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REVIEW

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REVIEW

New ICRP recommendations

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Abstract

This paper provides a review of the 2007 recommendations of the International Commission on Radiological Protection (ICRP). These new recommendations take account of the latest biological and physical information and consolidate the additional guidance provided by ICRP since 1990. The changes to the scientific data are not substantial. ICRP has retained its fundamental hypothesis for the induction of stochastic effects of linearity of dose and effect without threshold and a dose and dose-rate effectiveness factor (DDREF) of 2 to derive nominal risk coefficients for low doses and low dose rates. While the overall detriment from low radiation doses has remained unchanged, ICRP has made adjustments to the values of the radiation and tissue weighting factors. In particular, the tissue weighting factor for breast has increased while that for gonads has decreased. There are some presentational changes to the system of protection. While ICRP has maintained the three fundamental principles—justification, optimisation of protection, and dose limitation—it has attempted to develop a more holistic approach to radiological protection covering all exposure situations—planned, existing and emergency—and all radiation sources, whether of natural or artificial origin. This approach should ensure that attention is focused on those exposures that can reasonably be controlled. It has also strengthened the principle of optimisation of protection with a particular emphasis on the use of constraints for planned exposure situations and reference levels for existing and emergency exposure situations. Dose constraints and reference levels are categorised into three bands which should assist in rationalising the many values of dose restrictions given in earlier ICRP publications. There are no changes to the dose limits. ICRP also indicates its intentions with respect to the development of further guidance on the protection of the environment. The fact that these new recommendations are more a matter of consolidation of previous ICRP recommendations and guidance should provide confidence that the system of protection established by and large in its present form several decades ago has reached a certain level of maturity. As such, no major changes to radiological protection regulations based on the 1990 recommendations should be necessary.

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1. Introduction

The process of reviewing the 1990 ICRP recommendations started around 1998 with a discussion paper prepared by the then Chairman, Roger Clarke [1]. It was motivated by a desire to reduce the complexity that had arisen as a consequence of the way in which radiological protection had evolved and to cover exposures from all radiation sources in a more holistic way. It involved technical discussions with professionals throughout the world, most notably at two major gatherings—the IRPA meetings in Hiroshima in 2000, and Madrid in 2004. In addition, proposed new recommendations were made available on the web for full consultation on two separate occasions—in 2004 and 2006. The relevant international organisations, most notably, IAEA, EC and NEA/OECD, contributed significantly during the development process. Two progress reports were prepared during the process of development [2, 3]

ICRP approved its new recommendations at its meeting in Essen, in March 2007. They are now published in the *Annals of the ICRP* [4]. These new recommendations take account of the latest biological and physical information and trends in the setting of radiation safety standards. They also take account of the developments in ICRP guidance since 1990, when the previous recommendation were agreed [5], particularly the numerical dose criteria developed for various purposes. This paper presents a summary of the new recommendations.

2. Biological basis

Radiological protection has always been grounded in the latest understanding of the biological effects induced by exposure to radiation. These effects are comprehensively reviewed in the new recommendations

As far as deterministic effects (ICRP now prefers the term 'tissue reactions' for these effects) are concerned, ICRP notes that 'in the absorbed dose range up to around 100 mGy (low LET or high LET) no tissues are judged to express clinically relevant functional impairment. This judgement applies to both single acute doses and to situations where these low doses are experienced in a protracted form as repeated annual exposures'.

The main focus these days is, however, on 'stochastic effects', primarily cancer but also hereditary disorders. In its review of these effects, ICRP considered possible challenges to its linear non-threshold model but concluded that for the purposes of radiological protection, it is scientifically plausible to assume that the incidence of cancer or hereditary disorders will rise in direct proportion to an increase in the equivalent dose in the relevant organs and tissues, below about 100 mSv. ICRP also considered issues such as cellular adaptive responses, genomic instability and bystander signalling but notes that 'since the estimation of nominal cancer risk coefficients is based upon direct human epidemiological data, any contribution from these biological mechanisms would be included in that estimate'.

There is a growing amount of evidence that there other radiation-associated health consequences—heart disease, stroke, digestive disorders and respiratory disease [6]. However, ICRP concluded that the data are insufficient to allow for their inclusion in the estimation of detriment following low radiation doses (i.e. <100 mSv).

3. Nominal risk coefficients

The cancer risk estimates have not greatly changed since 1990. Furthermore, ICRP continues to consider that a dose and dose-rate effectiveness factor (DDREF) of 2 is still appropriate in order to derive nominal risk coefficients for low doses and low dose rates. The values are given in table 1 along with those given in the 1990 recommendations. All values are nominal in

Table 1. Detriment-adjusted nominal risk coefficients for stochastic effects after exposure to radiation at low dose rate (10^{-2} Sv^{-1}).

Exposed population	Cancer		Heritable effects		Total detriment	
	2007	1990	2007	1990	2007	1990
Whole	5.5	6.0	0.2	1.3	5.7	7.3
Adult	4.1	4.8	0.1	0.8	4.2	5.6

that the new values were based upon data on cancer incidence weighted for lethality and life impairment, whereas the 1990 values were based upon fatal cancer risk weighted for non-fatal cancer, relative life years lost for fatal cancers and life impairment for non-fatal cancer. The decimal places in the table are not intended to indicate a high level of precision; they are simply the outcome of ICRP's calculations.

Thus, the combined detriment from stochastic effects has remained unchanged at around 5% Sv^{-1}. If anything, the total detriments are somewhat lower which is largely a reflection of the reduction in the risk of serious heritable effects.

4. Risk to embryo and foetus

Regarding the risks to embryo and foetus, ICRP has essentially confirmed the position that it took previously, which is that at doses under 100 mGy, lethal effects in the pre-implantation period of embryonic developments will be very infrequent. As far as the induction of malformations is concerned, ICRP judges that there is a true dose-threshold of around 100 mGy. As far as severe mental retardation is concerned, it supports a dose-threshold of at least 300 mGy during the most sensitive pre-natal period (8–15 weeks post-conception). It also concludes that any effects on IQ following *in utero* exposure to less than 100 mGy would be of no practical significance and judges that the life-time cancer risk following *in utero* exposure will be similar to that following irradiation in early childhood, i.e. at most, about three times that of the population as a whole.

5. Radiation weighting factors and equivalent dose

In its 1990 recommendations [5], ICRP applied radiation weighting factors (w_R), based on the RBE of the radiation of interest, to the absorbed dose in an organ or tissue to derive the equivalent dose. This approach has been maintained in the new recommendations, but there has been some adjustment to the values used (see table 2).

The main changes are: the value for protons has been reduced from 5 to 2; charged pions have been introduced and also assigned a value of 2; the values for neutrons are now given only as a continuous function of energy (previously a step function was also recommended [5]).

Table 2. Recommended radiation weighting factors.

Radiation type	Radiation weighting factor, w_R
Photons	1
Electrons and muons	1
Protons and charged pions	2
Alpha particles, fission fragments, heavy ions	20
Neutrons	A continuous function of neutron energy

Table 3. Recommended tissue weighting factors.

Tissue	Tissue weighting factor, w_T	Sum of w_T values
Bone-marrow (red), colon, lung, stomach, breast, remainder tissues[a]	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
Total		1.00

[a] Remainder tissues: Adrenals, extrathoracic (ET) region, gall bladder, heart, kidneys, lymphatic nodes, muscle, oral mucosa, pancreas, prostate (♂), small intestine, spleen, thymus, uterus/cervix (♀).

6. Tissue weighting factors and effective dose

In its 1990 recommendations [5], ICRP also defined the quantity effective dose as the sum of the equivalent doses in the principal tissues and organs, each weighted by a tissue weighting factor (w_T). Revised values of w_T are given in the new recommendations (see table 3) derived from the data on the risks of cancer induction and heritable disease. Four changes are noted. First, two more tissues have been included (brain and salivary glands). Second, the value assigned to gonads has been reduced from 0.20 to 0.05 reflecting the reduced significance of hereditary disease. Third, the w_T for breast has been increased from 0.05 to 0.12 in the light of recent epidemiological findings and the focus on cancer incidence in the detriment calculations. And fourth, the weighting of the so-called 'remainder tissues' has been modified so as to avoid earlier minor deviations from the desired additivity of effective doses.

ICRP emphasises that the effective dose provides a measure of radiation detriment for protection purposes only. It does not provide an individual-specific dose and should not be used for epidemiological evaluations. Furthermore, the collective effective dose, the main use of which is in the optimisation of radiological protection, should not be used in epidemiological studies and in assessing the hypothetical number of cases of cancer or heritable disease in an exposed population.

7. System of radiological protection

In its 1990 recommendations [5], ICRP subdivided its system of protection into '*practices*' and '*intervention*'. The three well-known principles of justification, optimisation of protection and dose limits applied to practices. Justification, in the sense of doing more good than harm, and optimisation of protection also applied to intervention, but dose limits did not. ICRP now considers that it is a better to define three categories of exposure situations, namely: *planned exposure situations* which involve the deliberate introduction and operation of sources; *emergency exposure situations*, which require urgent action in order to avoid or reduce undesirable consequences; and *existing exposure situations*, which include prolonged exposure situations after emergencies. In adopting this approach, ICRP affirms that its system of protection can be applied in principle to any situation of radiation exposure. Similar procedures are used for deciding on the extent and level of protective actions, regardless of exposure situation. In particular, ICRP considers that this may lead to an enhanced implementation of protection for what previously were categorised as interventions.

The principles of protection remain as previously: justification and optimisation, which apply universally to all three exposure situations; and dose limits, which apply only to planned

Table 4. Recommended dose limits in planned exposure situations.

Type of limit	Occupational, mSv in a year	Public, mSv in a year
Effective dose	20, averaged over 5 years, with no more than 50 mSv in any one year	1 (exceptionally, a higher value of effective dose could be allowed in a year provided that the average over 5 years does not exceed 1 mSv in a year)
Equivalent dose to lens of the eye	150	15
Equivalent dose to skin	500	50
Equivalent dose to hands and feet	500	—

exposure situations, except those involving medical exposure of patients. ICRP also concludes that the slight differences in nominal detriment coefficients between those derived in the new recommendations and those given in its 1990 recommendations (see table 1) are of no practical significance and therefore has not changed the dose limits. The limits are reproduced in table 4.

Additional restrictions apply to the occupational exposure of pregnant women. If a female worker has declared that she is pregnant, ICRP has recommended that the level of protection for the embryo/foetus should be broadly similar to that provided for members of the public.

8. Dose constraints and reference levels

The term 'dose constraint'[1] was introduced in the 1990 recommendations. Their stated function was 'to limit the inequity likely to result from the inherent economic and social judgements' in the optimisation of protection in practices. Thus, they are intended to restrict the range of options that should be considered in the optimisation process. In the case of public exposure, they provide for the possibility that a member of the public could be exposed to be a number of separate sources and still remain within the overall dose limit. A dose constraint might therefore be used by a regulatory body as the basis for establishing authorised limits for the discharge of radioactive material to the environment. In the case of occupational exposure, where workers are normally exposed to only one significant source, the dose constraint helps to focus the attention on good management of the exposure of workers, in the design of facilities, and in the planning of operations. ICRP has retained the term with the same meanings for planned exposure situations.

The term 'diagnostic reference level' is now used in the context of the optimisation of the protection of patients undergoing medical exposure. These are intended to act as a benchmark figure against which doses from common diagnostic procedures can be compared.

ICRP now uses the term 'reference level' in the context of emergency and existing exposure situations 'for the restriction on 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'. As with dose constraints, options resulting in doses greater in magnitude than the reference level should be rejected at the planning stage.

[1] The term 'risk constraint' was also introduced in the 1990 ICRP recommendations. Dose constraints relate to exposures normally or routinely received, while risk constraints relate to potential exposures (i.e. those that are not expected to be delivered with certainty but may result from an accident or other event of a probabilistic nature). The concept of risk constraint is not considered further in this review, although the new recommendations do also deal with the concept.

Table 5. Framework for dose constraints and reference levels.

Bands of effective dose, mSv (acute or annual)	Characteristics	Requirements	Examples
20–100	Controlled by action on exposure pathway	Consider reducing doses	Reference level for radiological emergency
1–20	Controlled by action on source or exposure pathway	For planned exposure situations, individual dose assessment and training	Constraints for occupational exposure Constraints for comforters and carers of patients treated with radiopharmaceuticals Reference level for radon in dwellings
<1	Controlled by action on source	Periodic cheques on exposure pathway	Constraints for public exposure in planned situations

9. Numerical values

ICRP considers that all numerical values for dose constraints and reference levels can be grouped into 3 bands. These bands are given in summary form in table 5. The upper end of the top band was set based on considerations of deterministic effects. The upper ends of the other two bands are equivalent to the dose limits for workers and the public, respectively.

The lower band relates to public exposure from planned exposure situations and is entirely consistent with earlier guidance from ICRP of no more than 0.3 mSv in a year from waste management operations [7] and no more than 0.1 mSv in a year from situations of prolonged exposure [8].

The middle band relates to all exposure situations—planned, emergency and existing. Dose constraints for occupational exposure from planned exposure situations should be below the average dose limit of 20 mSv in a year and based on well-designed or well-managed operations [9]. Similarly, dose constraints for those who comfort and care for patients (i.e. friends and members of the family) already recommended by ICRP are of the order of a mSv or so up to 5 mSv/episode [10]. ICRP had also previously recommended that the action level for remedial action for radon in dwellings be selected within the range of about 3–10 mSv for the annual effective dose [11].

The upper band relates to reference levels for emergency exposure situations. They relate to projected or residual doses and therefore complement the intervention levels given previously by ICRP which relate to the dose to be averted by the countermeasure [12]. As ICRP notes 'the reference level would act as a benchmark for evaluating the effectiveness of protective actions and as one input into the need for establishing further actions'. Further guidance on this matter can be expected in due course as ICRP currently has a Task Group working on emergency exposure situations.

10. Protection of the environment

In its 1990 recommendations, ICRP stated 'the Commission believes that the standard of environmental control needed to protect man to the degree currently thought desirable will ensure that other species are not put at risk. Occasionally, individual members of non-human species might be harmed, but not to the extent of endangering whole species or creating imbalance between species'. The interest in environmental protection has greatly increased since then and ICRP now sees the need to develop guidance on the matter[2]. In its new recommendations, ICRP indicates its intentions to develop a clearer framework 'in order to assess the relationships between exposure and dose, and between dose and effect, and the consequences of such effects, for non-human species, on a common scientific basis'. The framework will be developed through the establishment of relevant data for a small set of reference animals and plants that are typical of 'the major environments'. At this stage, however, ICRP does not propose to set any form of 'dose limits' with respect to environmental protection.

11. Conclusions

In broad terms, the changes that have been introduced in the new recommendations are of two types, the first is technical and the second is presentational.

The technical changes are the adjustments to the weighting factors, w_R and w_T. The new values, combined with the new computational phantoms of the human body will necessitate recalculation of the relevant conversion coefficients. The overall impact, however, is unlikely to be substantial and ICRP advises against the recalculation of any doses received in the past.

The presentational changes are in the approach to radiological protection, with three categories of exposure situation replacing the previous categorisation into practices and intervention. This categorisation should ensure that attention is focused on those exposures that can reasonably be controlled. Furthermore, the categorisation of dose constraints and reference levels into three bands should assist in rationalising the many values of dose restriction that have been given in earlier ICRP publications.

Overall, these new recommendations are more a matter of consolidation of the previous recommendations and subsequent guidance, any changes that have been introduced being in the nature of refinements rather than fundamental. The fact that this is so should provide confidence that the system of protection established by and large in its present form several decades ago has reached a certain level of maturity and remains appropriate and therefore that no major changes in the systems of control of radiation exposure that have been established throughout the world would appear to be necessary. As ICRP itself states, '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 improving the already high standards of protection' and 'these revised recommendations should not imply any substantial changes to radiological protection regulations that are based on its previous recommendations and subsequent policy guidance'.

References

[1] Clarke R H 1999 Control of low-level radiation exposure: time for a change? *J. Radiol. Prot.* **19** 107–15

[2] ICRP 2001 A report on progress towards new recommendations: a communication from the International Commission on Radiological Protection *J. Radiol. Prot.* **21** 113–23

[3] ICRP 2003 The evolution of the system of radiological protection: the justification for new ICRP recommendations *J. Radiol. Prot.* **23** 129–42

[4] ICRP 2007 Recommendations of the International Commission on Radiological Protection *ICRP Publication 103; Ann. ICRP* **37** (2–4)

[2] ICRP's initial thoughts on the protection of the environment are given in [13].

[5] ICRP 1991 Recommendations of the International Commission on Radiological Protection *ICRP Publication 60; Ann. ICRP* **21** (1–3)

[6] Preston D L, Shimizu Y, Pierce D A, Suyama A and Mabuchi K 2003 Studies of mortality of atomic bomb survivors. Report 13: solid cancer and non-cancer disease mortality 1950–1997 *Radiat. Res.* **160** 381–407

[7] ICRP 1998 Radiological protection policy for the disposal of radioactive waste *ICRP Publication 77; Ann. ICRP* **27** (Suppl.)

[8] ICRP 1999 Protection of the public in situations of prolonged radiation exposure *ICRP Publication 82; Ann. ICRP* **29** (1/2)

[9] ICRP 1997 General principles for the radiation protection of workers *ICRP Publication 75; Ann. ICRP* **27** (1)

[10] ICRP 2004 Release of patients after therapy with unsealed sources *ICRP Publication 94; Ann. ICRP* **34** (2)

[11] ICRP 1994 Protection against radon-222 at home and at work *ICRP Publication 65; Ann. ICRP* **23** (2)

[12] ICRP 1993 Principles for intervention for protection of the public in a radiological emergency *ICRP Publication 63; Ann. ICRP* **22** (4)

[13] ICRP 2003 A framework for assessing the impact of ionising radiation on non-human species *ICRP Publication 91; Ann. ICRP* **33** (3)