.

(291) The underlying theme of the Commission's recommendations on radon is the controllability of exposure. The ability to control exposure distinguishes the circumstances under which exposure to radon in workplaces, including underground mines, may need to be subject to the Commission's system of protection and where the need for action to limit radon exposure in dwellings should be considered. There are several reasons to treat radon-222 in this separate manner. The exposure route differs from that of other natural sources, and there are dosimetric and epidemiological issues peculiar to radon-222. For many individuals radon-222 is an important source of exposure which, in principle, can be controlled. The

Commission issued the current recommendations for protection against radon-222 at home and at work in *Publication 65* (ICRP, 1994a). The policy has found wide acceptance and the present recommendations broadly continue the same policy, with an adaptation to the new approach based on exposure situations with the central role given to the optimisation principle and the use of reference levels.

(292) In *Publication 65* (ICRP, 1994a), the policy was based upon first setting a level equivalent to an effective dose of 10 mSv per year from radon-222 where action would certainly be warranted to reduce the exposure. National authorities were expected to apply the optimisation of protection in a generic way to find a lower level at which to act, in the range from 3 to 10 mSv. The effective dose was converted into a value of radon-222 concentration, which was different between homes and workplaces largely because of the relative number of hours spent at each. For dwellings this range was a radon concentration of between 200 - 600 Bq m^{-3}, while the corresponding range for workplaces was 500 - 1500 Bq m^{-3}. The result of the optimisation was to set action levels above which action was required to reduce the dose.

(293) Now, the Commission recommends applying the source-related principles of radiological protection for controlling radon exposure. This means that national authorities need to set national reference levels to aid the optimisation of protection. Even though the nominal risk per Sv has changed slightly, the Commission, for the sake of continuity and practicality, retains the upper value of 10 mSv for the individual dose reference level and the corresponding activity concentrations as given in *Publication 65*. This means that the upper values for the reference level expressed in activity concentrations remain at 1500 Bq m^{-3} for workplaces and 600 Bq m^{-3} for homes (Table 7).

Table 7. Reference levels for radon-222[†]

Situation	Reference level
Domestic dwellings	600 Bq m^{-3}
Workplaces	1500 Bq m^{-3}

[†]Head or initial radionuclide of the decay chain activity level.

(294) It is the responsibility of the appropriate national authorities, as with other sources, to establish their own national reference levels, taking into account the prevailing economic and societal circumstances and then to apply the process of optimisation of protection in their country. All reasonable efforts should be made to reduce radon-222 exposures in homes and at working places below the reference levels that are set at the national level and to a level where protection can be considered optimised. The actions taken should be intended to produce substantial reduction in radon exposures. It is not sufficient to adopt marginal improvements aimed only at reducing the radon concentrations to a value just below the national reference level.

(295) The implementation of the optimisation process will result in concentration activities at home and at work below, and often well below, the national reference

levels. In general no further action will be required, apart from perhaps monitoring activity concentration sporadically to ensure that levels remain low. National authorities should, however, periodically review the values of the national reference levels for radon exposure to ensure that they remain appropriate.

(296) Responsibility for taking action against radon in houses and other premises will often fall on the individual owners, who cannot be expected to carry out a detailed optimisation exercise for each property. Therefore, in addition to reference levels, national authorities may also wish to specify levels at which protection against radon-222 can be considered optimised, i.e., where no further action is needed.

(297) In the interest of international harmonisation of occupational safety standards, a single action level value of 1000 Bq m^{-3} was established in the BSS (IAEA, 1996). For the same reasons, the Commission considers that this internationally established value might be used globally to define the entry point for occupational protection requirements for exposure situations to radon. In fact, this international level serves *inter alia* for a much needed globally harmonised monitoring and record-keeping system. This is relevant for determining when the occupational radiological protection requirements apply - i.e., what is actually included within the system of regulatory control.

(298) It is now recognised that in some occupational exposure situations, particularly mines, radon-222 exposure can be merged with other exposures to ionising radiation, making it difficult to apply a criterion specified in terms of radon concentration. In such exposure situations, the Commission recommends that the reference level for radon-222 exposure in the workplace should be set in terms of dose at a value that ensures compliance with the Commission's occupational dose limits. In general, for occupational radon exposure, a level should be set at which the system of protection is applied and the resulting doses should be recorded in the worker's dose record.

(299) The Commission reaffirms that radon exposures at work at levels below the reference level selected by national authorities should not be regarded as part of occupational exposure whereas exposures from radon levels above the reference level should be considered as part of occupational exposure (ICRP, 1997a).

6.4. Protection of the embryo/fetus in emergency and existing exposure situation

(300) For planned exposure situations, the Commission continues to recommend that the embryo/fetus should be afforded a level of protection similar to that of any member of the public (cf. Section 5.4.1). For existing and emergency exposure situations, where doses are not planned in advance, protection measures aimed at reducing extant doses may or may not be required. Since natural background radiation causes annual effective doses of at least around 1 mSv, existing or emergency exposure situations will inevitable lead to total doses exceeding this value, and it is not feasible to limit the annual dose to the embryo/fetus to 1 mSv. The issue here is to what extent special provisions will be required for pregnant women in these situations.

(301) In *Publication 82* (ICRP, 1999b), the Commission concluded provisionally that prenatal exposure would not be a specific protection case in prolonged exposure

situations with prolonged annual effective doses well below about 100 mSv. This was because organ malformations would not be expected at such dose levels, a practical threshold for mental retardation could be assumed (in particular taking account of the short period of sensitivity during gestation), and the lifetime risk of stochastic effects induced during pregnancy would be small compared with the risk induced by the prolonged exposure after birth. In *Publication 84* (ICRP, 2000c), the Commission provided practical recommendations concerning in-utero exposures and re-iterated its position that there is no need to make any general distinction between the two sexes in the control of occupational exposures, but when a female worker is known to be pregnant, additional measures should be considered in order to protect the embryo/fetus. Dose coefficients for the embryo/fetus due to intakes of radionuclides by the mother were provided in *Publication 88* (ICRP, 2001a). The Commission's interim conclusion in *Publication 90* (ICRP, 2003a) was that newly available information on in-utero risk at low doses (up to a few tens of mSv) supported the advice developed in *Publications 60*, *82*, *84*, and *88*.

(302) The Commission continues to judge that protection of the embryo/fetus should not be a specific protection case in prolonged existing and emergency exposure situations involving annual effective doses well below 100 mSv. Optimisation of protection for the general population should be sufficient to afford an adequate level of protection to the embryo/fetus of pregnant women in the population. However, as indicated in Section 5.10, the Commission recommends that female workers who are or may be pregnant or are nursing an infant should not be employed as first responders undertaking life-saving or other urgent actions in emergency exposure situations.

6.5. Comparison of radiological protection criteria

(303) The current recommended values for protection criteria are compared in Table 8 with those provided by the previous recommendations in *Publication 60* (ICRP, 199b) and the derivative publications. The comparison shows that the current recommendations are essentially the same as the previous recommendations for planned exposure situations. In the case of existing and emergency situations, the current recommendations generally encompass the previous values but are wider in their scope of application.

Table 8. Comparison of protection criteria between the 1990 and the 2007 Recommendations

Categories of exposure (Publications)	1990 recommendations and subsequent publications	2007 recommendations
Planned exposure situations		
	Individual dose limits [a]	
Public exposure (60)	1 mSv/year	1 mSv/year
Occupational exposure (60,68,75) including recovery operations (96)	20 mSv/year average over defined periods of 5 years	20 mSv/year average over defined periods of 5 years
- lens of the eyes	150 mSv/year [b]	150 mSv/year [b]
- skin	500 mSv/year [b]	500 mSv/year [b]
- hands and feet	500 mSv/year [b]	500 mSv/year [b]
- intake of radionuclides	20 mSv/year [c]	20 mSv/year [c]
- pregnant women, remainder of pregnancy	2 mSv to the surface of abdomen, 1 mSv to the fetus	1 mSv to the fetus
	Dose constraints [a]	
Public exposure (60)		
- radioactive waste disposal (77)	≤0.3 mSv/year	≤0.3 mSv/year
- long-lived radioactive waste disposal (81)	0.3 mSv/year	0.3 mSv/year
- prolonged exposure (82)	0.3 mSv/year and <1 mSv/year	0,3 mSv/year and 1 mSv/year
- prolonged component from long-lived nuclides (82)	0.1 mSv/year	0.1 mSv/year
- individual volunteers for biomedical research (62)		
If benefit of society is:		
- minor	< 0.1 mSv	< 0.1 mSv
- intermediate	~ 1mSv	~ 1mSv
- moderate	1-10 mSv	1-10 mSv
- substantial	> 10 mSv	> 10 mSv
Occupational exposure (60)	Below 20 mSv/year	Below 20 mSv/year
Emergency exposure situations		
	Intervention levels [d]	**Reference levels** [a]
Radiological emergency (63)		
- foodstuffs	10 mSv/year	
- sheltering	5-50 mSv	To be selected between
- evacuation	50-500 mSv/day	20 to 100 mSv/year according
- distribution of stable iodine	50-500 mSv (thyroid) [b]	to the situation
- relocation	1000 mSv	(See Sections 5.9 and 6.2)

Radiological attack (96) ***Occupational exposure:*** - rescue operations ***Public exposure:*** - sheltering - temporary evacuation - distribution of stable iodine - relocation	No dose restrictions ~ 10 mSv in 2 days ~ 50 mSv in 1 week ~ 100 mSv (thyroid) [b] ~ 1000 mSv [d] or ~ 100 mSv the first year	To be selected between 20 to 100 mSv /year according the situation (See Sections 5.9 and 6.2)
Existing exposure situations		
	Actions levels [a]	**Reference levels [a]**
Radon (65) - at home - at work	3–10 mSv/year (200–600 Bq m^{-3} in homes) 3-10 mSv/year (500 –1500 Bq m^{-3} for workers)	10 mSv/year (600 Bq m^{-3} in homes) 10 mSv/year (1500 Bq m^{-3} for workers)
	Generic reference levels [e]	**Reference levels [a]**
NORM, natural background radiation, radioactive residues in human habitat (82) Interventions for prolonged exposure: - unlikely to be justifiable - may be justifiable - almost always justifiable	 < ~ 10 mSv/year > ~ 10 mSv/year towards 100 mSv/year	To be selected between 1 and 20 mSv/year according the situation (See Sections 5.9 and 6.3)

[a] Effective dose unless otherwise specified
[b] Equivalent dose
[c] Committed effective dose
[d] Averted dose

6.6. General considerations

(304) This section addresses the general implementation of the Commission's recommendations, dealing with factors which are common to the three types of exposure situations. It focuses on organisational features that may help in the implementation of the Commission's recommendations. Since the organisational structures will differ from country to country, the chapter is illustrative rather than exhaustive. The International Atomic Energy Agency and the Nuclear Energy Agency of OECD issue further advice on the infrastructure required for radiological protection in various circumstances to their member states (see, e.g., IAEA, 1996a; 2000, 2002 and NEA, 2005). Generic advice on organisation for health and safety at work is provided by the International Labour Organization, the World Health Organization and the Pan-American Health Organization.

6.6.1. The infrastructure for radiological protection and safety

(305) An infrastructure is required to ensure that an appropriate standard of protection is maintained. This infrastructure includes at least a legal framework, a regulatory authority, the operating management of any undertaking involving

ionising radiation (including the design, operation, and decommissioning of equipment and installations as well as adventitious enhancement of natural radiation including aviation and space flight), and the employees at such undertakings. It may include additional bodies and persons responsible for protection and safety.

(306) The legal framework must provide for the regulation as required of undertakings involving ionising radiation and for the clear assignment of responsibilities for protection and safety. A regulatory authority must be responsible for the regulatory control, whenever required, of undertakings involving radiation and for the enforcement of the regulations. This regulatory authority must be clearly separate from organisations that conduct or promote activities causing radiation exposure.

(307) The nature of radiological hazards necessitates a number of special features in the legal framework and the provision of expertise within the regulatory authority. The important issues are that radiological questions are addressed properly, that the appropriate expertise is available, and that decisions concerning radiation cannot be unduly influenced by non-radiological considerations.

(308) The operating management of an undertaking involving radiation has, in most cases, the primary practical responsibility for radiological protection. However, in some cases, there may not be a relevant operating management available. For instance, the radiation may not have been caused by any human undertaking, or an undertaking may have been abandoned and the proprietors could have disappeared. In such cases, the national regulatory authority, or some other designated body, will have to accept some of the responsibilities usually carried by the operating management.

(309) The primary responsibility for achieving and maintaining a satisfactory control of radiation exposures rests on the management bodies of the institutions conducting the operations giving rise to the exposures. When equipment or plant is designed and supplied by other institutions, they, in turn, have a responsibility to see that the items supplied will be satisfactory, if used as intended. Governments have the responsibility to set up national authorities, which then have the responsibility for providing a regulatory, and often also an advisory, framework to emphasise the responsibilities of the management bodies while, at the same time, setting and enforcing overall standards of protection. They may also have to take direct responsibility when, as with exposures to many natural sources, there is no relevant management body.

(310) In all organisations, the responsibilities and the associated authority are delegated to an extent depending on the complexity of the duties involved. The working of this delegation should be examined regularly. There should be a clear line of accountability running right to the top of each organisation. The delegation of responsibilities does not detract from that accountability. There is also an interaction between the various kinds of organisation. Advisory and national authorities should be held accountable for the advice they give and any requirements they impose.

(311) Requirements, operating instructions, regulatory approvals and licences, and other administrative devices are not, of themselves, enough to achieve an appropriate standard of radiological protection. Everyone in an undertaking, from the individual workers and their representatives to the senior management, should regard protection and emergency prevention as integral parts of their every-day

functions. Success and failure in these areas are at least as important as they are in the primary function of the undertaking.

(312) The imposition of requirements expressed in general terms and the acceptance of advice do not reduce the responsibility, or the accountability, of the operating organisations. This is also true in principle of prescriptive requirements, where the regulatory authority prescribes in detail how protection standards are to be maintained. However, prescriptive requirements concerning the conduct of operations result in some de facto transfer of responsibility and accountability from the user to the regulator. In the long run, they also reduce the user's incentive for self-improvement. Therefore, it is usually better to adopt a regulatory regime that places a more explicit responsibility on the user, and forces the user to convince the regulator that adequate protection methods and standards are used and maintained.

(313) Therefore, the use of prescriptive requirements should always be carefully justified. In any event, they should never be regarded as an alternative to the process of optimising protection. It is not satisfactory to set design or operational limits or targets as an arbitrary fraction of the dose limit, regardless of the particular nature of the plant and the operations.

6.6.2. External expertise and advice; delegation of authority

(314) The prime responsibility for radiological protection and radiation safety in an undertaking involving ionising radiation rests with the operating organisation. In order to assume this responsibility, the organisation needs expertise in radiological protection. It is not always necessary or reasonable to demand that this expertise is available within the operating organisation. As an alternative, it may be acceptable and recommendable for the operating organisation to use consultants and advisory organisations, particularly if the operating organisation is small and the complexity of the radiological protection issues is limited.

(315) Such an arrangement will not in any way relieve the operating organisation of its responsibility. The role of a consultant or an advisory organisation will be to provide information and advice as necessary. It still remains the responsibility of the operating management to take decisions and actions on the basis of such advice, and individual employees still need to adhere to a 'safety culture', constantly asking themselves whether they have done all that they reasonably can to achieve a safe operation.

(316) Similarly, the use of consultants or advisory bodies will not in any way diminish or change the responsibility of the regulatory authority. Furthermore, it will be particularly important when the regulator uses consultants that these are free from any conflicts of interest and are able to provide impartial advice. The need for transparency in decision-making should also be kept in mind.

6.6.3. Mutual trust and emergency reporting

(317) The interaction between a regulatory authority and an operating organisation should be frank and open whilst still maintaining a degree of formality. Mutual understanding and respect are crucial in order to achieve satisfactory radiological protection.