Copied for Dr. Karl Z. Morgan
Oak Ridge National Laboratory
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Comments and Revisions Relative to the Report

Maximum Permissible Internal Dose

by the

Subcommittee on Permissible Dose for Internal Radiation

to the

International Commission on Radiological Protection

The Subcommittee on Permissible Dose for Internal Radiation met in Copenhagen, Denmark on July 13 and 14, 1953. Members present were Karl Z. Morgan, chairman, E. E. Pochin and A. J. Cipriani. Invited participants at the meetings were J. S. Mitchell, Sir Ernest Rock Carling and B. Christensen. It was decided to submit the report, Maximum Permissible Internal Dose (draft copy revised June 16, 1953) to the International Commission in its present form and to recommend that certain revisions as listed below be made prior to its publication.

Revisions:

1 - Page 2. Change lines 11 and 12 to read, "In the case of all bone seeking radioisotopes (with the exception of radium, P^{32} and radioisotopes that emit only X or γ radiation) a factor of 5 is applied to the calculations to take into account the uneven distribution ..."

Comments: The old Chalk River values were retained for P^{32} and the factor of 5 was not introduced because of its distribution within the cells, its high energy, its short half life and perhaps the numerous experiments with this radioisotope do not indicate the need for such a factor in this case. This factor of 5 is not to be applied where only X or γ radiation is emitted (e.g., K-capture) because the energy absorption is not localized.

2 - Page 7. Table 2. Values in this table were tentatively adopted. E. E. Pochin will search the literature to see if masses of fat = 7,000 g, red marrow = 1500 g, blood = 5400 g and contents of G I tract = 500 g are the best values. Help in this literature search will be sought from W. H. Langham, Shields Warren, H. Lisco, M. J. Cook and others.

Comments: The values in the 4th column of Table 2 are required in equation 5 on page 24 and correspond to the term X given in the expression $(1-e^{-\sigma_i X})$ which is the fraction of the X or γ energy lost in the critical organ per disintegration. These values usually are not very critical in the calculation of the effective energy. The only way known to get accurate values for X is by phantom measurements. The committee proposes retaining these values unless and/or until better information is available. We would welcome any help from someone willing to undertake the necessary experiments to obtain this information.

3 - Page 8. Table 3. It was decided to delete the last two paragraphs in Table 3 and replace them by the information in table form as given in Table III of the British report, "Proposals from the Medical Research Council's Committee on Protections Against Ionizing Radiations". This table from the British report would be revised before inclusion as follows:

Particulates in Respiratory Tract

Retention of particulate matter in the lungs depends on many factors, such as the size, shape and density of the particles, the chemical form and whether or not the person is a mouth breather; however when specific data are lacking it is assumed ~~the distribution is as indicated~~ below:

Distribution	Readily Soluble Compounds	Other Compounds
Exhaled	25%	25%
Deposited in upper respiratory passages and subsequently swallowed	50%	50%
Deposited in the lungs (lower respiratory passages)	25% (this is taken up into the body)	25% *

* Of this, half is eliminated in the first 24 hours and is swallowed; the remaining half is retained in the lungs with a half life of 120 days, it being assumed that this portion is taken up into body fluids.

The total swallowed is 62 1/2%.

Comments: Two differences in the British and American calculations have resulted from different interpretation of data given in this table. These differences have been as follows: 1) In the case of inhalation of soluble materials the British took into account only the 25% deposited in the lungs whereas the Americans have taken into account not only the 25% deposited in the lungs and taken up into the body but also the 50% swallowed and the portion of this entering the blood stream. This latter method was considered the correct procedure. 2) The British have used a water intake of 2500 cc per day whereas the Americans have used the water intake data as originally given at the Chalk River Conference, namely 2200 cc/day intake of water in fluids and foods and 300 cc/day as the water of oxidation. Equation 10 on page 28 is based on this 2200 cc/day and it was decided to retain this equation in its present form.

4 - Page 9, line 24. Change equation "$f_a = 0.10$" to "$f_a = 0.12$".

5 - Page 12. Place a note at the bottom of table 4 as follows:

* "For soluble compounds".

6 - Page 19, second line from bottom of page change "for all the references ..." to read "for additional references ..." .

7 - Page 25. Change all of page 25 beyond line 5 to read as follows: "Since this value depends upon the value of W (the energy to produce an ion pair) and P (the mass stopping power of tissue relative to air) which in turn are functions of the energy of the radiation, the physical equivalent of a roentgen is a function of energy and may deviate considerably from 93 ergs per gram of tissue. Therefore, the unit of dose of ionizing radiation in this report is taken as 100 ergs/gm of tissue and is called the rad with the understanding that it is only approximately equivalent to the roentgen.

Another unit of dose of ionizing radiation used in this report is the rem. This unit corresponds to that amount of ionizing radiation absorbed in tissue that is considered to lead to approximately the same (or equivalent) biological damage as is produced by one roentgen of X-radiation (of about 200 KV).

By definition, 1 rem $= \frac{1 \text{ rep}}{\text{RBE}} = \frac{100}{\text{RBE}}$ ergs/gm of tissue in which RBE = relative biological effectiveness of the radiation.

The note indicated by an asterisk at the bottom of page 25 should be modified to read as follows:

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* $1 \ \frac{\text{esu}}{\text{cc air}} = \frac{1.602 \times 10^{-12} \times 32.5}{4.8 \times 10^{-10} \times 0.001293} = 83.9$ ergs per gm air per roentgen. This corresponds approximately to 83.9 P ergs/gm of tissue in which P is the mass stopping power of tissue relative to air. In the Compton X-ray region P $\doteq$ electron density of water relative to air or 1.11. Therefore, in the Compton X-ray region the physical equivalent of a roentgen has been taken commonly as 83.9 x 1.11 = 93 ergs/gm tissue."

8 - Page 26. Equation 6 and lines 14, 15 and 16 would be rewritten as follows:

$$" q = \frac{0.1}{5} \times \frac{15.6}{\sum_K \left(f_K E_K (RBE)_K\right)} = \frac{~~3.1~~ \ .31}{\sum_K \left(f_K E_K (RBE)_K\right)}$$

in which the total weighted energy per disintegration of Ra-226 plus 45% of its daughter products down to RaD plus the energy of the recoil atoms is 15.6 Mev. Values of this weighted energy are given in column 5 of table 5 and are obtained by applying an RBE of 1 to β and γ radiation, an RBE of 10 to α radiation and an RBE of 20 to radiation of recoil atoms of mass greater than 4."

Comments: The Weighted energy of 15.6 for Ra^{226} + daughters is to be checked and the values given in column 5 of table 5 are to be revised to include the weighted recoil energy of the atoms.

9 - Page 27. Lines 11 and 12 would be changed to read,

"RBE = relative biological effectiveness

(= 1 for beta and gamma, 10 for α and 20 for recoil atoms of mass greater than 4)."

10 - Table 6, pages 30 through 34-d. All the values in table 6 will be rechecked by members of the Subcommittee on Permissible Dose for Internal Radiation and modifications made to obtain the best values presently available when using the methods outlined in this report.

Comments: A major decision must be reached relative to table 6; namely, if we have a radioisotope which has a very low uptake from the GI tract to the blood and a correspondingly low deposition in some other body organ - say bone for illustration -, the dose to the GI tract, even under equilibrium conditions, may be many times that to the other body organs (bone for example). Under these conditions should we use the GI tract as the critical organ?

Those present at the subcommittee meetings were inclined to feel that the GI tract should be the critical organ in cases where it receives the greatest dose of ionizing radiation. The committee would welcome an expression of opinion from the Main Committee on Radiological Protection and from others interested in this problem. *

It should be noted that the maximum permissible concentration of H^3 in air has been reduced from the Harriman Conference value of 2×10^{-5} μc/cc to 1×10^{-5} μc/cc to take into account not only the skin absorption but also the fact that the equilibrium half-life of hydrogen in the body is 19 days (instead of 10 days which is the equilibrium half-life of water in the body).

It was decided to include values for insoluble natural thorium in table 6 (as well as values for the soluble).

One should note the last two values at the bottom of page 34-d. These general values ** are very convenient to have for short periods of operation because they do away with the requirement of difficult and expensive chemical analysis so long as these general values for mixtures are not exceeded. When these values are exceeded a chemical analysis should be made and this in general will permit the use of less restricting values.

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* The Main Committee considered this matter at a later meeting and recommended that in cases in which the ionizing radiation dose is greater to the GI tract (or lungs) than to some other body organ that the GI tract (or lungs) should be taken as the critical body organ. This brings a number of the values given in Table 6 closer to those recommended by the British, who have used the GI tract (or lungs) in these cases in question.

** The meeting of the Main Committee later gave approval to the use of these general values.

11 - Page 38, change line 10 to read "It is believed that when using the values given in table 6 without the addition of the safety factor of 10 that biological changes would ..."

GENERAL COMMENTS:

1 - The single factor of safety of 10 as agreed on at the Harriman conference is referred to on pages 3, 26 and 38. It is believed that any larger values - such as 100 for some rivers - are a matter for the individual countries.

2 - It is considered that the definition of the critical organ on page 5 is the one that should be used and that the report of the Subcommittee on Permissible Dose for External Radiation gives a definition of critical organ that is not inconsistent.

3 - The new value of 0.2% K by weight as agreed on at Harriman conference and as given in table 1, page 6 seems to be confirmed by several experiments.

4 - When the GI tract is taken as the critical organ, the fraction remaining in the GI tract (and with its contents) should be $(1-f_1)$ and not 1.0.

5 - The use of 70 years as the average life span and consequent increase in maximum permissible values for natural thorium, Pu^{239}, Sm^{151} and Ra^{226} as explained on page 14 and applied in Equation 9 and 10 on page 28 seems justified.

6 - The reason for using the "product of effective energy and RBE" or the "weighted energy" in table 5 is to reduce the size of the report and simplify the equations and their application.

7 - There is some question whether or not to use 2 π or 4 π geometry, when dealing with the submersion problem (see discussion at bottom of page 28). However, it seems wise to continue to use the 4 π geometry as was done at the Chalk River Conference. In many cases this is an additional factor of safety that ranges from 2 to 4.