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Report of the Task Group on Dose Calculations at the Meeting of ICRP Committee 2 April 23–26, 1979 Harwell, England

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OAK RIDGE NATIONAL LABORATORY
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ABSTRACT

The task group is responsible for calculating the dosimetric data for the forthcoming report of the International Commission on Radiological Protection (ICRP) Committee 2 entitled, *Limits for Intakes of Radionuclides by Workers* (revision of ICRP Publication 2). Since the last meeting of the Committee (May, 1978), the task group has completed the computation of Annual Limit on Intake (ALI) and Derived Air Concentration (DAC) values for the 21 elements (187 radionuclides) planned for inclusion in the first volume of the report. Supplemental data tables of energy values, accumulated activities, and committed dose equivalent values have been completed also. These supportive data will be issued as a supplement to the Committee report. Plans have been formulated for proceeding with the calculation of dosimetric data for the next report in the sequence.

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During the time since the last meeting of the Committee, (May 22-27, 1978, at Stockholm) the task group has completed the computation of the dosimetric data for the first group of 21 elements (187 radionuclides). This group of elements comprises the total number of elements originally planned for inclusion in the first volume of the report with the exception of technetium, which was withdrawn from the list because of revisions to be made in the metabolic model. These data have been furnished to the Committee chairman in the form of computer output suitable for publication. That is, the amount of data to be presented, number and arrangement of data tables, table headings, page size, type of printing and paper type conform to an agreement between the Committee chairman, Pergamon Press, and the task group. The Committee plans to include only the table of annual limits on intake (ALI) and derived air concentration (DAC) values in the Committee report and that table is to be type-set, but the computer formated version of the table will appear in the supplemental volume.

A supplement to each volume of the Committee report is planned which will give further data for each radionuclide covered in the corresponding volume. These further data will be produced directly from the computer printouts mentioned above. They will consist of a drawing showing the half-life and mode of decay of each radionuclide considered plus five tables of data. The data tables will give (1) the specific effective energy (SEE) for relevant source to target organs; (2) number

of transformations over 50 years in each source organ, as defined in the corresponding metabolic model, per unit intake of the radionuclide by ingestion and/or by inhalation; (3) committed dose equivalent in contributing target organs or tissues; (4) weighted committed dose equivalent, as defined in ICRP Publication 26, in the contributing target organs; and (5) the ALI for ingestion and inhalation and the DAC for the relevant inhalation class or classes.

All of these drawings and data tables for the 187 radionuclides have been computed by the task group and furnished to the Committee chairman for the first supplement. In cases where a radionuclide decays successively to other radionuclides before reaching a stable state, the complete decay chain drawing is shown. Also, the table of SEE values for each member of the chain and the other tables have been lengthened to accommodate the chain members.

The data tables for the various radionuclides have a variable number of source and target organs depending, of course, in the case of source organs, on the metabolic model for that element. Other restrictions as defined in the Committee report have been programmed to eliminate source and target organs that fail to contribute significantly to the dose. These include the 10% rule for eliminating target organs whose weighted committed dose equivalent is not 10% of the maximum weighted committed dose equivalent. The 10% rule is applied separately for each route of intake and/or class of aerosol. The 1% rule is performed to eliminate source organs. All source organs are eliminated that contribute less than 1% to the committed dose equivalent in a target organ not eliminated by the 10% rule. The 1% rule is applied separately for each

route of intake. After the final set of source and target organs is determined in this way for the dose tables, the SEE and nuclear transformations tables are printed. They are a composite of all the source and target organs with corresponding values that were not eliminated by the 10% and the 1% rule for each route of intake and class of aerosol. Termination of the computations for a chain of radionuclides for members failing to contribute significantly has been programmed also according to the Committee report. Thus, data for a radioactive daughter are only printed if that daughter contributes more than 0.1% to the total weighted committed dose equivalent for at least one of the modes of intake of its inhaled or ingested parent radionuclide.

The computer drawn decay chains are high quality, large size, pen and ink drawings from which Pergamon Press can make photo-reduced, final publication copies. Concerning the drawings, (1) the height of the letters is 5.3 mm, which for our plotter devices is an optimum height to give high quality lettering with a minimum of distortion; (2) if the half-life is very large or the percent intensity of a decay branch is very small, standard computer exponential notation is used, that is, 1.585E5y implies a half-life of 1.585×10^5 years; and (3) the percent intensity of a decay branch is listed only in cases where there is branching (e.g., where a nuclide decays partly by α-decay and partly by β^--decay). In a very few cases the percent intensity is listed when there is apparently only one decay mode. For example, in the ^{231}U decay chain the 99.9% β^--decay of ^{223}Fr is the only decay mode shown. However, ^{223}Fr has a very small percentage α-decay, but no decay data are presently available for the α-decay branch. A similar situation applies to the

β^--decay of ^{228}Ac in the ^{236}U chain. The decay of ^{228}Ac is marked as 100% β^--decay, but actually there is also a very low intensity α-decay branch for which decay data are not available.

Concerning the criteria for selecting the isotopes of the 21 elements to include in the report, the Committee report as originally drafted stated that all isotopes with a half-life equal to or greater than 10 minutes would be included. The task group was prepared to do this even though inclusion of all such isotopes would require a time consuming search of the open literature in many cases to find adequate decay data. However, in view of the urgency for an early publication of the values, agreement was reached at the last meeting to include all isotopes with a half-life equal to or greater than 10 minutes for which the decay data are readily available. "Readily available" was interpreted to mean available from the Evaluated Nuclear Structure Data File, ENSDF. The ENSDF is a computerized file, generated and maintained by the Nuclear Data Project at the Oak Ridge National Laboratory (ORNL) upon which the data published in the *Nuclear Data Sheets* are based. The *Nuclear Data Sheets* is a serial publication edited by the personnel of the Nuclear Data Project and published by Academic Press, New York.

This data file is a fairly recent accomplishment, and except for it, the list of isotopes that the task group could include fairly quickly in the report would be quite restricted---restricted, most likely, to very few more than appear in ICRP Publication 2. The file is updated regularly as work on the Project progresses, and it happens that the data for some of the elements (e.g., polonium) have not been reviewed recently. Thus, although the project has data for other polonium isotopes

than are in ENSDF, it considers that the data have not been updated recently enough to include in ENSDF. This arrangement results in some "uneveness" in the number of isotopes treated for the various elements, but the task group is at a loss to do better under the time constraints.

The decay data from ENSDF are used as "input data" for a computer code that provides "output data". The "output data" consist of a detailed listing in a form suitable for dose calculations of the energy emitted per transformation. Briefly, the code calculates (1) the average energy of the various β^+ or β^- branches present in beta decay, (2) the energies and intensities of various X-ray and Auger electron groups present in electron-capture decay, (3) the energies and intensities of the internal-conversion electron groups as well as the X-ray and Auger electrons that are present as a result of the internal conversion of any gamma rays present in a decay process, (4) the bremsstrahlung spectra accompanying beta decay and monoenergetic Auger and internal conversion electrons, and (5) the radiations accompanying spontaneous fission.

This computer code provides the radioactive decay data base for the Committee report. It was developed by L. T. Dillman, a task group member who has published similar data for the Medical Internal Radiation Dose (MIRD) Committee. For the present work of Committee 2, Dr. Dillman has updated and extended the previous codes, and he is presently in the process of documenting this version. All the decay data, both "input data" and "output data" used by the task group in making the calculations for the Committee report are available intact in retrievable form for publication or by use of those who may wish to compute directly from

magnetic tape. Dillman has also updated his code that provides computer drawn decay schemes.

Now that the dosimetric data have been completed for the first volume of the report as well as for the first supplemental volume, the task group chairman takes this opportunity to acknowledge on behalf of the membership the kind assistance and support of the Committee members and of the secretariat. We are particularly grateful for the able guidance of our chairman, Dr. Vennart. Without his firm backing to proceed with the calculations in an orderly and logical manner we would be issuing a report far less complete and exact than the one currently in publication. We are indebted also to Dr. Dolphin in this regard.

Special thanks go to M. C. Thorne for providing the cumulated activities of the alkaline earth elements. Having already coded Marshall's formula to compute these values prior to last year's meeting, he agreed to supply these data to the task group. We are grateful also to N. Adams for supplying the preliminary values that have served as a check of the final values.

The task group, based primarily in the Health and Safety Research Division (HASRD) at ORNL, has benefited greatly from ORNL facilities such as the Information Center for Internal Exposure, the Computer Sciences Division, and the Nuclear Data Project. The group is especially grateful to its administrative personnel for their encouragement and their support in maintaining a productive working environment. The administrative staff of HASRD during this phase of the work has included: K. F. Eckerman, group leader of the Metabolism and Dosimetry Group; D. C. Parzyck, section head of the Health Studies Section; and S. V. Kaye, division director. The keen interest and encouragement of C. R. Richmond,

ORNL Associate Director for Biomedical and Environmental Science, helped to provide the environment for the working group to meet its many commitments.

The next phase of the task group effort will be concerned with the second group of elements (about 30) for inclusion in the second volume of the Committee report and in the second supplement. In fact, work is already underway toward preparing the file of ENSDF data ("input data") for processing through Dillman's code to produce the "output data" needed in making the dose estimates. Dillman is presently involved in computerizing the checking of ENSDF for errors and in automating his codes to produce the drawing of radioactive decay chains simultaneously with the computation of "output data."

The first group of 21 elements has included most of the more interesting and important elements encountered in internal dosimetry as well as certain additional elements selected to illustrate various dosimetric techniques. Thus, little novelty in computational methods is expected with the remaining elements. One complicating factor does arise, however, with this second group that should be mentioned. This complication involves the fact that two of the elements, namely, copper and mercury, concentrate to some extent in the brain; and absorbed fractions of photon energy are not available in the Reference Man Report (the source reference for other photon absorbed fractions) for the brain as a source organ. The task group has been aware of this deficiency for sometime and has initiated a program to produce the values. The same computational techniques and the anthropomorphic phantom used in computing the absorbed fractions for the reference report will be used. These data are expected to be available soon in a reference document.

Another project that the task group has undertaken is the documentation of the computer program used by ORNL to produce the dosimetric

calculations for the Committee report. Although this project is not sponsored by the Committee, it is one in which the membership will, no doubt, have considerable interest. The documentation will include a description of the dosimetric models, computational considerations, program descriptions, user information, program listings, sample input and output material, job control language statements, and other information that a programmer might need in order to duplicate the values in the report. Obvious advantages to various international installations in having the code readily available include computing dose estimates for isotopes not listed or updating values as metabolic and decay data are revised.

The task group has concerns for the future regarding the completion of its task on which it should like to have consideration and guidance by the Committee. These items include:

(1) The addition of isotopes of elements already published. As the computations proceed on the next group of elements, decay data will, no doubt, become available in the ENSDF file for other isotopes of such elements as polonium. Should dosimetric data for these additional isotopes be computed? If so, when and where should they be published? Of course, there is also the matter of updating as revised metabolic and decay data become available.

(2) The publication of nuclear decay data used in the computations. Is this to be a task group or a Committee publication (i.e., a blue or brown cover report)? Is one publication of these data envisioned or a publication corresponding to each volume of the Committee report? What about the cut-off point of the "input-output" data? That is, the complete listing of decay data sometimes extends to many pages. Pergamon Press will probably not be

interested in publishing such a lengthy listing. Should the listing be limited in some way, say, to transitions ≥0.01% per decay? Also, is direct photocopying of computer output to be used?

(3) The metabolic data for the third and last group of about 40 elements. Is a list of these available? What is the task group's responsibility in this effort? Has the group, in fact, already furnished metabolic data for these elements?

(4) The appropriate time-frame for completion of data for the next reports in the sequence. Does the urgency for completion of the dosimetric data extend beyond the volume now in publication? Data for the supplement to volume one have been furnished to the Committee chairman. Should the task group wait before sending data for the second volume until data for the first supplement have gone to Pergamon Press?

(5) The format and arrangement of data for succeeding volumes. Will the same arrangement and formating be maintained in the next volumes?

The task group members during this time were: Mary R. Ford, Chairman, and S. R. Bernard, HASRD, ORNL; Sarah B. Watson, Computer Sciences Division, ORNL; L. T. Dillman consultant to HASRD, Ohio Wesleyan University; and J. W. Poston, Georgia Institute of Technology.