NIRS/PC Prefiled Exhibit 119
Docketed 09/23/05

RADIATION PROTECTION

ICRP PUBLICATION 26

Recommendations of the International Commission on Radiological Protection

(ADOPTED JANUARY 17, 1977)

PUBLISHED FOR
The International Commission on Radiological Protection
BY
PERGAMON PRESS
OXFORD : NEW YORK : FRANKFURT

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n Rates

scription, including postage and insurance (1977) $45.00
bscription, including postage and insurance (1977/78) $85.50

ICRP is published as 4 issues per year. Each report will be published as soon as material is
n the ICRP, so that issues will not necessarily appear at regular intervals.

tion and order enquiries should be addressed to:

Subscription Fullfillment Manager
Pergamon Press Ltd
Headington Hill Hall
Oxford OX3 0BW
England

bscriptions and Back Issues

all previously published volumes are available in the regular editions and on microfilm and microfiche.
riptions are available on microfiche simultaneously with the paper edition and on microfilm on com-
subscription year.

511 4

Pergamon Press

Hill Hall
0BW, England

Maxwell House, Fairview Park
Elmsford, NY 10523, USA

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limited to the minimum amount consistent with the medical benefit to the individual patient. The individual receiving the exposure is himself the direct recipient of the benefit resulting from the procedure. For this reason it is not appropriate to apply the quantitative values of the Commission's recommended dose-equivalent limits to medical exposures. With certain medical exposures a very much higher level of risk may in fact be justified by the benefit derived than by the level judged by the Commission to be appropriate for occupational exposure or for exposure of members of the public.

(93) It has already been indicated in paragraph 89 that the Commission's recommended dose-equivalent limits are intended for planning purposes and refer to that component of risk resulting from a particular practice to which radiation protection applies. Under the assumption of linearity the risk from such a practice is unaffected by the risks from other sources, and it is therefore justifiable to consider separately the doses received from such practices from the doses acquired from medical exposure. In view of the considerations detailed in paragraph 92, the Commission considers that radiation doses resulting from medical exposures should not influence any of the procedures of dose limitation applied to exposures from other sources. However, because of the possibility of non-stochastic effects developing in the exceptional cases of workers who have undergone radiodiagnosis or radiotherapy involving heavy irradiation of part of the body, and whose work would involve substantial exposure of those parts, the working situation should be reviewed by the competent medical authority.

Implications for non-stochastic effects

(94) As already stated, the Commission's recommended dose-equivalent limits for the limitation of *stochastic* effects do not apply to contributions from natural radiation sources or from medical exposure. However, the question of *non-stochastic* effects merits consideration.

(95) When exposure is limited by consideration of stochastic effects, it is unlikely that the addition of occupational exposures and normal medical or natural radiation exposures would cause a total dose equivalent that would be near threshold values of any harmful non-stochastic effect. Although, in principle, contributions to the dose equivalent from *all* sources (i.e. also from medical sources and normal natural background) should be added in assessing the likelihood of non-stochastic damage occurring, the Commission considers that in practice it is not necessary that this should be done. High doses from natural radiation sources would only be expected to occur under the special conditions mentioned in paragraph 89 and should in any case then be included under the dose-equivalent limits to the extent that the elevated exposures are subject to human control. In the case of high medical exposures (e.g. in radiotherapy) it would be the doses from these exposures that would dominate, and the consideration of possible risks of non-stochastic effects (e.g. to the lens of the eye) would be part of the medical considerations in the treatment of the patient, rather than the task of those responsible for radiation protection in general.

Dose-equivalent limits for workers

(96) As stated in paragraph 77, the Commission's recommended dose-equivalent limits for occupational exposure have been in effect for over 20 years. In view of the emphasis that the Commission places on risk estimations, it believes it appropriate to assess the levels of risk that are associated with its dose-equivalent limits. The Commission believes that for the foreseeable future a valid method for judging the acceptability of the level of risk in radiation work is by comparing this risk with that for other occupations recognized as having high standards of safety, which are generally considered to be those in

which the average annual mortality due to occupational hazards does not exceed 10^{-4}*. In most occupations, fatalities, whether due to accidents or disease, are accompanied by a much larger number of less severe consequences. Radiation exposure, on the other hand, at levels imposed by adherence to recommended dose-equivalent limits, is expected to cause very few injuries or illnesses in exposed workers other than any malignant diseases which may be induced. In assessing the implication of dose-equivalent limits therefore the Commission believes that the calculated rate at which fatal malignancies might be induced by occupational exposure to radiation should in any case not exceed the occupational fatality rate of industries recognized as having high standards of safety.

(97) Other criteria than fatality rates could be used in ensuring that radiation exposure, as controlled by recommended dose-equivalent limits, involves no greater hazard than in other safe industries. Ideally, account should be taken of all components of the harm, or detriment, involved in the various occupations —including the sum of all accidents, illnesses, genetic defects and fatalities involved, as well as the anxieties of workers or their families about the hazards or conditions of work in different industries. As a first approximation it can be stated that an assessment based only on the mortality criterion can be regarded as conservative since experience has shown that the non-fatal effects of irradiation are much less frequent than the non-fatal effects encountered in other safe occupations. However, the summation and comparison of the diverse contributions to total detriment are difficult to make on an objective basis.

(98) Account can be taken of some components of disability by estimating the average amount of time lost (e.g. per worker year) from full activity—whether from accidents, industrial disease or, in the extreme case, by death from occupational causes. A review of the problems involved in developing any "Index of Harm" on this basis is given in a report on this topic being prepared for the Commission; however, no such criterion can be regarded as more than indicative of broad differences in risk. It should be mentioned, however, that an accidental death appears to involve an average loss of about 30 years of life in many industries, and to be associated with an approximately equal total loss of working time from industrial accidents. A fatal malignancy induced by occupational exposure to radiation would be expected to involve the loss of about 10 years of life, owing to the long latency in the development of such a condition, without appreciable associated time loss from accidents.

(99) When making comparisons with other safe occupations, it should be realised that the level of risk representative of a safe occupation relates to the *average* risk for all workers in that occupation, the risk for individual workers varying with their job and being distributed around this average. A similar distribution of individual risks also occurs in radiation work; in many cases of occupational exposure where the Commission's system of dose limitation has been applied, the resultant annual average dose equivalent is no greater than one-tenth of the annual limit.† Therefore the application of a dose-equivalent limit provides much better protection for the average worker in the group than that corresponding to the limit.

(100) In the case of uniform exposure of the whole body, in circumstances where the Commission's recommendations, including the annual dose-equivalent limit of 50 mSv, have been applied, the distribution of the annual dose equivalents in large occupational groups has been shown very commonly to fit a log-normal function, with an arithmetic mean of about 5 mSv, and with very few values approaching the limit. The application of the risk factors given in paragraphs 40–60 to the above mean dose indicates that the average risk in these radiation occupations is comparable with the average risk in industries (but see also paragraph

(101) The Commission's do limits are primarily intende adequate protection even for th exposed individuals. In many workers who are exposed ne equivalent limits are unlikely to doses each year of their occupati it would be their expected l equivalent that would indicat individual risk. In this sens comparable with individuals wh randomly to higher risks in "sa tions. Exposures consistently n would be comparable with a situ higher-than-average risk has be for certain individuals in non-rad tries.

(102) However, if the exposur in any particular occupation *planned* so that a large fractio received dose equivalents which the annual limit, the average ex rise substantially above one-tent There would thus be a correspo the average risk, even though the equivalent limit was not excee individual worker. Long-contin of a considerable proportion of t or near the dose-equivalent limit be acceptable if a careful cost–ber had shown that the higher r would be justified.

Recommended dose-equivalen

The Commission's recommen intended to prevent non-stoch and to limit the occurrence o effects to an acceptable level. T sion believes that non-stochastic be prevented by applying a dos limit of 0.5 Sv (50 rem) in a year except the lens, for which the recommends a limit of 0.3 Sv (3 year. These limits apply irre whether the tissues are expose together with other organs, a

*See the Commission's report on Problems Involved in Developing an Index of Harm (in preparation).

†See Annex E of the 1977 Report of the United Nations Scientific Committee on the Effects of Atomic Radiation.

parable with the average risk in other safe industries (but see also paragraph 29).

(101) The Commission's dose-equivalent limits are primarily intended to ensure adequate protection even for the most highly exposed individuals. In many occupations workers who are exposed near the dose-equivalent limits are unlikely to receive such doses each year of their occupational life and it would be their expected lifetime dose equivalent that would indicate their total individual risk. In this sense they are comparable with individuals who are exposed randomly to higher risks in "safe" occupations. Exposures consistently near the limits would be comparable with a situation where a higher-than-average risk has been identified for certain individuals in non-radiation industries.

(102) However, if the exposure of workers in any particular occupation were to be *planned* so that a large fraction of workers received dose equivalents which approached the annual limit, the average exposure could rise substantially above one-tenth of the limit. There would thus be a corresponding rise in the average risk, even though the annual dose-equivalent limit was not exceeded by any individual worker. Long-continued exposure of a considerable proportion of the workers at or near the dose-equivalent limits would only be acceptable if a careful cost–benefit analysis had shown that the higher resultant risk would be justified.

Recommended dose-equivalent limits. (103) The Commission's recommendations are intended to prevent non-stochastic effects and to limit the occurrence of stochastic effects to an acceptable level. The Commission believes that non-stochastic effects will be prevented by applying a dose-equivalent limit of 0.5 Sv (50 rem) in a year to all tissues except the lens, for which the Commission recommends a limit of 0.3 Sv (30 rem) in a year. These limits apply irrespective of whether the tissues are exposed singly or together with other organs, and they are intended to constrain any exposure that fulfils the limitation of stochastic effects (see paragraphs 104–110).

(104) For stochastic effects the Commission's recommended dose limitation is based on the principle that the risk should be equal whether the whole body is irradiated uniformly or whether there is non-uniform irradiation. This condition will be met if

$$\sum_T w_T H_T \leq H_{\mathrm{wb},L},$$

where, w_T is a weighting factor representing the proportion of the stochastic risk resulting from tissue (T) to the total risk, when the whole body is irradiated uniformly, H_T is the annual dose equivalent in tissue (T), $H_{\mathrm{wb},L}$ is the recommended annual dose-equivalent limit for uniform irradiation of the whole body, namely 50 mSv (5 rem).

(105) The values of w_T recommended by the Commission are shown below:

Tissue	w_T
Gonads	0.25
Breast	0.15
Red bone marrow	0.12
Lung	0.12
Thyroid	0.03
Bone surfaces	0.03
Remainder	0.30

The value of w_T for the remaining tissues requires further clarification. For the reasons stated in paragraphs 58 and 59 the Commission recommends that a value of $w_T = 0.06$ is applicable to each of the five organs or tissues of the remainder receiving the highest dose equivalents, and that the exposure of all other remaining tissues can be neglected. (When the gastro-intestinal tract is irradiated, the stomach, small intestine, upper large intestine and lower large intestine are treated as four separate organs.)

(106) It is recognized that the risk associated with a given exposure will vary with the age and sex of the individual exposed. However, the values of w_T given in paragraph 105 are recommended as appropriate for the protection of

any worker, regardless of these sources of variability (see also paragraph 38).

(107) The values of w_T presented in paragraph 105 are intended as guidance for those concerned with calculating secondary and derived limits (see section F). In particular, they are used by ICRP Committee 2 in calculating values of annual limits of intake (ALI) for radionuclides, which take account of the dose equivalent in each tissue. In practical situations, however, it will usually suffice to use the two secondary limits that are applicable to external and internal exposure, namely, the limit to the dose-equivalent index H_I (see paragraph 108) and ALI (see paragraph 109).

(108) With *external exposures* to penetrating radiation, on those occasions when information is lacking concerning the actual distribution of dose equivalent in the body, it is possible to assess the *maximum* value of dose equivalent that would occur in a 30 cm sphere (the deep dose-equivalent index, H_I)*. The limitation of the dose-equivalent index to an annual value of 50 mSv would afford a level of protection that would be at least as good as that provided by the method recommended in paragraph 104.

(109) With *internal exposure* resulting from the intake of radionuclides protection can be based on annual limits of intake (ALI). These are calculated by ICRP Committee 2, from knowledge of the various organ committed dose equivalents per unit intake, by application of the principles discussed in paragraphs 104 and 105; such exposures are also subject to the limits for non-stochastic effects given in paragraph 103.

(110) When external and internal exposures are received together, the Commission's recommended dose limitation for stochastic effects will not be exceeded if:

$$\frac{H_1}{H_{wb,L}} + \sum_J \frac{I_J}{I_{J,L}} \leq 1$$

where, H_1 is the annual dose-equivalent index, $H_{wb,L}$ is the annual dose-equivalent limit, I_j is the annual intake of radionuclide j, $I_{j,L}$ is the annual limit of intake for radionuclide j.

(111) Although the Commission no longer proposes separate annual dose-equivalent limits for individual tissues and organs irradiated singly, the implied values of such limits may be obtained, if required, by dividing the dose-equivalent limit $H_{wb,L}$ (50 mSv in a year) by the relevant value of w_T. Such values would be subject to the limits, based on non-stochastic effects, given in paragraph 103.

(112) It should be recognized that the limits have been derived for application in average situations, for all adult ages and for both sexes and without regard to individual circumstances which might enhance the risk. The Commission believes that, for example, any variation in risk with age will not influence the total risk from a lifetime exposure unless the exposure is limited to a special group. Additional precautions and dose limitations may be necessary, however, to limit the irradiation of an embryo or foetus in the case of occupational exposure of pregnant women (see paragraphs 115 and 116).

Planned special exposures. (113) Situations may occur infrequently during normal operations when it may be necessary to permit a few workers to receive dose equivalents in excess of the recommended limits. In such circumstances external exposures or intakes of radioactive material may be permitted provided the dose-equivalent commitment does not exceed twice the relevant annual limit in any single event, and, in a lifetime, five times this limit. The Commission wishes to

*International Commission on Radiation Units and Measurements, The Conceptual Basis for the Determination of Dose Equivalent, *ICRU Report 25*, International Commission on Radiation Units and Measurements, Washington, 1976.