Is guidance in ICRP publications consistent on the application of reference levels?

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Abstract. In ICRP 103, which has replaced ICRP 60, it is stated that no fundamental changes have been introduced compared to ICRP 60. This is true except that the application of reference levels in emergency and existing exposure situations seems to be applied inconsistently, and also in the related publications ICRP 109 and ICRP 111.

ICRP 103 emphasizes that focus should be on the residual doses after the implementation of protection strategies in emergency and existing exposure situations. If possible, the result of an optimised protection strategy should bring the residual dose below the reference level. Thus the reference level represents the maximum acceptable residual dose after an optimised protection strategy has been implemented. It is not an 'off-the-shelf item' that can be set free of the prevailing situation. It should be determined as part of the process of optimising the protection strategy. If not, protection would be sub-optimised. However, in ICRP 103 some inconsistent concepts have crept into the text, e.g. in paragraph 279 which states: *'All exposures above or below the reference level should be subject to optimisation of protection, and particular attention should be given to exposures above the reference level'.*

If, in fact, all exposures above and below reference levels are subject to the process of optimisation, reference levels appear superfluous. It could be considered that if optimisation of protection below a fixed reference level is necessary, then the reference level has been set too high at the outset.

Up until the last phase of the preparation of ICRP 103 the concept of a dose constraint was recommended to constrain the optimisation of protection in all types of exposure situations. In the final phase, the term 'dose constraint' was changed to 'reference level' for emergency and existing exposure situations. However, it seems as if in ICRP 103 it was not fully recognised that dose constraints and reference levels indeed are conceptually different.

The use of reference levels as they have been applied in radiological protection is reviewed. It is concluded that the recommendations in ICRP 103 and related ICRP publications seem to be inconsistent regarding the use of reference levels in existing and emergency exposure situations.

KEYWORDS: ICRP, reference levels, emergency exposure, existing exposure, optimisation

INTRODUCTION

The latest general recommendations from ICRP were published in 2007 as Publication 103 (ICRP103, 2007), which replaced ICRP Publication 60 (ICRP60, 1991) published in 1991. In ICRP 60, the system of protection was applied separately to *practices* and *interventions*. The difference between ICRP 60 and ICRP 103 with regard to exposure situations is that intervention situations have been subdivided into *existing* and *emergency* exposure situations; and practices have been re-titled *planned* exposure situations. Intervention levels in terms of avertable individual doses have been replaced in ICRP 103 by reference levels of individual doses.

The principles of radiation protection in ICRP 103 remain as previously, namely justification and optimisation, which apply universally to all three exposure situations; and dose limits, which apply only to planned exposure situations, except those involving medical exposure. The ICRP 103 recommendations are more a matter of consolidation of previous ICRP recommendations and subsequent guidance. However, there seems to be some inconsistency in ICRP 103 as far as the application of reference levels is concerned. Unfortunately, this has resulted in ambiguity in other ICRP publications (ICRP109, 2009 and ICRP111, 2009).

Up until the late phase of the preparation of ICRP 103 the concept of dose constraints was recommended for constraining the optimisation of protection in all three exposure situations. In the final phase, *dose constraint* was changed to *reference level* for emergency and existing exposure situations. However, it seems as if it was not recognized that a dose constraint and a reference level are conceptually different. Dose constraints restrict individual doses at the planning stage so doses to a representative individual will *not exceed* the constraint.

Reference levels for emergency and existing exposure situations will, however, depend upon the prevailing circumstances. The goal is that residual individual doses *after* the implementation of an optimised protection strategy should be below the reference level (ICRP103, 2007).

Reference levels have been used in radiation protection for decades and their earlier use and the application as recommended in ICRP 103 are reviewed.

REFERENCE LEVELS USED IN RADIATION PROTECTION

It is often helpful in the management of operations to establish values of measurable quantities above which some specified action or decision should be taken. The use of such levels can avoid unnecessary or unproductive work and can help in the effective deployment of resources. ICRP has earlier defined reference levels as (ICRP75, 1997):

> *Reference levels are values of measured quantities above which some specified action or decision should be taken. They include recording levels, above which a result should be recorded, lower values being ignored; investigation levels, above which the cause or the implications of the result should be examined; intervention levels, above which some remedial action should be considered; and, more generally, action levels above which some specified action should taken.*

Reference levels are defined in the same way in the IAEA Safety Glossary as action level, intervention level, investigation level and recording level (IAEA, 2007).

ICRP Publication 82 (ICRP82, 2000) provides guidance on the application of the Commission's system of radiological protection to prolonged exposure to radiation. Typical prolonged exposures are those delivered by *natural* sources such as radionuclides in primordial decay chains. Some *artificial* sources may also deliver prolonged exposures; for example, long-lived radioactive residues from human activities are a common cause of prolonged exposure. For radiation protection in prolonged exposure situations, ICRP 82 has recommended the use of so-called *Generic Reference Levels* and *Specific Reference Levels* (ICRP82, 2000).

The Generic Reference Level is defined as a level that can be expressed in terms of the existing annual dose. It is particularly useful when intervention is being considered in some situations, such as exposures to high natural background radiation and to those radioactive residues that are a legacy from the distant past. The Specific Reference Level is defined as levels such as intervention levels and action levels for particular prolonged exposure situations amenable to protective measures and can be expressed in terms of avertable annual dose, or some related operational quantity (ICRP82, 2000).

In ICRP Publication 103 the reference levels for protection in emergency or existing controllable exposure situations are defined as the level of dose or risk, above which it is judged to be inappropriate to plan to allow exposures to occur, and for which therefore protective actions should be planned and their extent be decided through justification and optimisation. The chosen value for a reference level will depend upon the prevailing circumstances of the exposure situation under consideration (ICRP, 2007), paragraph 234). Reference levels should be used in the optimisation of protection with focus on the re-

sidual doses after implementation of protective strategies (ICRP103, 2007, paragraph (t) in Executive Summary):

> *Emphasis on optimisation using reference levels in emergency and existing exposure situations focuses attention on the residual level of dose remaining after implementation of protection strategies. This residual dose should be below the reference level, which represents the total residual dose as a result of an emergency, or in an existing situation, that the regulator would plan not to exceed. ...*

Up until the publication of ICRP 82 the meaning of a reference level and the derived quantities which could be directly measured was unambiguous. The definition in ICRP 82 of a *Generic Reference Level* and a *Specific Reference Level* as well as the definition in ICRP 103 of a *Reference Level* has somehow obscured the understanding of a reference level as defined in earlier ICRP publications and elsewhere.

It is obvious that the *generic reference level* defined in ICRP 82 and the *reference level* as it is defined in ICRP 103 are alike. Similarly, the *specific reference level* defined in ICRP 82 is in fact an action level or an intervention level, i.e., a reference level in its original definition.

While the reference level in ICRP 103 (paragraph (t)) and the generic reference level in ICRP 82 are, strictly speaking, new members of the old *reference-level-family*, the way *reference level* in ICRP 103 is to be applied is somewhat confusing, and raises the question: is it a reference level or something different. To examine this it is useful to review the radiation protection system as described in ICRP 103.

INTERPRETING THE ICRP 103 RADIOLOGICAL PROTECTION SYSTEM

The Commission continues to regard the principles of protection for practices separately from intervention situations as recommended in ICRP 60 as fundamental for the system of protection (ICRP103, 2007, paragraph 203). However, in the ICRP Publication 103 `practice' is replaced by *planned exposure situation* and *intervention* by *emergency exposure situation* and *existing exposure situation*.

Justification and optimisation of protective measures

ICRP 103 has formulated a single set of principles that apply to planned, emergency, and existing exposure situations. The ICRP 103 recommendations clarify how the fundamental principles apply to radiation sources and to the individual, as well as how the source-related principles apply to all controllable situations (ICRP, 2007). The principles of justification and optimisation are source-related and apply in all exposure situations.

> *The principle of justification*: *Any decision that alters the radiation exposure situation should do more good than harm.*

In existing and emergency exposure situations the exposures can be controlled mainly by action to modify the pathways of exposure and not by acting directly on the source. In these circumstances, the principle of justification is applied in making the decision as to whether to take action to avert further exposure.

> *The principle of optimisation of protection: The likelihood of incurring exposures, the number of people exposed, and the magnitude of their individual doses should all be kept as low as reasonably achievable, taking into account economic and societal factors.*

This means that the level of protection should be the best under the prevailing circumstances, maximizing the margin of benefit over harm. The process of optimisation of protection is intended for application to those situations that have been deemed to be justified, i.e., when new sources are introduced (planned exposure situations) and when protective measures or strategies are introduced in emergency and existing exposure situations.

ICRP recommends that reference levels, set in terms of individual dose, should be used in conjunction with the implementation of the optimisation process for exposures in existing and emergency exposure situations. The objective is to implement an optimised protection strategy, or a progressive range of such strategies, which will reduce individual doses to below the reference level.

Application of dose constraints and reference levels

A dose constraint for planned exposure situations, where the quantity is *dose received*, is an upper bound on the exposure of individuals, e.g., the annual dose to representative persons in the population living around a nuclear facility. The radiation protection should here be optimised *below* the dose constraint. In principle, dose constraints should be established on a case-by-case basis, with due consideration of the maximum annual dose that would be acceptable from a new source at a single location, taking into account exposures from other sources subject to control and equity considerations.

After implementation of an optimised protection strategy in emergency and existing exposure situations the residual dose should be *below* the reference level. The optimisation process therefore applies to initial levels of individual doses *above* the reference level. However, the value for the reference level is not fixed but depends upon the prevailing circumstances of the exposure situation and represents a target for the total residual dose after implementation of protection strategies that the regulator would plan not to exceed. This is stated in Paragraph 234 of Publication 103:

> (234) In emergency or existing controllable situations, **the reference levels represent the level of dose or risk, above which it is judged to be inappropriate to plan to allow exposures to occur** (cf. Section 6.2), and for which therefore protective actions should be planned and optimised. The chosen value for a reference level will depend upon the prevailing circumstances of the exposure situation under consideration.

A subsidiary and perhaps self-evident application of a reference level is that after one has been determined it may subsequently be used as a benchmark to assess the success of protective actions taken. This application is described in Paragraph 235 of Publication 103:

> (235) **When an emergency situation has occurred, or an existing exposure situation has been identified**, and protective actions have been implemented, doses to workers and members of the public can be measured or assessed. **The reference level may then assume a different function as a benchmark against which protection options can be judged retrospectively**. The distribution of doses that has resulted from the implementation of a planned protective strategy may or may not include exposures above the reference level, depending on the success of the strategy. Efforts should, however, be aimed at reducing any exposures that are above the reference level to a level that is below, if possible.

Dose constraints for planned exposure situations and reference levels for emergency and existing exposure situations are conceptually different quantities, and the application of these quantities is illustrated in Fig. 1.

In planned exposure situations, the restriction on individual doses can be applied at the planning stage, and the doses can be forecast so as to ensure that the dose constraint will *not be exceeded*. In existing exposure situations, a wider range of exposures may exist, and the optimisation process will apply to initial levels of individual doses *above* the reference level (ICRP103, 2007). Therefore, it seems illogical compared with already existing recommendations that ICRP 103 recommends that all exposures *above or below* the reference level should be subject to optimisation of protection.

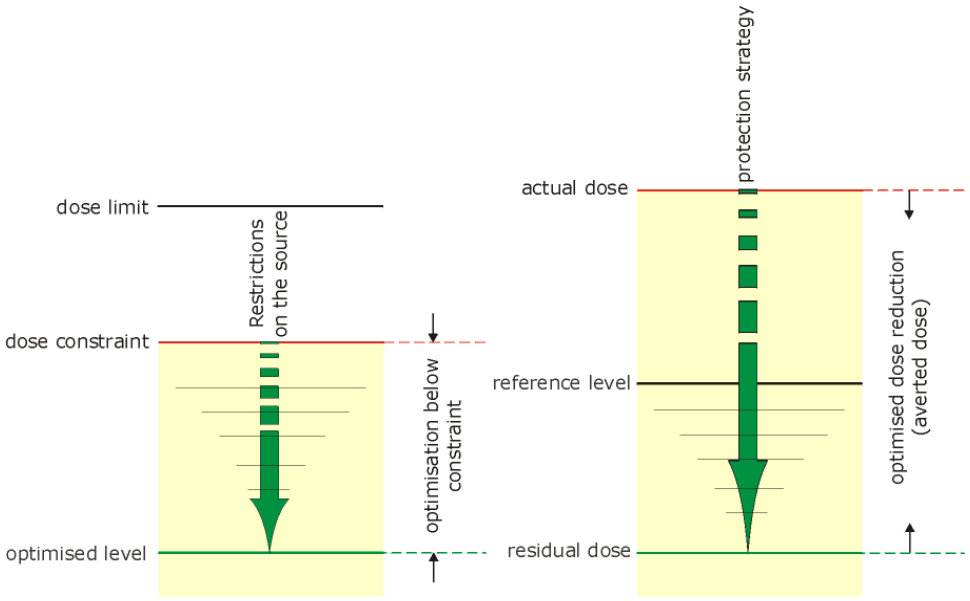

Fig. 1 Application of a dose constraint in the optimisation of protection of the public in a planned exposure situation (left-hand picture) vis-à-vis the application of a reference level in the optimisation of protection of the public in an existing or emergency exposure situation (right-hand picture). The optimisation process in a planned exposure situation excludes any protection options that would result in individual annual doses above the selected dose constraint (dose received). In an existing exposure situation, the actual exposure of the population affected by the source (contaminated foodstuffs, contaminated land, radon etc.) may be at the outset deemed to be inappropriate to allow it to occur. Therefore, the optimised protective actions or strategy should be aimed at reducing any exposures that are above the reference level to a level that is below.

The result of an optimised protection strategy that evolves over time with a fixed reference level is shown in Fig. 2 (ICRP103, 2007 and ICRP111, 2009). It appears from Fig. 2 that the progressive implementation of an optimised protective action strategy will gradually reduce the number of people receiving doses above a fixed reference level. If, however, the reference level had been reduced over time, the number of people receiving doses above this `moving' reference level (moving target) might not have been reduced, but may even have increased.

If there are N exposure pathways, the total projected dose from all the exposure pathways can be determined as:

$$E_{\text{proj}} = \sum_{i=1}^{N} \int_{0}^{\tau} \dot{E}_i(t) \cdot \mathrm{d}t$$

where τ_i is the exposure time for the different exposure pathways.

An optimised protection strategy will reduce the individual doses from the different exposure pathways to a fraction of the initial doses, f_i, having a value between 0 and 1, and perhaps even being a function of time. Each of the protective actions in the strategy might start at different times, T_i, and continue over different time periods, $\Delta\tau_i$, resulting in a total averted dose, E_{avert}:

$$E_{\text{avert}} = \sum_{i=1}^{N} \int_{T_i}^{T_i+\Delta} (1 - f_i) \cdot \dot{E}(t) \cdot \mathrm{d}t$$

The protection strategy, $S = \{f_1, f_2, f_3, ..., f_N\}$, involves a number of different protective actions, and the strategy is the result of an optimisation process. The residual dose is the difference between the pro-

jected dose and the averted dose, $E_{proj} - E_{avert}$, and this dose is fixed after implementation of the optimised strategy. Thus, the residual dose is directly dependent on the optimisation of the protection.

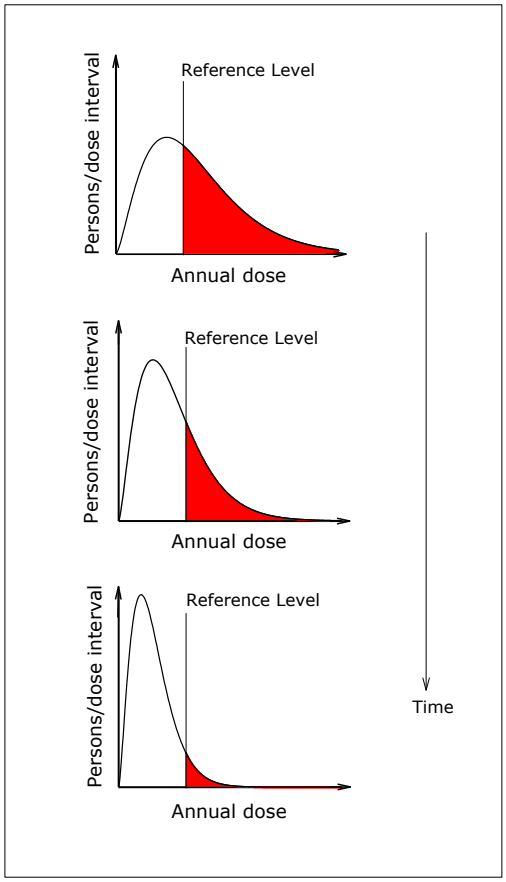

Fig. 2 Application of reference level in an existing exposure situation and the evolution of the distribution of individual annual doses with time as a result of the implementation of an optimised protection strategy. The graphs show the distribution of people by annual dose and the red area represents the number of people receiving doses above a fixed reference level.

DISCUSSION AND CONCLUSIONS

In ICRP 103 it is stated that no fundamental changes have been introduced compared to ICRP 60: *The Commission anticipates that although the revised Recommendations do not contain any fundamental changes to the radiological protection policy, these Recommendations will help to clarify application of the system of protection in the plethora of exposure situations encountered, thereby further improving the already high standards of protection* (paragraph (x) in the Executive Summary (ICRP103, 2007).

This is true except that the recommendations on the application of reference levels for emergency and existing exposure situations appear to be inconsistent both in ICRP 103, and in ICRP 109 and ICRP 111. Table 1 shows selected paragraphs from these publications on the application of reference levels in emergency and existing exposure situations and critical comments to the paragraphs.

Table 1 Selected paragraphs from ICRP 103, ICRP 109 and ICRP 111 on application reference levels and comments to these paragraphs.

ICRP Publication	Comments
ICRP 103: (279) Planning should result in a set of actions that would be implemented automatically once an emergency exposure situation has occurred, should the actual circumstances require such urgent actions. Following a decision on such immediate action, the projected residual dose distribution can be assessed, and the reference level acts as a benchmark for assessing the effectiveness of protection strategies and the need to modify or take additional actions. All exposures above or below the reference level should be subject to optimisation of protection, and particular attention should be given to exposures above the reference level.	If, in fact, all exposures above or below the reference level are subject to the process of optimisation, the setting of reference levels appears superfluous. In the case of radon (see paragraphs 297 and 298 in ICRP 103), a reference level is set on largely the same basis as an action level in previous recommendations (ICRP65, 1993), where concentrations below the action level do not warrant further consideration. It could be considered that if optimisation of protection below a fixed reference level is necessary, then the reference level has been set too high at the outset.
ICRP 103: (Glossary, reference level) In emergency or existing controllable exposure situations, this represents the level of dose or risk, above which it is judged to be inappropriate to plan to allow exposures to occur, and below which optimisation of protection should be implemented. The chosen value for a reference level will depend upon the prevailing circumstances of the exposure under consideration.	This definition appears to be that of a dose constraint below which optimisation of protection should be implemented in planned exposure situations. The definition is different from the wording in paragraph 234 in ICRP 103.
ICRP 109: (39) The Commission has introduced the concept constrained optimisation below reference levels in order to ensure that the response, as well as being optimised, avoids inequity of individual exposures.	This statement appears to be the requirement for applying a dose constraint below which optimisation of protection should be implemented in planned exposure situations. For emergency and existing exposure situations the optimisation of protection starts above the reference level, and the goal is that the residual dose after implementation of an optimised protection strategy should be below the reference level.
ICRP 111: (44) The source-related concept of reference level as defined by the Commission in Publication 103 (ICRP 103, Para. 230) represents the level of dose or risk above which it is judged to be inappropriate to plan to allow exposures to occur, and below which optimisation of protection should be implemented.	This statement appears to be the definition of applying a dose constraint in a planned exposure situation; paragraph 230 in ICRP 103 deals only with dose constraints - not reference levels. It seems here as if dose constraints for planned exposure situations and reference levels for emergency and existing exposure situations are considered to be conceptually equal.
ICRP 103: (218) The best option is always specific to the exposure situation and represents the best level of protection that can be achieved under the prevailing circumstances. Therefore it is not relevant to determine, a priori, a dose level below which the optimisation process should stop. Depending on the exposure situation, the best option could be close to or well below the appropriate source-related constraint or reference level.	This seems to be an unnecessary statement. The optimisation of protection continues (form, scale and duration) until the individual doses are as low as reasonable achievable. As a result of this the net benefit of the protection strategy is maximized and the endpoint reached where residual doses are close to or below the reference level.
ICRP 111: (53) The fact that exposures have been reduced below the reference level is not a sufficient condition to discontinue protective actions as long as there is room for further reduction in exposure in conformity with the optimisation process. The continuation of such actions would probably be a prime mechanism to maintain exposures close or similar to those in normal situations as recommended by the Commission.	The optimisation process will dictate when to discontinue the protective actions, namely when the net benefit is maximized. If there is `room for further reduction' this would already have been justified and included in the optimisation of the protection strategy. This is addressed in ICRP 60 (paragraph 212) as `the duration of countermeasures influences the averted dose and therefore the provisional decision about the withdrawal of the countermeasures should be taken as part of the optimisation process.

The reference level for emergency and existing exposure situations in ICRP 103 represents a level below which the residual doses - after an optimised protection strategy has been implemented - should fall. A kind of a definition of a reference level is given (Executive Summary, paragraph (t)) as:

> *Emphasis on optimisation using reference levels in emergency and existing exposure situations focuses attention on the residual level of dose remaining after implementation of protection strategies. This residual dose should be below the reference level, which represents the total residual dose as a result of an emergency, or in an existing situation, that the regulator would plan not to exceed.*

The author of this paper interprets this paragraph as:

> *The reference level of individual doses in emergency and existing exposure situations is an upper target for the residual individual doses after the implementation of an optimised protection strategy.*

This interpretation is supported by the example in Table 5 in ICRP 103 on existing exposure as *Reference level for the highest planned residual dose from radon in dwellings*, and also by the ICRP statement on the Fukushima accident in which the Commission Chairman and Scientific Secretary state *For the protection of the public during emergencies the Commission continues to recommend that national authorities set reference levels for the highest planned residual dose in the band of 20 to 100 millisieverts (mSv) (ICRP 2007, Table 8)* (Cousins, C. & Clement, C. (2011)).

Protective actions would thus at the outset start at initial dose levels above the reference level as illustrated in the right-hand picture in Fig. 1. If the actual doses were already below the reference level, they were by definition acceptable, or the reference level has been set too high at the outset.

It seems therefore illogical that optimisation of protection should be implemented below a reference level. In planned exposure situations, however, the optimisation of protection should be below the dose constraint, which is an upper bound for the individual doses to a representative individual. But reference levels are conceptually different from dose constraints in the way they are applied.

ICRP 111 provides advice on setting reference levels that differs from existing ICRP guidance that continues to be valid. In particular it avoids consideration of ICRP 82 (ICRP82, 2000) and ICRP 96 (ICRP96, 2006). ICRP 82 gives guidance on the existing exposure situation stating *the Commission concludes that an existing annual dose approaching about 10 mSv may be used as a generic reference level below which intervention is not likely to be justifiable for some prolonged exposure situations*. What this assessment implies is that any reasonable analysis of an existing exposure situation will generally lead to the conclusion that *on radiation protection grounds* no protective actions are likely to be justifiable (result in an overall net benefit) for doses less than 10 mSv per annum, i.e. that the optimized action for doses of less that 10 mSv per annum is likely to be *do nothing*. Indeed, the advice in the publications ICRP 82 and ICRP 96 coupled with the range of annual doses of 1 - 20 mSv in ICRP 103, from which the reference level is to be "*selected*", implies protective actions could normally be expected to be justifiable and implemented in the 10 - 20 mSv annual dose range.

It could be considered that the generic reference levels for intervention established in ICRP 82 for situations of prolonged exposure owe as much to comparisons with exposures to natural sources as they do to estimates of risk (see e.g. paragraph 76), reflecting the widespread unease in the radiation protection community about the magnitude or even existence of detriments arising from doses of a magnitude within common variations from place to place of exposures to natural sources. Paragraph (76) states:

> "*… the Commission considers that a high level of existing annual dose - e.g., due to high natural background levels - should not per se justify a particular component of annual dose - e.g., a high*

level of annual dose attributable to long-lived radioactive residues. This should always be restricted following the principles of the system of radiological protection for intervention. However, as the expected radiation health effects depend on the dose received and not on the source origin, the Commission also considers that the typically elevated levels of existing annual doses from 'natural' sources, which have not triggered any protective action, may provide a useful insight into decisions related to intervention."

The generic reference level of 10 mSv/a below which intervention is unlikely to be justified in ICRP 82 is the upper level of the range of annual doses from natural sources that are commonly encountered. The level at which intervention would almost always be justified, of 100 mSv/a, corresponds to about the upper limit of human exposure to natural sources. The justification for a dose rate of 10 mSv/a could be seen as not only a dose rate within the common natural range, but also not a level of concern in countries with such a dose rate (e.g. central France). From these types of comparison it is not unreasonable for the ICRP to propose that undue resources should not be devoted to dose reductions below those naturally experienced perpetually by whole populations in some countries.

Whether or not the reference level could be set close to *normal*, as stated in ICRP 111, paragraph 53, will depend upon the prevailing circumstances (feasibility etc.). If a prime goal is to maintain exposures close or similar to those in normal situations, as ICRP 111 proposes - irrespective of the optimisation of protection - this is in direct conflict with basic radiation protection principles. ICRP 60 states in paragraph 131 *The use of ... dose limits, or of any other pre-determined dose limits, as the basis for deciding on intervention might involve measures that would be out of all proportion to the benefit obtained and would then conflict with the principle of justification*.

The ambiguity in deriving a reference level for an existing exposure situation is seen also in the ICRP Statement on the Fukushima nuclear power plant accident (Cousins, C. & Clement, C. (2011)). Paragraph 5 of the Statement, cited above relating to the emergency exposure situation, clearly indicates the selection of a specific value for the reference level based on prevailing circumstances. However, paragraph 6 dealing with an existing situation states *when the radiation source is under control contaminated areas may remain. Authorities will often implement all necessary protective measures to allow people to continue to live there rather than abandoning these areas. In this case the Commission continues to recommend choosing reference levels in the band of 1 to 20 mSv per year, with the long-term goal of reducing reference levels to 1 mSv per year (ICRP 2009b, paragraphs 48-50)* (Cousins, C. & Clement, C. (2011). This implies firstly selection of a value based on the prevailing circumstances but subsequently a time varying reference level, reducing ultimately to 1 mSv/year. That the ultimate goal should be a reference level of 1 mSv/year is not found in paragraphs 49 and 50 of Publication 111 which the Statement gives as reference, and is directly at variance with Publication 82.

The following conclusions have been drawn from the review and discussions above:

- The term *reference level* as defined in ICRP 103 has been used in more than one way in Publications 103 and 111. It should be used consistently as in the application to radon, cf. paragraphs 297 and 298 in ICRP 103 and in ICRP 65 (ICRP65, 1993).

- Dose constraints for planned exposure situations and reference levels for emergency and existing exposure situations are conceptually different. A dose constraint for planned exposure situations, where the quantity is *dose received*, is an upper bound below which optimisation of protection should be implemented. A reference level for emergency and existing exposure situations is an upper target for the individual residual doses after implementation of an optimised protection strategy (ICRP103, 2000, paragraph 286); the residual dose is derived making use of the dose quantity *avertable dose* (ICRP103, 2000).

- A reference level for emergency and existing exposure situations is not an *off-the-shelf item* that can be set free from the prevailing circumstances. It should be determined as part of the process of optimising the protection strategy. If not, protection might be sub-optimised. The process of optimisation will continue to use the dose averted by specific countermeasures as an important input into the development of optimised strategies (ICRP103, 2000, Executive Summary, paragraph (t)). *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* (ICRP103, 2000, paragraph 286).
- Exposures below the reference level in emergency and existing exposure situations should not directly be subject to optimisation of protection. If so, the reference level has been set too high at the outset. This is in line with the ICRP 103 recommendations on the use of reference levels in radon exposure situations. Indeed, the implementation of a global protective strategy, e.g. agricultural countermeasures, to reduce individual doses above the reference level would also reduce individual doses already below the reference level, cf. Fig. 2. However, this is not the primary target of the protection strategy, which is to bring individual doses above the reference level to below the reference level.
- In the still valid ICRP 82 (ICRP82, 2000) it is recommended that no protective actions are likely to be justifiable (result in an overall net benefit) on radiological protection grounds for annual doses less than 10 mSv in existing prolonged exposure situations. The dose range in ICRP 103 of 1 - 20 mSv/a from which possible values of a reference level in existing exposure situations should be selected, therefore seems to be in conflict with the recommendations in ICRP 82 as far as the lower 1 - 10 mSv/a range is concerned.
- The optimisation process will determine when to discontinue the protective actions in a protection strategy. The endpoint is when the net benefit is maximized whereby the residual individual doses are at least no higher than the reference level, and preferably lower.

It remains unclear how to apply the reference levels recommended in ICRP Publication 103 for existing and emergency exposure situations. It is therefore suggested that ICRP should consider issuing a statement on dose constraints in `dose received' (planned exposure) situations and reference levels in `dose averted' (emergency and existing exposure) situations with emphasis on the conceptual difference between reference levels and dose constraints. Guidance on the practical application of reference levels in emergency and existing exposure situations is also needed and could be issued as a Supporting Guidance document to Publication 103 and the related Publications 109 and 111.

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