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 publication[1] 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.

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[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.