

STATEMENT FROM THE 1978 STOCKHOLM MEETING OF THE INTERNATIONAL COMMISSION ON RADIOLOGICAL PROTECTION

The International Commission on Radiological Protection (ICRP) held its annual meeting in Stockholm in May, 1978, together with its four expert committees. Sixty-five individuals from seventeen countries were present to review the Commission's current work and to decide on a programme of work for the next 4-year period. Representatives or observers were also present from the Commission of the European Communities, the International Atomic Energy Agency, the International

Commission on Radiation Units and Measurements, the International Electrotechnical Commission, the International Radiation Protection Association, the International Society of Radiology, the OECD Nuclear Energy Agency, the United Nations Environment Programme, the United Nations Scientific Committee on the Effects of Atomic Radiation and the World Health Organization.

ICRP PUBLICATION 26

The Commission also reviewed its 1977 recommendations (*ICRP Publication 26*) and identified the following points that require clarification.

Estimates of radiation risk

The risk factors given by the Commission in *ICRP Publication 26* (paragraphs 36-60) are based on advice received from its committee on radiation effects. They are consistent with data available in the scientific literature and with information included in the 1977 report of the UNSCEAR.

In the light of its continuing review of the published information on the epidemiological and radiobiological evidence of radiation risks to man, the Commission has concluded that the information available up to May 1978 does not call for changes in the risk factors given in *ICRP Publication 26*. These risk factors

are intended to be realistic estimates of the effects of irradiation at low annual dose equivalents (up to the Commission's recommended dose-equivalent limits).

In dealing with the stochastic effects of ionizing radiation the Commission recommended (in paragraph 105 of *ICRP Publication 26*) weighting factors for application to the dose equivalent in various organs and tissues. The Commission wishes to point out that it did not intend the hands and forearms, the feet and ankles, the skin and the lens of the eye to be included in the "Remainder". These tissues should therefore be excluded from the computation of $\sum_T w_T H_T$. In order to prevent the occurrence of non-stochastic effects, the Commission recommends that the relevant dose-equivalent limits given in paragraph 103 should apply to these tissues.

In the assessment of detriment from exposure of population groups a small risk of fatal cancer resulting from exposure of

the skin may need to be taken into account, for example in the case of exposure of the whole skin from soft beta radiation. In this case a risk factor in the region of 10^{-4} Sv^{-1} may be applied to the mean dose over the entire surface of the skin, which would correspond to a value of w_T of about 0.01.

The Commission's occupational dose limits are intended to apply to all workers, and are based on average values of risk factors for male and female adults. The variations of risk with exposure at different ages in the two sexes, referred to in paragraph 38 of *ICRP Publication 26*, are discussed in *ICRP Publication 27*, a report to the Commission on "Problems involved in developing an index of harm". This report also reviews the basis for the selection, in *ICRP Publication 26* (paragraph 60) of an average genetically significant fraction (0.4) of occupational exposure and the mean mortality risk factor (10^{-2} Sv^{-1}) for both sexes and all ages.

Effective dose equivalent

The Commission recommends that the sum $\sum_T w_T H_T$ (see paragraph 104 of *ICRP Publication 26*) be called the effective dose equivalent (denoted H_E).

Modifications to the text of ICRP Publication 26

The Commission believes that the following textual revisions to certain paragraphs in *ICRP Publication 26* will clarify their meaning.

- (38) The fourth and fifth sentences should read:
For protection purposes therefore, sufficient accuracy is obtained by using a single effective dose-equivalent limit for all workers regardless of age or sex. This limit is based upon the average-risk levels described

below for the various organs or tissues.

- (79) The first sentence should read:
The Commission's dose-equivalent limits for workers are intended to apply to the sum of the dose equivalent resulting from external exposure during 1 year and the committed dose equivalent from that year's intake of radionuclides.
- (79) Add the following sentence at the end of the paragraph:
Similar principles apply to the dose-equivalent limits for members of the public.
- (89) In the second sentence the following should be deleted:
"are intended as guides for planning purposes, and thus"
- (93) In the first sentence the following should be deleted:
"are intended for planning purposes and"
- (107) The end of the last sentence should read:
. . . namely, the limit to the deep and shallow dose-equivalent indices $H_{1,d}$ and $H_{1,s}$ (see paragraph 108) and ALI (see paragraph 109).
- (108) The last part of the first sentence should read:
. . . it is possible to assess the *maximum* value of dose equivalent that would occur at a depth of 1 cm or more in a 30 cm diameter sphere (the deep dose-equivalent index, $H_{1,d}$).
- (108) The following sentence should be added at the end of the paragraph:
In addition, the shallow dose-equivalent index (the maximum dose equivalent in the shell from 0.07 mm to 10 mm depth in the 30 cm sphere) should be limited to 500 mSv to

provide protection for the skin. In practical situations, these limits on the deep and shallow dose-equivalent indices will limit the annual dose equivalent in the lens of the eye to less than 300 mSv.

(110) The paragraph should read:

When external and internal exposures are received together, the Commission's recommended dose limits will not be exceeded if both the following conditions are met:

$$\frac{H_{I,d}}{H_{E,L}} + \sum_j \frac{I_j}{I_{j,L}} \leq 1$$

and

$$\frac{H_{I,s}}{H_{sk,L}} \leq 1$$

where $H_{I,d}$ is the annual deep dose-equivalent index, $H_{I,s}$ is the annual shallow dose-equivalent index, $H_{E,L}$ is the annual limit of the effective

dose equivalent (50 mSv), $H_{sk,L}$ is the annual limit of dose equivalent in the skin (500 mSv), I_j is the annual intake of radionuclide j , $I_{j,L}$ is the annual limit of intake for radionuclide j .

(113) The second sentence should read:

In such circumstances external exposures and intakes of radioactive material may be permitted provided that the sum of the dose equivalent from the external exposure and the committed dose equivalent from the intake of radionuclides does not exceed twice the relevant annual limit in any single event, and, in a lifetime, five times this limit.

(187) In the first sentence, the term "dose-equivalent limit" should be replaced by "system of dose limitation".

(238) In the last sentence the term "monitoring of control" should read "monitoring or control".

SECONDARY LIMITS FOR INTERNAL EXPOSURE

The first group of values of annual limits of intake (ALI) for radiation workers, together with the text of a report that includes the methods of calculation and metabolic data for 22 elements, were available at the Commission's meeting in Stockholm, and are now in the course of publication in a report to be entitled "Limits for intakes of radionuclides by workers". Similar information on additional elements

will be published as soon as it becomes available.

Organ dose estimates for members of the public cannot be derived directly from the data given for workers because of differences in metabolism, organ size and duration of exposure. The Commission is therefore planning to issue specific guidance on the assessment of internal exposure of members of the public.

CURRENT WORK OF ICRP

Four reports are being completed, preparatory to publication in the *Annals of the ICRP*. The titles of the reports are: —

— Biological effects of inhaled radionuclides.

— Limits for intakes of radionuclides by workers (to replace *ICRP Publication 2*).

— Radionuclide releases into the environment: assessment of doses to man.

- Monitoring for internal contamination due to occupational exposure (to replace *ICRP Publications 10 and 10A*).
- Risks to the human embryo and foetus – with special reference to occupational exposure of women.
- Doses to patients from radiopharmaceuticals.
- Protection in all fields in which ionizing radiations are employed in medicine.
- The practical application of the Commission's recommendations.
- Application of the ICRP system of dose limitation to practices that modify man's exposure to natural background radiation.

A full programme of work is planned for the Commission and its committees and task groups in the immediate future. Subjects receiving urgent review include the following:

- Non-stochastic effects of irradiation.
- Risks and RBEs of high-LET radiation for carcinogenesis.
- Somatic and hereditary risks of irradiation at low doses.

During its term of office the Commission plans to prepare revised versions of its Publications 7, 10, 12, 13, 15/21, 16, 17 and 24.

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F. D. SOWBY,
*Scientific Secretary,
 ICRP,
 Clifton Avenue,
 Sutton, Surrey, SM2 5PU*

STATEMENT AND RECOMMENDATIONS OF THE INTERNATIONAL COMMISSION ON RADIOLOGICAL PROTECTION FROM ITS 1980 MEETING

The International Commission on Radiological Protection (ICRP) held its annual meeting in Brighton, England from March 17–26, 1980, together with all four of its committees. In addition, representatives attended from the Commission of the European Communities, the International Atomic Energy Agency, the International Commission on Radiation Units and Measurements, the International Commission for Protection against Environmental Mutagens and Carcinogens, the International Electrotechnical Commission, the International Organization for Standardization, the International Radiation Protection Association, the OECD Nuclear Energy Agency, the United Nations Environment Programme, the United Nations Scientific Committee on the Effects of Atomic Radiation and the World Health Organization.

The Commission and its committees reviewed the extensive programme of work being performed within the ICRP, including reports on occupational exposure limits for radon, on the dose-equivalent limit for the lens of the eye, and a survey of the currently available information on estimates of radiation risk. The conclusions of these three points are included in this statement (*q.v.*).

The Commission authorised Committee 1 to establish a new task group to define non-stochastic effects and to advise on their bearing on ICRP recommendations. The Commission reviewed the committee's work proceeding on other topics, such as the effects of high LET radiation, the risks to the embryo and foetus from irradiation, and the combined carcinogenic effect of ionising radiation and chemicals.

Committee 2 is completing its report *Limits for Intakes of Radionuclides by Workers (ICRP Publication 30)*. Part 1 of the report, containing ALIs for radioisotopes of twenty-one elements has already been published. Parts 2 and 3, to include ALIs for 30 and 44 further elements, will be published in 1980/81, along with supplements to each of the parts. The committee is also preparing a report on doses to patients from radiopharmaceuticals, and is planning to prepare a statement on the exposure of members of the public to radioactive material.

Committee 3 is currently preparing revised versions of the medical aspects of *ICRP Publication 15 and 21—Protection Against Ionizing Radiation from External Sources*—as well as of *ICRP Publication 16—Protection of the Patient in X-ray Diagnosis*; these are expected to be completed in 1981.

A task group of Committee 4 has submitted a draft of a report on the application of the Commission recommendation on the need for the optimisation of radiation protection. This is expected to be completed in 1981. Committee 4 is also preparing revised versions of *ICRP Publication 7—Principles of Environmental Monitoring Related to the Handling of Radioactive Materials*; *Publication 10—Evaluation of Radiation Doses to Body Tissues from Internal Contamination due to Occupational Exposure*; *Publication 10a—The Assessment of Internal Contamination Resulting from Recurrent or Prolonged Uptakes*; *Publication 12—General Principles of Monitoring for Radiation Protection of Workers*; *Publication 13—Radiation Protection in Schools*; and *Publication 24—Radiation Protection in Uranium and Other Mines*, which will then conform to the policies enunciated in the Commission's recommendations in *ICRP Publication 26*. Other topics being considered by the committee include practices that modify man's exposure to natural background, and the general principles for protection of the public in the event of radiation accidents.

As a result of its discussions at the Brighton meeting, the Commission decided to issue statements on the following points:

Lens of the eye

In *ICRP Publication 26* the Commission concluded that a dose equivalent in the lens of the eye accumulated over a working lifetime of 15 Sv would not produce opacities that would interfere with vision. The Commission's committee on radiation effects (Committee 1) has reviewed the available human information and has concluded that, at this level of accumulated dose equivalent, some opacities might be produced which, while not in themselves detrimental to vision, might develop without further exposure to the point of causing deterioration of vision.

Although the combined effects of the present dose-equivalent limit for skin and the effective dose-equivalent limit make it very unlikely that dose equivalents in the lens would reach 15 Sv in a working lifetime, the Commission has decided to reduce its recommended dose-equivalent limit for the lens of the eye from 0.3 Sv in a year to 0.15 Sv in a year.

In most practical situations, the limits on the deep and shallow dose-equivalent indices will achieve compliance with the revised limit for the lens. The Commission therefore continues to recommend the use of the deep and shallow indices for estimates of dose equivalent at corresponding depths.

Recent estimates of radiation risk

The Commission in its 1978 Statement* referred to information available to May 1978. The Commission has reviewed the very extensive epidemiological and radiobiological information that has become available up to March 1980. Apart from the change recommended for the lens of the eye, the Commission has concluded that the new information does not call for changes in the risk factors for stochastic effects or the dose-effect relationships for nonstochastic effects underlying the dose-equivalent limits recommended in *ICRP Publication 26*.

Annual limits for intakes of radionuclides

In *ICRP Publication 30* the Commission is now in process of recommending Annual Limits for Intakes (ALIs) of Radionuclides by Workers that replace its earlier recommendations in *ICRP Publication 2* (1960). The system of dose limitation now used by the Commission takes account of all body tissues that are irradiated following intake of the radioactive material instead of only the critical organs as previously. The system ensures that the total risk from irradiation of any combination of organs does not exceed that from irradiation of the whole body at the recommended dose-equivalent limit. This summation of risks from individual organs can now be made on the basis of the much better knowledge of the sensitivity of each organ to radiation damage than was available 20 years ago. These improvements have in themselves caused only small changes in the values of ALI for individual radionuclides, but might require a reduction in the limits for some mixtures of radionuclides.

Much larger changes, however, have resulted from improved knowledge of the uptake and retention of radionuclides in body tissues, and of the radioactive decay schemes of some radionuclides. As a result of this new information, a few values of ALI now recommended in Part 1 of *Publication 30* (1979) are substantially greater, and others substantially smaller, than those that can be derived from *ICRP Publication 2*.

*Reference: 1978 Statement. Annals of ICRP, Vol. 2, No. 1, 1978.

Occupational exposure to Radon-222 and its daughters

The Commission reached a conclusion about the appropriate limit for occupational exposure to radon and its daughter nuclides. It took as the basis for this limit the level of risk corresponding to the present limit on effective dose-equivalent of 50 mSv in a year. There are several ways of assessing the relationship between the inhaled amount of radon and its daughters and the level of risk. The dosimetric method used for most radioactive materials in *ICRP Publication 30* and a similar method, slightly modified because of the special problems of the short-lived daughters of radon, have both been used. Epidemiological studies have provided a third method. There is a reasonably close agreement between the results of these methods, and the Commission recommends a limit which is at the low end of the dosimetric results and which is consistent with the epidemiological conclusions. These conclusions are not specific to radon because they relate to the consequences of exposure to the whole mining environment which includes some potentially hazardous nonradioactive agents. A Commission report is being prepared for publication.

The recommended annual limit for intake by inhalation, the ALI, for radon-222 daughters, in terms of inhaled potential α -energy, is 0.02 J in a year. The corresponding derived air concentration (see *ICRP Publication 30*) expressed in the practical units previously widely used is then 0.4 working levels.

The system of dose limitation of the Commission requires the addition of exposures to external radiation and intakes of radioactive material. In the special case of exposure in uranium mines this additivity has the effect of requiring the inhalation of radon and its daughters to be kept below the recommended limit by an amount that depends on the exposure to external radiation and ore dust. A reduction of 20% is common.

These recommendations are intended for competent authorities for general application and they may not always be appropriate for application in particular cases. The Commission is aware that some mining conditions are such that it may not be possible to operate within the combined limits recommended by the Commission on a year to year basis. The national authorities will then have to take decisions on how best to deal with these few, but difficult, situations.

Assessment of total detriment

In *ICRP Publication 26*, the Commission introduced the effective dose equivalent as the sum of the dose equivalents in individual organs H_T , each weighted by an organ weighting factor w_T :

$$H_E = \sum_T w_T H_T.$$

The organ weighting factors were chosen by the Commission to reflect the relative risk of death from cancer or occurrence of severe hereditary effects in the first two generations after uniform whole body exposure. It was considered that, in assessing the risk for an individual, in contrast to that for the population as a whole, the hereditary effects of essential importance were those that might be expressed in the children or grandchildren of the exposed individual. If only one organ (T) were exposed, the risk would be $w_T H_T \cdot r$, where r is the risk per unit dose equivalent in the case of uniform whole body exposure. As reported in *ICRP Publication 27*, the value of r was assumed to be $1.65 \cdot 10^{-2} \text{ Sv}^{-1}$ ($1.25 \cdot 10^{-2} \text{ Sv}^{-1}$ for fatal cancers and $0.4 \cdot 10^{-2} \text{ Sv}^{-1}$ for the hereditary effects).

The effective dose equivalent was introduced as the quantity to be compared with the Commission's basic dose limits in the protection of individual workers or members of the public. It was recognised, and further illustrated in *ICRP Publication 27*, that the actual risk at a given effective dose equivalent would depend on sex and age, but the Commission regarded these

variations as sufficiently small to justify the use of average values to apply under most circumstances (paragraphs 38 and 106 of *ICRP Publication 26*).

The variation of the genetic risk with age was given special attention. The average risk of hereditary harm of a severe nature in the first two generations was assumed to be 10^{-2} Sv^{-1} in a population if based on the genetically significant dose. In a general population with normal age distribution, the risk would be expected to be 40% (the ratio of mean reproductive age to mean life expectancy) of this value. This gave the weighting factor $w_T = 0.4/1.65 = 0.25$ recommended for the gonads.

If a population of *workers* had uniform age distribution, the genetic risk (for the first two generations) may be assumed to be 25% (the ratio of 30–18 to 65–18) of the risk per unit of genetically significant dose, because of the shorter period of risk within the reproductive age. This difference, which would strictly have meant a total risk of $1.50 \cdot 10^{-2} \text{ Sv}^{-1}$ and a gonad weighting factor $w_T = 0.25/1.50 = 0.17$ for workers, was not considered sufficiently large to justify the use of different weighting factors and reference risk values for workers and members of the public. The Commission has found no reason to change this policy: the accuracy of the risk and dose estimates would not justify any more accurate procedure in the application of the dose limits.

The weighting factors and the risk estimates did not include the genetic harm *after* the first two generations, because this was considered less relevant in the limitation of the risk to which individuals are exposed. Nor did they include non-lethal cancer. The justification of the latter—deliberate—omission was that the acceptability of the detriment in relation to the dose limit had been based on comparison with the risk of *lethal* effects in safe industries. In paragraph 97 of *ICRP Publication 26*, the Commission noted that this is likely to be a conservative comparison, since experience has shown that the non-lethal effects of radiation are much less frequent than the non-lethal effects encountered in other safe occupations.

Since the publication of *ICRP Publication 26*, there has been an increased use of the effective dose equivalent not only for comparison with the dose limits but also in assessments of collective dose in optimisation procedures. Questions have been raised whether it is then appropriate to use the effective dose equivalent without consideration of the total genetic harm and the non-lethal cancers.

The Commission has reviewed this matter and has reached the following conclusions with regard to the use of the effective dose equivalent in optimisation assessments. The addition of the future genetic harm in the case of uniform whole body exposure would add a further risk of $0.4 \cdot 10^{-2} \text{ Sv}^{-1}$ in the case of the public, or rather less in the case of the average worker, to the total assumed risk of $1.65 \cdot 10^{-2} \text{ Sv}^{-1}$; i.e. it would increase the total detriment by at most 24%. In the less likely case that the gonads would receive the dominating dose, the genetic harm would be twice that implied by the effective dose equivalent alone.

The weight of the additional detriment attributed to nonlethal cancer would depend upon the weight to be attached to a given length of time lost from normal health (during illness prior to cure) relative to an equal period of life lost as a result of death from fatal cancer. If that relative weight (*K*) is taken to be 0.1 (as in *ICRP Publication 27*), the addition of the detriment due to nonlethal cancer and the induction of benign tumours would only increase the total non-genetic detriment by 2% in the case of uniform whole-body exposure. If organs such as thyroid and skin, for which cancers have a low fatality rate, are irradiated alone and *K* is taken to be as high as 0.5, the total detriment will approach about twice that implied by the use of the effective dose equivalent alone. In most cases of external exposure or exposure to mixtures of radionuclides, however, the use of the effective dose equivalent alone would not significantly underestimate the total detriment.

It may be added that, in the original use of the dose equivalent for the protection of the worker, the non-stochastic dose limit will limit the maximum risk after exposure of single organs to a greater extent than indicated by the organ weighting factors derived on the basis of the risk of stochastic effects.

In the case of selective irradiation of the thyroid, the non-stochastic limit of 0.5 Sv y^{-1} is more restrictive than the implied stochastic limit based on the induction of fatal thyroid cancers (1.7 Sv y^{-1}). It would remain more restrictive than the stochastic limit even if this were based on the induction of all thyroid cancers, whether fatal or not, and of benign tumours also. If all tumours were taken into account in this way, the implied stochastic limit would become 1.3 Sv y^{-1} if K were taken as 0.1, or 0.7 Sv y^{-1} for $K = 0.5$, as discussed above.

Future meetings

The Commission's committees will each meet again towards the end of 1980 to review the progress of their work and to complete reports that will be considered by the Commission when it meets in Tokyo in March 1981.

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F. D. Sowby
Scientific Secretary
ICRP
Clifton Avenue
Sutton, Surrey, SM2 5PU
England

STATEMENT FROM THE 1983 MEETING OF THE INTERNATIONAL COMMISSION ON RADIOLOGICAL PROTECTION

The International Commission on Radiological Protection met in Washington, USA, in October, 1983. During the meeting the Commission identified the following points requiring clarification.

Annual Limits on Intakes (ALI) and Derived Air Concentrations (DAC) for Members of the Public

Introduction

Exposure to radioactive materials must be constrained by the relevant dose-equivalent limits recommended in *ICRP Publication 26* (1977) to reduce stochastic effects to an acceptable level and to prevent non-stochastic effects from occurring in the organs and tissues of the body. An ALI of a radionuclide or a DAC for submersion in an atmosphere contaminated with a radioactive chemically inert gas is then determined by the dose equivalent to which the organs and tissues of the body are committed as the result of such exposures. The values of ALI and DAC recommended in *ICRP Publication 30* are for workers based on a Reference Man; the factors by which they would differ from those that would be appropriate for members of the public are many and various, as discussed below.

Dose-equivalent Limits

For stochastic effects in members of the public the Commission recommends that the committed effective dose equivalent from exposure to radioactive materials in any year be limited to 5 mSv, and, for repeated exposures over prolonged periods, that it would be prudent further to restrict this to 1 mSv from each year of lifelong exposure.

For an individual exposed over the whole lifetime, the committed effective dose equivalent will depend partly on the age-specific relationship between annual intakes and committed dose equivalent and partly on age-specific factors influencing the annual intake. In practice, the exposure of the public will be limited by applying environmental constraints aimed at ensuring an adequate limitation on dose for the age group in which the committed effective dose equivalent will be the greatest. For most nuclides, a limit on the annual committed effective dose equivalent of 5 mSv applied to this group will result in a lifetime average exposure below the limit of 5 mSv but not necessarily below the value of 1 mSv. The ratio of the lifetime average to the limit of 5 mSv in a year will depend on the nuclide and also on factors that are determined by environmental considerations and by the lifestyle of the individuals concerned.

The resulting variations are too large for it to be appropriate for the Commission to recommend average or typical values of the various parameters as it has been able to do for workers, and each situation must therefore be dealt with on its own. The Commission can, however, give guidance on the metabolic and dosimetric models that provide an age-specific relationship between intake in a year and the resulting committed effective dose equivalent.

The use of the committed effective dose equivalent calls for two remarks. In *ICRP Publication 30*, the Commission uses an integrating time of 50 years in computing the committed dose equivalent in an organ of a worker. The Commission believes that this period is also adequate for a member of the public since the correction factor would be no more than

70/50. Exceptionally, the more complicated, but more rigorous, approach of integrating from the age of intake up to the age of, say, 70 years could be applied.

The second remark concerns non-stochastic effects. Many of the ALIs for workers are limited by the need to restrict the accumulated dose in single organs to a value small enough to avoid significant non-stochastic effects. In these cases, an intake limit based on committed effective dose equivalent alone would not be adequate. For members of the public, the lifelong average annual effective dose equivalent will not exceed 1 mSv, giving a maximum lifetime effective dose equivalent of less than about 70 mSv. The smallest organ weighting factor used in deriving the effective dose equivalent is 0.03, so that the greatest possible organ dose equivalent will only just exceed 2 Sv in a lifetime. The Commission's dose limit for single organs of members of the public, which is chosen to avoid the occurrence of non-stochastic effects, corresponds to a lifelong total dose equivalent of about 3.5 Sv. The limitation of the committed effective dose equivalent is therefore sufficient to provide compliance over a lifetime with the limit for single organs, thus avoiding non-stochastic effects.

Body Size

Even if there were no differences with age in the uptake and retention of a radionuclide, the committed dose equivalent in a particular tissue per unit intake of the radionuclide would be greater in children than in adults (and the ALI correspondingly less) because of the smaller masses of their organs and tissues. For the extreme case of a child in the first year of life, whose body mass at age 6 months is about 7 kg (ICRP, 1975), the committed dose equivalent in an organ or tissue per unit intake of a short-lived radionuclide emitting poorly penetrating radiations would be about 10 times greater than for a 70 kg adult. As described by Adams (1981) this factor would be about 2 for intakes of long-lived radionuclides that are long retained in body tissues (e.g. plutonium-239) because the child grows during the prolonged irradiation. For radionuclides emitting penetrating photons the modifying factors for body size are smaller, the committed dose per unit intake of a radionuclide being approximately inversely proportional to body mass^{2/3} rather than body mass (Adams, 1981). Although organ mass is not a constant proportion of body mass, and the shapes and relative positions of organs change with age, these differences will usually have only a small effect on the factors discussed above. Therefore, to allow for body size alone, committed dose equivalents per unit intake for young members of the public will be greater (and ALIs correspondingly less) than those for workers by factors ranging from less than 2 up to 10, the actual value for any age depending not only on the mass of the individual but also on the types of radiation emitted by the radionuclide and its retention in body tissues.

The values of DAC for submersion in radioactive chemically inert gases that are given in *ICRP Publication 30* for workers would also need to be modified to provide corresponding values for members of the public who have different dimensions and mass. In most cases this effect on a DAC for submersion would be small, but the annual duration of exposure may be longer than the 2000 hours assumed for workers.

Metabolism

Children can have a very different metabolism from that of adults, taking up different fractions (often more) of a chemical substance from the blood into their organs and tissues and eliminating it at different rates (often more rapidly). For a radioisotope of a chemical element in the substance, uptake and retention into the organs and tissues of the body will additionally depend on its radioactive half-life. It would be misleading to generalize about the effect this might have on the relative values of ALI for people of different ages, bearing in mind the

complex interplay of rates of biological uptake and loss, together with radioactive decay in the many organs and tissues that might determine an ALI, and it would be prudent to consider carefully each separate case. In fact, relevant data are scarce but the following examples will serve to illustrate the nature of the problem.

From considerations of water balance, the mean life of water in the body is about 14 days for adults and 6 days for infants aged 6 months (ICRP, 1975) and that of the long-lived radionuclide tritium in the form of tritiated water will have similar values. In consequence, the committed dose equivalent to body tissues from unit intake of tritium as tritiated water will be only about four times greater for such infants than for adults, rather than the ten times greater factor derived above that would be expected on the basis of their differences in mass alone. Similarly, as a consequence of the more rapid turnover of the long-lived caesium-137 in people of smaller mass (Cryer and Baverstock, 1972), the committed dose equivalent in body tissues from unit intake of the radionuclide is only about 1.5 times greater for the 6-month infant than it is for adults (Medical Research Council, 1975).

The mean life of iodine in the thyroid also increases with age, but this may be accompanied by a small decrease in the uptake into the gland from the blood, (Medical Research Council, 1975; UNSCEAR, 1977; Dunning and Schwarz, 1981; Stather and Greenhalgh, 1983). For the relatively short-lived radionuclide iodine-131, differences in biological turnover are of little consequence because its rate of loss from the thyroid is dominated by radioactive decay and its mean life in that organ is therefore about the same at all ages. In consequence, the committed dose equivalent to the thyroid per unit intake of iodine-131 is about ten times greater for the infant aged 6 months than it is for adults (Medical Research Council, 1975), reflecting their approximately 10-fold difference in thyroid mass. However, for the very long-lived iodine-129, the more rapid biological turnover in young people tends to offset their smaller mass, and the committed dose equivalent to the thyroid per unit intake of iodine-129 for the 6-month child is only about twice that for adults (UNSCEAR, 1977).

Papworth and Vennart (1973) and Leggett *et al.* (1982) have described how the uptake of strontium into bone and its retention therein varies with age. The former authors have given values for the committed dose equivalent in red bone marrow and on bone surfaces from unit intake of dietary strontium-90 and strontium-89. For the long-lived strontium-90, the value for a 6-month infant is about five times the adult value, but for the much shorter-lived strontium-89 the corresponding ratio lies in the range 20-40, the actual value depending on the model used for the dosimetry of the radionuclide in bone. There may be additional contributions to the committed effective dose equivalent from other organs and tissues for which the factors might be different.

Chemical Form

Values of ALI given in *ICRP Publication 30* are usually appropriate to those chemical compounds of a radionuclide that are most likely to be encountered at a place of work. Compounds of the same radionuclide found in the environment or in food may be metabolized differently. The consequent changes in values of committed effective dose equivalent have to be considered very carefully. For example, increased absorption of a radionuclide from the gastrointestinal tract into the blood will decrease the committed dose equivalent to the lower part of the tract, but increase the doses in other tissues of the body; such increases are most marked when radioactive decay is small during the time taken for transfer from the gastrointestinal system to the other organs and tissues.

It is known that absorption of some elements from the gastrointestinal system is increased in new-born animals of several species by factors up to 100 for compounds that are very poorly

absorbed by adults, e.g., the actinide elements, as described by Sullivan (1980a and b). This enhanced absorption occurs only early in life and decreases to the adult value at about the time of weaning. It is often accompanied by increased retention in the walls of the gastrointestinal tract. If it occurs in children, this increased absorption and retention could markedly increase the committed dose equivalent in the tissues of the body from intakes of some radionuclides very early in life, with a consequent need for more stringent controls by responsible authorities.

Information on the absorption of some actinides from the gastrointestinal system has been reviewed by Harrison (1982). He suggests that the fractional absorption f_1 of dietary plutonium might be 1% in the first 3 months of life, decreasing during weaning to the value of 0.05% at about 9 months, after which it does not vary with age. Alternatively, Harrison suggests a constant value of 0.5% during the first year of life and 0.05% thereafter. These values are respectively 50 and 5 times greater than the value used in *ICRP Publication 30* to determine the ALI for ingestion by workers of all plutonium compounds other than the very insoluble oxides and hydroxides. An ALI for ingested plutonium-239 will be inversely proportional to the value of f_1 and proportional to the mass of tissues at different ages. In the absence of any evidence to the contrary, it is assumed that there is no change with age in the prolonged retention of the radionuclide in body tissues. Therefore, using the values of f_1 suggested by Harrison, together with the mass factor of 2 discussed above for radionuclides that are long retained in body tissues, the committed dose equivalent per unit intake of dietary plutonium-239 for the 6-month old infant is 20 times greater than for adult members of the public and 100 times greater than the value used in *ICRP Publication 30* to calculate the smallest value of the ALI for the ingestion of plutonium-239 compounds at work. Variations in the value of f_1 of the magnitude suggested here will have little effect on estimates of the ALI for inhaled plutonium-239 because these are determined mainly by the larger fraction of the radionuclide that transfers directly to the blood from the lung.

Other Factors

There are a number of other factors that might be worthy of further research: for example, the dosimetric models developed in *ICRP Publication 30* for the respiratory and gastrointestinal systems and the skeleton are for adults. Until more information is available, they may of necessity have to be used for children, making appropriate allowances for breathing rates and food intake.

There is a need to consider pregnant women and the chronically sick. More needs to be known about the metabolism of radionuclides by the embryo and foetus and about their radiosensitivities. The Commission will keep under review possible differences in radiation sensitivity between tissues at various ages; meanwhile it does not believe that these differences are significant enough to recommend for members of the public a set of weighting factors that are different from those for workers (Para. 125, *ICRP Publication 26*, 1977).

Conclusion

The limitation of the committed effective dose equivalent for members of the public is sufficient to provide compliance over a lifetime with the limit for single organs, thus avoiding non-stochastic effects. Relative values for infants and adults of the committed dose equivalent in a number of tissues per unit intake for each of a few radionuclides have been given above: the values for infants are just more than 1 up to 100 times greater than those for adult workers. In each of these cases the appropriate annual dose-equivalent limits recommended by the Commission for members of the public are 10 times less than the corresponding values for workers: the resulting ALI for infants aged 6 months will be smaller than the values given in

ICRP Publication 30 for limiting stochastic effects in workers by factors that range from just more than 10 (for caesium-137) to 1 000 (for ingested plutonium-239). Intermediate factors would apply for older members of the public. The magnitude of the range emphasizes the need to consider each situation carefully.

Clearly, to choose a single factor for all circumstances would be unnecessarily restrictive in many cases, and none is recommended. On the other hand, to give an exhaustive list of factors for every case would be a daunting and possibly unrewarding task. The Commission plans to extend the list of examples as information increases and as other nuclides are identified as being of particular interest. Information of this kind, together with information about environmental features and about the behaviour patterns of members of the public, will enable national authorities to limit releases to the environment and to assess the doses likely to result from such releases.

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The Derived Air Concentration (DAC)

In *ICRP Publication 30* the values of DAC for occupational exposure to short-lived nuclides (other than isotopes of noble gases) are based on the dose equivalents to organs and tissues as the result of inhalation. The Commission wishes to draw attention to the fact that there is an additional contribution to these dose equivalents from external irradiation. In situations where short-lived materials are widely distributed in the workplace, this additional contribution may be greater than that due to inhalation by a factor that increases from about 1 to 100 as the half-life of the radionuclide decreases from 1 day to 10 min. Such contributions should be assessed as part of the external irradiation.

Average Annual Doses in a Work Force

In discussing dose-equivalent limits for workers in *ICRP Publication 26* the Commission compared their average risks with those in various industries. The Commission did not imply that there should be a specific limit for the average dose equivalent. Rather, the collective dose equivalent, and thus the average dose equivalent, should be limited by the process of optimization of protection, i.e., it should be kept as low as reasonably achievable, economic and social factors being taken into account.

Exposure of Women to Ionizing Radiation

In a recent publication¹ M. Otake and W. J. Schull have drawn attention to the risk of causing severe mental retardation in children exposed to ionizing radiation *in utero*. The risk has been identified as arising from irradiation in the limited period from 8 weeks to about 15 weeks after conception, i.e., after two menstrual periods would have been missed. In the interval leading up to the above-mentioned publication, the Commission examined the implications of this information for its recommendations concerning the employment of pregnant women in work involving exposure to ionizing radiation and concerning radiological examination of pregnant women.

Occupational Exposure of Pregnant Women

Paragraph 116 of *ICRP Publication 26* recommends that the conditions of occupational exposure of women diagnosed as being pregnant should be limited to those in which it is most unlikely that annual exposures would exceed 3/10 of the dose-equivalent limits (Working Condition B).

The Commission has concluded that the new information does not increase substantially the total risk previously judged by the Commission to result from occupational exposure of a pregnant woman (including her foetus) under these conditions. However, the new information, which shows that the risk of inducing mental retardation is confined to a limited period of time, makes some additional recommendations appropriate.

The methods of protecting pregnant women at work should provide a standard of protection for the foetus broadly comparable with that provided by protection of members of the general public. If, under Working Condition B, as would be expected, substantial irregularities in the dose rate do not occur, the dose received by the foetus over the critical period of 2 months would not be expected to exceed about 1 mSv. The Commission recommends that specific operational arrangements should be made to avoid irregularities in the rate at which the dose could be received and to keep the dose to the foetus as low as reasonably achievable.

Occupational Exposure of Women of Reproductive Capacity

No risk comparable with that described by Otake and Schull is incurred from irradiation in the period prior to the first missed menstruation. The Commission's recommendations for occupational exposure of women of reproductive capacity relate to women who may be, but are not known to be, pregnant. These recommendations impose no special dose limits, in addition to that of an effective dose equivalent of 50 mSv in any year, provided that the exposure occurs at an approximately regular rate. The recommendations remain valid.

¹ M. Otake and W. J. Schull, *Br. J. Radiol.* In press.

Diagnostic Exposure of Women

The information published by Otake and Schull has a bearing also on the diagnostic examination of women in the third and fourth months after the onset of the preceding menstruation. The Commission took this information into account when it prepared *ICRP Publication 34* (Protection of the Patient in Diagnostic Radiology), which includes practical guidance on the protection of pregnant patients. *ICRP Publication 34* also deals with examinations in the first 2 months of pregnancy, whether or not a pregnancy has been recognized.

During the first 10 days following the onset of a menstrual period, there can be no risk to any conceptus, since no conception will have occurred. The risk to a child who had previously been irradiated *in utero* during the remainder of a 4-week period following the onset of menstruation is likely to be so small that there need be no special limitation on exposures required within these 4 weeks.

STATEMENT FROM THE 1984 STOCKHOLM MEETING OF THE INTERNATIONAL COMMISSION ON RADIOLOGICAL PROTECTION

The International Commission on Radiological Protection (ICRP) held its annual meeting in Stockholm in May 1984, together with its four expert committees. Seventy individuals from seventeen countries attended and reviewed the Commission's current work. Representatives or observers were also present from the Commission of the European Communities, the International Atomic Energy Agency, the International Commission on Radiation Units and Measurements, the International Electrotechnical Commission, the International Radiation Protection Association, the OECD Nuclear Energy Agency, the International Commission for Protection against Environmental Mutagens and Carcinogens, and the United Nations Scientific Committee on the Effects of Atomic Radiation.

The Commission approved five reports for publication in the Annals of the ICRP later in the year. These are:

- Non-stochastic effects of ionizing radiation
- Protection of the patient in radiation therapy
- Major concepts and quantities in use by ICRP
- Protection of the public in the event of major radiation accidents
- Principles of monitoring for the radiation protection of the public.

The Commission reviewed the work of its committees and task groups, and noted that a number of reports are expected to be completed in the next year or so on the following topics:

- Developmental effects of irradiation of the embryo and fetus;
- Metabolism of plutonium and related elements;
- Doses to patients from radiopharmaceuticals;
- Protection of the patient in nuclear medicine;
- Data for evaluating the exposure of workers to external radiation;
- A revision of *ICRP Publications 10, 10A, 24 and 27*;
- Exposure of the public to radon.

In addition, task groups have been established to review the ICRP lung model, to review and upgrade the ICRP Reference Man, to report on the application of basic radiation protection principles to radioactive waste disposal, and to develop the application of techniques other than cost-benefit analysis in the optimization of radiation protection.

Committed Effective Dose Equivalent

At the Stockholm meeting the Commission reviewed those aspects of its policy underlying the use of committed dose equivalent. The Commission confirms that its policy is to limit the risk *committed* by each year of operation, no credit being taken for earlier years if these have committed lower risks or for future years in the expectation of improved conditions of exposure.

This objective is achieved by the use of annual limits on intake calculated from the committed dose equivalent, using a 50-year integrating period.

The Commission recognizes that there are practical difficulties in using monitoring results to estimate annual intakes of some materials, notably plutonium, but it believes that these difficulties can be overcome and that their existence does not invalidate the above conclusions.

Sealed Source Beam Therapy

In paragraph 157 of *ICRP Publication 33* ("Protection against ionizing radiation from external sources used in medicine") the Commission made the following recommendation:

Every sealed γ -ray source used for beam therapy shall be enclosed in a housing such that, with the beam control mechanism in the OFF position, the air-kerma rate from the leakage radiation measured at a distance of 1 m from the source does not exceed $10 \mu\text{Gy h}^{-1}$. At any readily accessible position 5 cm from the surface of the housing, the air-kerma rate from the leakage radiation shall not exceed $200 \mu\text{Gy h}^{-1}$.

This recommendation replaced one given in *ICRP Publication 15* ("Protection against ionizing radiation from external sources") in which the exposure rate at one meter from the source, while in the off position, was limited to 2 mR/h. This reduction by a factor of 2 was recommended by the Commission because the previous limit was based on designing the equipment to ensure that the dose limits were not exceeded rather than by the process of optimization of protection.

Information available to the Commission suggests that the collective dose from existing teletherapy units (designed according to the recommendation made in *ICRP Publication 15*) is unlikely to exceed 10^{-2} man. sieverts per year for each unit. For this reason, backfitting of existing equipment is not required, and design of new equipment should be based on the recommendation given in *ICRP Publication 33* unless realistic cost-benefit analysis, as described in *ICRP Publication 37*, clearly shows that this is not justified by the increased cost.

Review of the Bases of the Commission's Risk Estimates

The Commission and its expert committee on radiation effects has continued its critical review of epidemiological and related reports on the effects of human exposure to radiation. This review included a number of papers suggesting higher risks of cancer induction per unit dose at low doses than those used by ICRP for purposes of radiation protection; these papers were based mainly on studies of populations exposed as a consequence of test explosions in the USA. Other papers concerned with risk estimates were based on studies of the survivors of atomic bombs in Hiroshima and Nagasaki, and of exposures incurred during medical therapy. Reports were also examined which are described as indicating reductions in the risk of harmful effects as a result of exposure to low doses.

No reliable evidence could be derived from these reports to indicate that a change is needed in current estimates of the overall risk of cancer induction per unit dose, or in estimates for particular organs, these risk estimates being the basis of the Commission's recommendations.

Reports were received of the progress in re-evaluating the doses to which survivors in Hiroshima and Nagasaki were exposed. The implications of this re-evaluation, and of a continuing survey of reports of the cancer incidence and mortality in the survivors, will be reviewed when further information becomes available.

In 1982 the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) reported a lower estimate of the genetic risks of radiation than that based on the evidence available at the time of its 1977 report, from which the Commission's genetic risk estimates were derived. The bases for this reduction are under review, as are the estimates of the amounts of detriment resulting from the forms and frequencies of inherited abnormality and congenital anomalies that are induced by radiation. These estimates will be incorporated in the Commission's future appraisals of radiation risk.

UNSCEAR is engaged also in studies of the dose-effect relationships for radiation risks at

moderate and at low doses, and the frequencies observed in different organs and tissues at moderate doses. The Commission is in close touch with this work.

The Commission has also reviewed the information published recently¹ defining the periods during pregnancy at which mental retardation appears to have been caused by radiation exposure of the developing child, and the risk per unit dose of this occurrence. Attention has already been drawn to the impact of this finding upon the protection of the embryo or fetus.² The Commission is informed of the further studies in progress on the induction of these abnormalities.

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STATEMENT FROM THE 1985 PARIS MEETING OF THE INTERNATIONAL COMMISSION ON RADIOLOGICAL PROTECTION

The International Commission on Radiological Protection (ICRP) met in Paris in March 1985. The Commission reviewed the work of its committees and task groups, and approved for future publication a report on the quantitative bases for developing a unified index of harm.

The Commission identified four topics requiring comment:

Dose Limits for Members of the Public

In the recommendation on effective dose-equivalent limits* for members of the public, made in its 1977 Recommendations (*ICRP Publication 26*¹), two values were mentioned. The use of the limit of 5 mSv in a year was endorsed, but only under the conditions described in paragraphs 120 to 128 of *ICRP Publication 26*. For other circumstances the Commission recommended that it would be prudent to limit exposures on the basis of a lifetime average annual dose of 1 mSv.

The Commission's present view is that the principal limit is 1 mSv in a year. However, it is permissible to use a subsidiary dose limit of 5 mSv in a year for some years, provided that the average annual effective dose equivalent over a lifetime does not exceed the principal limit of 1 mSv in a year.

With this limitation on the effective dose equivalent, the non-stochastic organ dose limit of 50 mSv in a year becomes unnecessary for most organs.² However, since the dose equivalents in the skin and the lens of the eye are not included in the computation of effective dose equivalent for the individual,³ organ dose limits are still needed for these two tissues. The recommended dose-equivalent limit for both the skin and the lens is still 50 mSv in a year for members of the public.

The Value of the Quality Factor in the Case of Neutrons

The information now available on the relative biological effectiveness (RBE) for neutrons for a variety of cellular effects *in vitro*, and for life-shortening in the mouse, is being reviewed by the Commission. The implications of this information will be considered as part of a larger review of recommendations to be undertaken by the Commission over the next four years or so. Meanwhile, in the case of neutrons the Commission recommends an increase in Q by a factor of 2. The permitted approximation for \bar{Q} for fast neutrons thus changes from 10 to 20.

These changes relate only to neutrons, and no other changes in Q are recommended at this time.

Potentially Dangerous Radiological Practices

The Commission has been informed by its Committee on Protection in Medicine of some potentially dangerous practices in the use of fluoroscopic apparatus. Adherence to the

* The Commission's dose-equivalent limits apply to the sum of the effective dose equivalent resulting from external exposure during 1 year and the committed effective dose equivalent incurred from that year's intake of radionuclides.

recommendations and guidance given in the Commission's report *Protection against Ionizing Radiation from External Sources Used in Medicine*⁴ could prevent such situations. Specifically, the Commission is concerned about the introduction of fluoroscopic apparatus with over-couch tubes which can give substantial x-ray exposures to operators if they are not protected by shields. With the operator wearing a protective apron and standing beside the patient, the dose from an over-couch screening set, compared with that from an under-couch set, can be 250 times higher to the hands, 100 times higher to the eyes and 35 times higher to the whole body. For an operator with a heavy work load the dose to the lens of the eye can greatly exceed the Commission's recommended occupational limit of 150 mSv (15 rem) in a year, and, if continued, could lead to permanent damage.

Other examples of practices causing concern, which have been reported to the Commission, include complex radiological procedures undertaken by physicians or surgeons without training in radiology and radiation protection. The operators may feel that the obvious needs of the patient outweigh a future risk of radiation injury to themselves. Occasionally this has even led to the removal of individual monitoring devices to avoid identification of high dose levels.

These problems are compounded by the routine use of unnecessarily high fluoroscopic currents and unnecessarily long fluoroscopic times. The Commission believes that the use of appropriate protective shielding and careful attention to technique, including the use of video storage devices, could result in a substantial decrease in radiation doses to operators. Insistence on suitable training in radiation hazards, and detailed monitoring of doses to eyes and extremities, may be particularly helpful in reducing significantly these potentially dangerous doses to operators.

Reduced Doses to Patients

In its publication *Protection of the Patient in Diagnostic Radiology*⁵ the Commission recommended several changes of equipment and technique that would reduce the dose to patients at a very moderate cost. It now appears that these changes are not being introduced as rapidly as the Commission had hoped. The Commission therefore wishes to emphasise to manufacturers and radiological practitioners that these changes are effective and can be introduced at a cost that is much more than offset by the value of the reduction in detriment that they achieve.

In particular, the Commission recommends the wider use of rare-earth screens, and the selection of materials with very low attenuation (such as those made of carbon fibre) for cassette faces, table tops and the non-opaque parts of grids.

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