Dr Lars-Erik Holm, Chairman, International Commission for Radiological Protection (ICRP)

The 2006 Recommendations of the International Commission on Radiological Protection

ABSTRACT

The current recommendations of the International Commission on Radiological Protection (ICRP) were published in 1991. Since then, ICRP has published additional recommendations, and the system of protection has become increasingly complex. New scientific data have made it necessary to update the biological and physical assumptions underlying the recommendations. The Commission has decided to revise its recommendations while at the same time maintaining stability with the previous recommendations. The international consultation on the draft recommendations has involved health physics professionals all around the world. A revised draft was put on ICRP's website for consultation during the summer of 2006. When ICRP adopts its revised recommendations, 16 years will have passed since the 1990 recommendations were adopted.

INTRODUCTION

The primary aim of ICRP's recommendations is to provide an appropriate standard of protection for people and the environment, without unduly limiting the beneficial actions giving rise to radiation exposure. This aim is achieved through the combined use of scientific concepts and value judgements about the balancing of risks and benefits, i.e. an approach similar to other fields concerned with the control of hazards.

The system of radiological protection, set out in Publication 60 (1), was developed over some 30 years. Since then, there have been additional recommendations regarding numerical restrictions on dose, based on different ideas and spanning several orders of magnitude (2-10). A framework for environmental protection has also been published (11). The system has thus become increasingly complex, and it has in some respects been difficult to explain or understand completely the variations between different applications. New scientific data have been published, and the biological and physical assumptions and concepts need updating. There have also been societal developments in that more openness or transparency is expected in developing new recommendations that could be accepted globally. Therefore, while recognising the need for stability in international and national regulations, the Commission has decided to issue these revised recommendations having three primary aims in mind:

- to take account of new biological and physical information and of trends in the setting of radiation safety standards;
- to improve and streamline the presentation of the recommendations; and
- to maintain as much stability in the recommendations as is consistent with the new scientific information.

In the new recommendations, much will remain as in the 1990 recommendations because they have been demonstrated to work and are generally clear. Further explanation is needed, however, in some areas and where omissions have been identified, these will be addressed. There has also been an improved understanding in some areas, for example of radiation effects, which will result in some changes in recommendations, but the overall radiation risks are essentially unchanged. A series of documents have been and are being developed to underpin the revised recommendations:

Committee 1 (radiation effects):

- Low-dose extrapolation of radiation-related cancer risk (12).
- Biological and epidemiological information on health risks attributable to ionising radiation: A summary of judgements for the purposes of radiological protection of humans (will appear as an annex to the recommendations).

Committee 2 (dosimetry):

- Basis for dosimetric quantities used in radiological protection and their application (annex to the recommendations).

Committee 3 (protection in medicine):

- Radiological Protection in Medicine.

Committee 4 (application of ICRP's recommendations):

- Optimisation of radiological protection (13).
- Assessing dose to the representative individual (13).

Committee 5 (protection of the environment):

- The concept and use of reference animals and plants for the purposes of radiological protection.

Main Commission:

- The scope of radiological protection: exemption and exclusion.

The international consultation on the draft recommendations and of the above-mentioned documents was the culmination of several years of work and followed discussions with health physics professionals all around the world. The new recommendations should be seen as consolidating the 1990 recommendations and those published subsequently. The opportunity is also being taken to include a coherent philosophy for natural radiation exposures and to introduce an approach to radiological protection of the environment. The major features of the 2006 Recommendations are:

- maintaining the three fundamental principles of radiological protection, and clarifying how they apply to

Table 1. ICRP's revised tissue weighting factors, w_T

Tissue	w_T	$\sum w_T$
Bone-marrow, Colon, Lung, Stomach, Breast, Remainder Tissues*	0.12	0.72
Gonads	0.08	0.08
Bladder, Oesophagus, Liver, Thyroid	0.04	0.16
Bone surface, Brain, Salivary glands, Skin	0.01	0.04

*Remainder Tissues: Adrenals, Extrathoracic (ET) region, Gall bladder, Heart, Kidneys, Lymphatic nodes, Muscle, Oral mucosa, Pancreas, Prostate, Small intestine, Spleen, Thymus, Uterus/cervix.

radiation sources and to the individual, as well as establishing that the source-related principles apply to all controllable situations (planned, emergency and existing exposure situations);

- updating the understanding of the biology and physics of radiation exposure;
- updating the radiation and tissue weighting factors in the dosimetric quantity effective dose;
- maintaining the Commission's limits for effective dose and equivalent dose from all regulated sources that represent the most that will be accepted in planned situations by regulatory authorities;
- using the same conceptual approach of constraints in the source-related protection to all situations, regardless of the type of source. The dose constraints quantify the most fundamental levels of protection for workers and the public from a source;
- complementing the limits and constraints with the requirement to optimise protection from a source; and
- including a policy approach for radiological protection of non-human species.

RADIATION DETRIMENT

There have been developments in biological and dosimetric knowledge that justify a re-appraisal of the radiation-weighting factors, w_R (14). Most values of the relative biological effectiveness have been obtained at high doses and must therefore be extrapolated to the low doses that are of interest for radiological protection. For practical purposes, ICRP recommends the use of the same wR values for all organs and tissues. For photons and beta particles, a wR of unity is retained for all low-LET radiations, and a wR of 20 is retained for alpha particles. ICRP believes that a wR of 5 for all protons of energy > 2 MeV is an overestimate of the biological effectiveness, and recommends a wR of 2 for incident protons. For neutrons, ICRP recommends the use of wR values that depend upon energy of incident neutrons, and that a continuous function be used. The wR for neutrons should thus be decreased for energies below 1 MeV to take account of the absorbed dose contribution by low-LET gamma rays that are induced in the body by neutrons.

The fundamental role of radiation-induced DNA damage in the induction of mutations and chromosome aberrations provides a framework for the analysis of risks at low doses and low dose rates. For cancer and hereditary disease at low doses and dose rates, the evidence weighs in favour of the use of a simple proportionate relationship between increments of dose and increased risk. A dose and dose-rate effectiveness factor (DDREF) of 2 is retained. While the existence of a low-dose threshold does not seem unlikely for radiation-related cancers of certain tissues, the evidence as a whole does not favour the existence of a universal threshold, and there seems to be no particular reason to factor the possibility of a threshold into risk calculations for purposes of radiological protection. The linear, no-threshold (LNT) hypothesis remains a good basis for protection at low doses and low dose rates.

A better understanding of the mechanisms for radiation-related adaptive response, genomic instability, and bystander effects is needed before they can be evaluated as factors to be included in the estimation of risk after exposure to low levels of radiation. The dose responses for in utero radiation-induced tissue reactions, malformations and neurological effects are judged to show dose thresholds above a few tens of mSv. Uncertainty remains on the induction of IQ deficits but at low doses the risk is thought to be insignificant. Risks of non-cancer disease at low doses remain uncertain and no specific judgement is possible.

ICRP has revised the tissue weighting factors, w_T, and the most significant changes from Publication 60 (1) relate to breast, gonads and treatment of remainder tissues (*Table 1*).

Table 2. Detriment-adjusted nominal coefficients for cancer and hereditary effects (10^{-2} Sv^{-1})

Exposed population	Cancer		Heritable effects		Total	
	Present[1]	Publ. 60	Present[1]	Publ. 60	Present[1]	Publ. 60
Whole	5.5	6.0	0.2	1.3	6	7.3
Adult	4.1	4.8	0.1	0.8	4	5.6

The new nominal probability coefficients for cancer and heritable effects are 6 10^{-2} Sv^{-1} for the whole population and 4 10^{-2} Sv^{-1} for adult workers (*Table* 2). The nominal detriment coefficients for both a workforce and the general public are thus consistent with, although numerically somewhat lower than, those given in Publication 60. While the nominal risk estimates are now slightly smaller, for practical purposes the risk is in the same order of magnitude as before. Thus, the approximate overall risk coefficient of about 0.00005 per mSv on which the current international radiation safety standards are based continues to be appropriate for purposes of radiological protection.

CONSTRAINTS

The most fundamental level of protection is the source-related restrictions to the dose that individuals may incur, namely the dose constraint. This term was introduced by ICRP in 1990 as part of the principle of optimisation of protection:

> '*This procedure should be constrained by restrictions on the doses to individuals (dose constraints), or the risks to individuals in the case of potential exposures (risk constraints), so as to limit the inequity likely to result from the inherent economic and social judgements' (Paragraph 112, ICRP 60)*.

The constraint is used to provide a level of protection for the most exposed individuals from a source within a type of exposure. Compliance with the relevant constraint is not in itself a sufficient condition to satisfy ICRP's recommendations; radiological protection must also always be optimised. ICRP continues to emphasize that optimisation of protection is the most important concept to achieve a satisfactory protection against radiation.

ICRP now uses the same conceptual approach in the source-related protection, regardless of the type of source. This means that optimisation of protection is always constrained by a level of dose where action is almost always warranted. This level of dose constraint is aimed at excluding from the process of optimisation any protection options that would involve individual doses above the selected constraint. In the case of planned situations (practices), the regulator or the operator establishes the constraint and it is a continuous part of the optimisation process. In other situations, the constraint may be established once, and then not used more, e.g., in the case of the design of a source or in the selection of emergency constraints. In the case of exposure from diagnostic medical procedures, the diagnostic reference level serves as a kind of constraint for a specified examination or procedure, but it does not relate to individual patients. The important message from ICRP is that a similar approach is used in optimisation, regardless of the type of source or the terminology used.

The dose constraint is not a form of retrospective limit - this function is provided by dose limits. In planned situations, the constraint is less than the dose limits, and in emergency or existing exposure situations, it represents the level of dose or risk where action is almost always warranted. The chosen value will depend upon the circumstances of the exposure and will be established by the national regulator or by the operator.

ICRP regards dose limits as being close to the point where the doses from the sources to which its limits apply result in a level of risk that, if continued, could be described as unacceptable for those sources in normal circumstances. A dose limit is not a measure of the degree of rigour implied by the recommendations. That should be judged by the overall impact of the system of protection, of which the optimisation of protection is the most onerous and effective component.

DISCUSSION

The Commission recognises the need for stability in regulatory systems at a time when there is no major problem identified with the practical use of the present system of protection in normal situations. The use of the optimisation principle, together with the use of source-related constraints and the individual-related dose limits, has resulted in a general overall reduction in both worker and public doses over the past decade.

The philosophy of radiological protection is based on the LNT hypothesis. Because we do not know the level of risk associated with very low radiation doses, ICRP considers it to be the best approach to manage radiological protection. The LNT hypothesis also has characteristics that make it a useful tool and facilitates radiological protection. For example, it allows consideration of each source and exposure separately from other sources and exposures. It makes it possible to average dose within an organ or tissue over that organ or tissue, doses received at different times can be added, and doses received from one source can be considered independently of the doses received from other sources.

The probabilistic nature of stochastic effects makes it impossible to make a clear distinction between 'safe' and 'dangerous', and the major policy implication of the non-threshold relationship is that some finite risk must be accepted at any level of protection. This has led to the system of protection with its principles of justification, optimisation and individual dose limitation. These principles continue to be the cornerstones of ICRP's recommendations. A revised draft of the recommendations was put on ICRP's website for a second round of international consultation during the summer of 2006. When

ICRP adopts its revised recommendations, 16 years will have passed since the 1990 recommendations were adopted.

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