RADIATION PROTECTION

Recommendations of the International Commission on Radiological Protection

ICRP PUBLICATION 2

Report of Committee II

on

Permissible Dose for Internal Radiation

(1959)

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CONTENTS

ACKNOWLEDGMENTS

The "Report of Committee II on Permissible Dose for Internal Radiation (1959)" represents the combined efforts of many individuals from many countries. In preparing this report Committee II of the International Commission on Radiological Protection (ICRP) has worked very closely with Subcommittee 2 on Permissible Internal Dose of the U.S. National Committee on Radiation Protection and Measurements (NCRP), and the present manuscript may be considered as a joint effort of these two groups. As an acknowledgment of this cooperation the members of NCRP Subcommittee 2 are listed here:

K. Z. Morgan, Chairman
A. M. Brues
P. W. Durbin
J. W. Healy
J. B. Hursh
L. D. Marinelli
W. S. Snyder
Shields Warren

In addition, many scientists from other countries have contributed, not only through their original research which is the basis of the report, but also by their generous aid in interpreting and adjusting their results to fit the conditions considered in this report. Finally, the technical work of collecting the data and interpreting it for conditions of occupational exposure as well as the writing of the text is largely the work of the Internal Dosimetry Section of the Oak Ridge National Laboratory headed by Dr. K. Z. Morgan. In particular, Mary Jane Cook has been responsible for the collection and presentation of the biological data, Mary Rose Ford has been responsible for the physical data used and for computation, J. Muir and Janet Kohn have computed the tables for the gastrointestinal tract values and for the effective energies respectively, and Dr. W. S. Snyder has supervised the technical work and acted as secretary to the ICRP Committee II in preparing this report. Finally, the Committee acknowledges the valuable assistance of the Publication Committee of the ICRP in the final editing of the report.[1]

The members of the International Committee II presenting this report are:

K. Z. Morgan, Chairman
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A. M. Brues
W. H. Langham
L. D. Marinelli
W. G. Marley
M. K. Nakaidzumi
G. J. Neary
M. N. Pobedinski
E. E. Pochin
C. G. Stewart

[1] During the meetings of the ICRP at Munich in July 1959, the Commission adopted certain Explanatory Statements and Amendments which are supplementary to 1958 Recommendations. The Explanatory Statements and Amendments were adopted after the Report of Committee II had been approved, but since they clarify and interpret the 1958 Recommendations of the Commission concerning several questions relevant to the Report of Committee II they are included in this volume.

RECOMMENDATIONS OF THE INTERNATIONAL COMMISSION ON RADIOLOGICAL PROTECTION*

PREFACE

THE International Commission on Radiological Protection (ICRP) has been functioning since 1928 when it was established, under the name of International X-ray and Radium Protection Commission, by the Second International Congress of Radiology held in Stockholm, Sweden. It assumed the present name and organizational form in 1950 in order to cover more effectively the rapidly expanding field of radiation protection.

The recommendations published in the present volume represent concepts and practices evolved from discussions at formal and informal meetings of the Commission and its Committees, held in recent years. Prior to World War II the Commission published recommendations at intervals of about three years. The first meeting in the post-war period was held in London in 1950. An informal meeting was held in Stockholm in 1952 in connection with the conference organized by the International Joint Committee on Radiobiology primarily to discuss the genetic effects of radiation. The next meeting was held in Copenhagen in 1953, at which time four of the Committees held formal meetings for the first time. The results of the deliberations were published in 1955 as Supplement No. 6 of the British Journal of Radiology. The Commission and its Committees met again in the spring of 1956 in Geneva, at which time most of the recommendations in the present volume were adopted in principle. At this meeting the Commission became formally affiliated with the World Health Organization (WHO) as a "non-governmental participating organization".

The Commission (ICRP) and the International Commission on Radiological Units (ICRU) held a special joint meeting in New York in the fall of 1956 to consider an invitation from the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) for cooperation in the phase of its work involving exposure from medical procedures. The two Commissions accepted the assigned task and submitted a report to UNSCEAR, published in the October 1957 issue of *Physics in Medicine and Biology*. Funds for expenses incurred in the preparation of the report were provided by the UNSCEAR. At the time of this joint meeting the Commission held an informal meeting to discuss further the recommendations to be made following the deliberations in Geneva earlier in the year. Additional discussions were carried out at another special meeting of the Commission held in New York in the spring of 1958. At this time an ad hoc Publication Committee was appointed to expedite the preparation of the manuscripts. This Committee held a two-week meeting in New York in May and prepared a first draft of the recommendations, which was sent out to all members of the Commission. The Committee met again during the second half of July and revised the first draft in accordance with suggestions made by members of the Commission. At this time, the Committee reviewed also the available drafts of the reports of the Commission's Committees.

In the preparation of the Commission's recommendations, the Publication Committee found it necessary to fill certain gaps involving items that had not been formally discussed and approved by the Commission. For this reason advantage was taken of the presence of seven members of the Commission in Geneva in September 1958 to review the second draft and make appropriate changes. The amendments were sent to the members who could not attend this meeting. The final draft embodies further comments made by members of the Commission.

Many individuals, who are not members of the Commission, were consulted in the preparation of the recommendations and their cooperation is gratefully acknowledged. In particular the recommendations on genetic dose were discussed by the Chairman of the Publication Committee with several prominent geneticists at the Xth International Congress of Genetics in Montreal, August 1958. It should be noted, also, that Committee I at its 1956 meeting in Geneva, prepared the first draft of the new recommendations adopted by the Commission at that time, which provided the basis for the recommendations published in the present volume.

In recent years the Commission has received financial assistance from the International Society of Radiology, the National Association of Swedish Insurance Companies and private Swedish sources for incidental secretarial expenses. Practically all the work of the Commission has been done on a voluntary basis by its members and members of its Committees. The Commission is heavily indebted to them for their efforts and to their parent organizations for technical and secretarial help. The World Health Organization contributed funds for travel expenses of some members of the Publication Committee, for secretarial help and for incidental expenses in the preparation and circulation of the manuscripts. The Commission takes this opportunity to express its deep appreciation of these contributions, without which the preparation of the present recommendations would have been greatly hampered.

The chairman of the Publication Committee and the Temporary Secretary wish to thank the members of the Commission for their cooperative and prompt replies to the numerous questionnaires and ballots that had to be circulated in the course of preparing the final manuscript. Thanks are due also to the members of the Publication Committee who prepared the first two drafts.

The Commission is happy to announce that the Pergamon Press has generously assumed financial responsibility for the publication and distribution (at modest prices and without copyright restrictions) of the present volume and others in preparation embodying the reports of the Commission's Committees.

ROLF M. SIEVERT

Chairman of ICRP

GIOACCHINO FAILLA

Vice-Chairman ICRP
Chairman of Publication Committee

ORGANIZATION

Rules Governing the Selection and Work of the International Commission on Radiological Protection

(1) The International Commission on Radiological Protection (ICRP) functions under the auspices of the International Congress of Radiology. The following rules, amended in 1953 by the International Executive Committee (IEC) of the Congress, govern the selection and work of the ICRP.

I. (a) The International Commission on Radiological Protection (ICRP) shall be composed of a Chairman and not more than 12 members. The selection of members shall be made by the International Executive Committee (IEC) from a list of nominations submitted by he national delegations and by the International Commission on Radiological Protection itself. Members of the ICRP shall be chosen on the basis of their recognized activity in the fields of radiology, radiation protection, physics, biology, genetics, biochemistry, and biophysics, without regard to nationality.

(b) The members of the ICRP shall be selected during one International Congress to serve through the succeeding Congress. Not less than two, but not more than four, members of the ICRP shall be changed at each Congress. In the intervening period a vacancy caused by conditions beyond the control of the IEC shall be filled on the recommendation of the ICRP.

(c) In the event of a member of the ICRP being unable to attend the ICRP meetings, a substitute may be selected by the ICRP as a temporary replacement. Such a substitute member shall not have voting privileges at the meetings unless specifically authorized by the IEC.

(d) The ICRP shall be permitted to invite individuals to attend its meetings to give special technical advice. Such persons shall not have voting privileges, but may ask permission to have their opinion recorded in the minutes.

II. The continuance of the records of the ICRP shall be in the hands of a Secretary of the ICRP elected by the ICRP from among its regular members and subject to the approval of the IEC.

III. The ICRP shall familiarize itself with progress in the whole field of radiation protection. The Secretary shall be responsible for the preparation of a programme to be submitted to the Commission for discussion at its meetings. Preliminary reports shall be prepared and circularized to all members of the ICRP and other specially qualified individuals at least six months before the meeting of the Congress.

IV. The Chairman shall be elected by the ICRP during one Congress to serve through the succeeding Congress. The choice shall not be limited to the country in which it is proposed to hold the succeeding Congress.

V. Decisions of the ICRP shall be decided by a majority vote, with the Chairman casting the deciding vote in case of a tie. A minority opinion may be appended to the minutes of a meeting if so desired by any member and upon his submission of same in writing to the Secretary.

Policy of the Commission

(2) The policy adopted by the ICRP in preparing its recommendations is to deal with the basic principles of radiation protection, and to leave to the various national protection committees the right and the responsibility of introducing the detailed technical regulations, recommendations, or codes of practice best suited to the needs of their individual countries.

(3) The Commission's recommendations have been kept continually under review in order to cover the increasing number and scope of potential radiation hazards, and to amend safety factors in the light of new knowledge concerning the effects of ionizing radiations.

Official Relations with the World Health Organization

(4) In accordance with rules laid down by the World Health Assembly for the admission of non-governmental organizations into official relations with the World Health Organization, such relations were established between the ICRP and WHO in 1956 and were reaffirmed in 1958. This arrangement has been eminently satisfactory to the Commission and it is hoped that it will continue.

Composition of the ICRP and Its Committees

(5) During the preparation of these recommendations the ICRP has had the following composition:

Main Commission

1953–1956

Sir Ernest Rock Carling, Chairman (Great Britain)
W. Binks, Secretary (Great Britain)
A. J. Cipriani (Canada)
G. Failla (U.S.A.)
H. Holthusen (Germany)
J. C. Jacobsen (Denmark)
R. G. Jaeger (Germany)
W. V. Mayneord (Great Britain)
K. Z. Morgan (U.S.A.)
R. M. Sievert (Sweden)
R. S. Stone (U.S.A.)
L. S. Taylor (U.S.A.)
M. Tubiana (France)

1956–

R. M. Sievert, Chairman (Sweden)
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W. Binks, Secretary* (Great Britain)
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J. C. Jacobsen (Denmark)
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L. S. Taylor (U.S.A.)
E. A. Watkinson (Canada)
Sir Ernest Rock Carling, Chairman emeritus (Great Britain)

* Mr. Binks resigned as Secretary in 1957, for health reasons. After his resignation E. E. Smith (Great Britain) served as Acting Secretary, and since August 1, 1957, B. Lindell (Sweden) has served as Temporary Secretary.

Committee I (*Permissible dose for external radiation*)

1953–1956

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L. Bugnard (France)
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J. C. Jacobsen (Denmark)
J. F. Loutit (Great Britain)
H. J. Muller (U.S.A.)
Jens Nielsen (Denmark)
R. M. Sievert (Sweden)
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1953–1956

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F. D. SOWBY (Canada)
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1958 *Publication Committee* (ad hoc)

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RECOMMENDATIONS OF THE COMMISSION

A. PREFATORY REVIEW

(1) Prior to the Geneva meeting of the Commission in April 1956, permissible levels of exposure to ionizing radiation had been expressed in terms of a dose in a rather short interval of time (1 day or 1 week), that is, essentially, in terms of an average dose rate—the average referring to the temporal distribution of the dose in the specified interval of time. Implicitly, if not explicitly, it was assumed that

* From March, 1958

if this average dose rate was low enough, no appreciable bodily injury would become apparent in the lifetime of the individual. The assumption was based largely on radiological experience which indicated that substantial skin recovery occurred within a few months following a moderate therapeutic dose and that the latent period for some long-term effects of radiation (e.g. cancer of the skin) resulting from residual tissue damage, was longer the lower the dose (or dose rate in the case of chronic exposure). Thus, in an occupationally exposed individual a long-term effect might not become apparent in his lifetime, even if a certain amount of permanent injury had occurred.

(2) The basic permissible weekly dose at that time was 0.3 rem/week. Assuming that a person was occupationally exposed at this rate (50 weeks a year) for 50 years, the permissible accumulated dose would be 750 rems in the most critical organs or essentially throughout the body. It was realized then that this constituted a "large" lifetime dose and an appropriate warning was included in the Commission's report of 1955.

(3) The general awareness of radiation hazards, induced caution on the part of those responsible for the protection of workers. Administratively, liberal factors of safety were often used especially in large atomic energy installations. As a result it was found that in general the actual exposure of personnel was kept at levels much below the then existing permissible limits.

(4) At the 1956 meeting of the Commission it became evident that stricter recommendations were needed. The 1955 Conference on the Peaceful Uses of Atomic Energy had aroused great interest in the development of atomic power plants throughout the world. In time this would greatly increase the number of persons occupationally exposed and would also bring about actual or potential exposure of other persons and the population as a whole. More importantly, the pressure for producing power economically might well do away with the "safety factors" mentioned above. Also, the average duration of occupational exposure per individual worker might increase. On the biological side it was considered that perhaps "recovery" plays a less important part in the long-term effects of radiation to be expected from continued exposure at low levels, than was earlier supposed. Because of the larger number of persons who would be exposed, occupationally or otherwise, genetic damage assumed greater importance. This was accentuated in no small degree by the realization that in some countries the per capita genetic dose contributed by medical procedures was about the same as that contributed by background radiation.

(5) Statistical studies had shown that the incidence of leukemia in radiologists was significantly greater than in other physicians who presumably were not professionally exposed to radiation. Of necessity these radiologists included those who had practiced their specialty at the time when radiation protection was not very effectively carried out. Therefore, the accumulated doses received by those who developed leukemia may have been much higher than the 750 rems mentioned above. On the other hand, since most of the exposure of these radiologists resulted from diagnostic procedures carried out with low voltage X-rays, the lifetime dose in the blood-forming organs may have been lower than 750 rems even if the skin dose, especially in some parts of the body was much higher. The mechanism of leukemia induction by radiation is not known. It may be postulated that if the dose is lower than a certain threshold value no leukemia is produced. In this case it would be necessary to estimate the threshold dose and to make allowances for recovery, if any. There is not sufficient information to do this, but caution would suggest that an accumulated dose of 750 rems might exceed the threshold. The most conservative approach would be to assume that there is no threshold and no recovery, in which case even low accumulated doses would induce leukemia in some susceptible individuals, and the incidence might be proportional to the accumulated dose. The same situation exists with respect to the induction of bone tumors by bone-seeking radioactive substances.

(6) Presently available longevity studies differ as to whether there is a statistically significant life shortening in radiologists as compared to other specialists presumably not occupationally

posed to radiation. However, in mammals chronically exposed at different daily doses a definite effect on longevity becomes clearly apparent at the higher daily doses. If extrapolation to lower daily doses, and then to man, is justified, it may be concluded that occupational exposure at presently accepted permissible limits may entail some life shortening. This effect may be interpreted as a slight acceleration of the natural aging process.

(7) The effects just discussed illustrate the two different types of possible long-term somatic effect that must be considered in setting up permissible limits of exposure. The first type (leukemia) is a serious effect occurring in some individuals and, therefore, the aim of protection would be to reduce the incidence to the lowest practical limit. The second type (life shortening) is presumably an effect on every individual and, therefore, the aim of protection would be to reduce the degree of effect to the lowest practical value. The definition of permissible dose has been changed to include explicitly these two types of possible effect.

(8) Genetic effects manifest themselves in the descendants of exposed individuals. The injury, when it appears, may be of any degree of severity from inconspicuous to lethal. A slight injury will tend to occur in the descendants for many generations, whereas a severe injury will be eliminated rapidly through the early death of the individual carrying the defective gene. Thus the sum total of the effect caused by a defective gene until it is eliminated may be considered to be roughly the same. The main consideration in the control of genetic damage (apart from aspects of individual misfortune) is the burden to society in future generations imposed by an increase in the proportion of individuals with deleterious mutations. From this point of view it is immaterial in the long run whether the defective genes are introduced into the general pool by a few individuals who have received large doses of radiation, or by many individuals in whom smaller doses have produced correspondingly fewer mutations. However, even in this case it is desirable to limit the dose received by an individual.

(9) In view of the foregoing, recommendations are made in this report in terms of maximum permissible doses for individuals and for population groups. In either case limits are set on the basis of dose accumulated over a period of years rather than in terms of a weekly dose that could be received for an indefinite period of time. The concept of limiting the accumulated dose was introduced by the Commission at its 1956 meeting in Geneva. The limitation of accumulated dose suggested at the time corresponds roughly to a three-fold reduction in weekly dose, for example, in the case of whole body occupational exposure when the exposure takes place approximately at a constant rate.

(10) In practice the problem of chief concern is chronic exposure either at low dose rates or by intermittent small doses. Under these conditions it is reasonable to assume that the dose accumulated over a period of years is the controlling factor, *provided* the intermittent doses are sufficiently small. Thus, in addition to limiting the accumulated dose it is necessary to limit the magnitude of a single dose (that is, a dose received in a short interval of time). Previously a single exposure equal to the maximum permissible weekly dose ("seven consecutive days") was permitted. Following the same pattern, the single dose limit for occupational exposure recommended in the present report is expressed in terms of the maximum permissible dose accumulated in a period of "13 consecutive weeks". The recommended value for the relevant organ (e.g. 3 rems for the blood-forming organs) has been made as high as it appears prudent, in the light of present knowledge. The stipulation of any 13 *consecutive* weeks has been made to make sure that operations are carried out in such a way that intermittent doses approximating the full 13 week quota do not occur at short intervals.

(11) In the recommendations published in 1955 maximum permissible limits were set on the basis of doses received by certain organs and certain serious late effects known to occur in them with sufficiently large doses. Provisions were made by means of an arbitrary "dose distribution curve" (in the report of Committee I) to limit the dose in other organs and tissues. This was made necessary by the adoption of a

maximum permissible dose for the skin twice as large as that for the blood-forming organs (with an assumed effective depth of 5 cm). In the present report separate recommendations are made for three groups of organs or tissues:

(a) Blood-forming organs, gonads and lenses of the eyes.
(b) Skin and thyroid gland.
(c) All other organs or tissues, specifically as regards exposure essentially limited to the organ or tissue in question.

(12) For the blood-forming organs, gonads and the lenses of the eyes the limits for occupational exposure are set in terms of the dose accumulated at various ages, according to the formula $D = 5(N - 18)$, where D is the dose in rems and N is the age in years, with the additional stipulation that the dose accumulated during any 13 consecutive weeks shall not exceed 3 rems.

(13) For the skin and the thyroid gland the limit for occupational exposure is set in terms of the dose accumulated during any 13 consecutive weeks, and the recommended value is 8 rems. This is derived from an average of 0.6 rem/week (the maximum permissible weekly dose formerly recommended for the skin of the whole body) which in 13 weeks amounts to 7.8 rems, and the nearest whole number is used to avoid the implication of greater accuracy than is warranted by present knowledge. The limit for the dose in these tissues accumulated in 1 year is $(0.6 \times 50) = 30$ rems. It should be noted that the new recommendation refers to the dose in the skin itself, irrespective of the dose distribution in the subcutaneous tissues. Therefore, the comparison should be made with the previous recommendation for exposure to radiation of very low penetrating power, for which the recommended limit was 1.5 rem/week. Accordingly, in this case also a reduction has been made in the accumulated dose, but the single exposure limit has been increased from 1.5 to 8 rems. This should provide more flexibility in practice than was possible formerly.

(14) For all organs and tissues of the body except the blood-forming organs, the gonads and the lenses of the eyes, the limit for occupational exposure is set in terms of the dose accumulated during any 13 consecutive weeks. With the exception of the skin, the pertinent practical cases in this category relate to exposure from internal sources essentially limited to individual organs or tissues. The following points require consideration. Whereas in the case of the blood-forming organs, the gonads, the lenses of the eyes and the skin, the objective of protection is to prevent or minimize definitely known types of injury, in the case of other organs the type of injury is not known. (Bone constitutes the only exception, in which case the relevant injury is cancer and permissible limits may be set on the basis of data furnished by human subjects who accumulated radium in their skeletons.) Possibly, radiation in sufficient dosage may increase the incidence of cancer in one of these organs (e.g. the thyroid gland) or it may accelerate aging of the organ. In the absence of factual data, it was deemed prudent in earlier recommendations of the commission to set the maximum permissible limit for these organs, when irradiated by internal sources, as low as that for the more sensitive organs such as the gonads, that is, 0.3 rem/week. When the exposure is essentially limited to *one organ* because of the more or less selective accumulation of a certain radioactive isotope therein, it is obvious that this limit embodies a factor of safety not present when the *whole body* is exposed at the same permissible limit. For this reason and the fact that none of these organs is known to be as sensitive as the blood-forming organs, the gonads and the lenses of the eyes, the Commission has decided to retain the previously recommended maximum permissible dose of 0.3 rem/week for each organ singly (with some exceptions noted in the report of Committee II). However, the limit is now expressed in terms of 13 consecutive weeks, which makes it 4 rems, in round figures, with an annual accumulated dose of 15 rems. Committee II has made the necessary adjustments to conform with the lower permissible limits now recommended for some organs and for what may be regarded as constituting "whole body" exposure (e.g. isotopes distributed throughout the body, or several isotopes present simultaneously, each concentrating significantly in a different organ).

(15) The Commission has given particular

ttention to the difficult problem of setting permissible limits for exposure of persons in the neighborhood of radiation installations. The chief obstacle is the almost complete lack of knowledge of the deleterious effects that may result from low level exposure starting at conception and continuing throughout life. It is reasonable to expect a more marked effect than in the case of exposure starting after the individual has reached maturity (for one thing, because the period of exposure is longer), but it is very difficult to decide what allowance to make. Guidance could be obtained from suitable experiments carried out with mammals and it is hoped that such studies will be undertaken soon in some laboratories. In the meantime caution is in order. The Commission recommends that provisions be made in a controlled area or areas to make sure that under normal operating conditions no child residing outside such controlled areas, receive more than 0.5 rem/year (in the appropriate organs) from radiation or radioactive material originating in ıe controlled area or areas. In practice it may be expected that while fluctuations in exposure rate would occur, they would not be such as to require special limitations. It will be noted that this is one tenth of the *lowest* annual dose in any organ permitted for occupational exposure. It includes contributions made by external and internal sources but does not include doses contributed by natural background radiation or medical procedures.

(16) Special groups of *adults* in the vicinity of a controlled area are permitted to receive larger annual doses in the gonads, the blood-forming organs and the lenses of the eyes, by a factor of three (i.e. 1.5 rems). No biological significance should be attached to the magnitude of this factor, since present radiobiological information is grossly inadequate in this respect. The value recommended (1.5 rems/year) is one tenth of the former maximum permissible annual dose for occupational exposure, on the basis of 0.3 rem/week in the most sensitive organs. (See also paragraphs 54, 56 and 57.)

(17) Planning for the future expansion of nuclear energy programs and the more extensive uses of radiation, requires measures intended to protect whole populations. Genetic damage is of greatest concern in this regard. The problem has been discussed by various national and international groups and tentative suggestions have been made. The Commission considered the problem at its 1956 meeting and later issued a statement in general terms. However, recommendations in quantitative terms are needed in the design of power plants and other radiation installations and particularly in making plans for disposal of radioactive waste products. It is of the utmost importance in this connection to make sure that nothing is done now that may prove to be a serious hazard later, which cannot be corrected at all or will be very expensive to correct. The Commission is aware of the fact that a proper balance between risks and benefits cannot yet be made, since it requires a more quantitative appraisal of both the probable biological damage and the probable benefits than is presently possible. Furthermore, it must be realized that the factors influencing the balancing of risks and benefits will vary from country to country and that the final decision rests with each country (insofar as operations within one country do not affect other countries).

(18) The Commission wishes to point out that it is important to assign quotas of a maximum permissible genetic dose to the different modes of exposure, in order to make sure that those responsible for the control of exposure in one category do not take up a disproportionate share of the permissible total in their planning. However, at this time it is deemed best not to assign rigid quotas. As a tentative guide an illustrative apportionment is appended to paragraph 65.

(19) Briefly, the suggested limit for the genetic dose was arrived at in the following manner: Estimates made by different national and international scientific bodies indicate that a per capita gonad dose of 6–10 rems accumulated from conception to age 30 from all man-made sources, would impose a considerable burden on society due to genetic damage, but that this additional burden may be regarded as tolerable and justifiable in view of the benefits that may be expected to accrue from the expansion of the practical applications of "atomic energy". There is at present considerable uncertainty as to the magnitude of

the burden (see for example the report of the United Nations Scientific Committee on the Effects of Atomic Radiation) and, therefore, it is highly desirable to keep the exposure of large populations at as low a level as practicable, with due regard to the necessity of providing additional sources of energy to meet the demands of modern society. A genetic dose of 10 rems from all man-made sources is regarded by most geneticists as the absolute maximum and all would prefer a lower dose. In some countries the genetic dose from medical procedures has been estimated to be about 4.5 rems (see *Report of Joint Study Made by ICRP-ICRU for the U.N. Scientific Committee*). Therefore, if the limit for the genetic dose from all man-made sources were set at 6 rems, the contribution from all sources other than medical procedures, would be limited to 1.5 rems in these countries. This would impose unacceptable restrictions on these countries. Accordingly, as a matter of practical necessity the Commission recommends that medical exposure be considered separately and that it be kept as low as is consistent with the necessary requirements of modern medical practice. The joint study of ICRP-ICRU indicates that careful attention to the protection of the gonads would result in a considerable reduction of the genetic dose due to medical procedures without impairment of their value. In view of these considerations the Commission suggests a limit of 5 rems for the genetic dose from all man-made sources of radiation and activities, except medical procedures.

(20) At the present time the contribution to the genetic dose from all man-made sources (other than medical procedures) is small. With careful planning the rate of increase can be kept under control and the ultimate value of this contribution may never reach the suggested limit of 5 rems. Since the genetic dose from medical exposure in most countries is much lower than 4.5 rems and since in those countries in which it is high efforts are being made to reduce it, the total genetic dose from all man-made sources actually received by the world population may be expected to be considerably less than 10 rems, perhaps even less than 6 rems in the foreseeable future. Furthermore, if a thermonuclear reaction can be utilized as a source of power, the problem of radiation protection may be greatly simplified.

(21) The Commission is aware that compliance with the new recommendations may entail structural changes in some existing installations and/or changes in operative procedures. Since in fact the new recommendations are more restrictive because of the greater emphasis put on the dose accumulated over a long period of time, it is not essential that such changes be made immediately, although it is obviously desirable. As a practical guide it is suggested that the transition period during which the necessary changes would be made, should not exceed five years.

(22) The Commission wishes to point out again that the setting up of maximum permissible limits of occupational and non-occupational exposure (especially the latter) requires quantitative information not yet available about the risks and benefits of an expanded use of "atomic energy". For this reason the Commission will be glad to receive factual data and suggestions from those concerned with the production or utilization of ionizing radiation, so that as much pertinent information as possible may be available to it in its future deliberations.

B. BASIC CONCEPTS

Objectives of Radiation Protection

(23) Exposure to ionizing radiation can result in injuries that manifest themselves in the exposed individual and in his descendants: these are called somatic and genetic injuries respectively.

(24) Late somatic injuries include leukemia and other malignant diseases, impaired fertility, cataracts and shortening of life. Genetic injuries manifest themselves in the offspring of irradiated individuals, and may not be apparent for many generations. Their detrimental effect can spread throughout a population by mating of exposed individuals with other members of the population.

(25) The objectives of radiation protection are to prevent or minimize somatic injuries and to minimize the deterioration of the genetic constitution of the population.

Critical Organs and Tissues

(26) The organs and tissues of the body exhibit varying degrees of radiosensitivity, and it is therefore necessary, for purposes of protection, to consider their radiosensitivity with respect to specific functions as well as the doses they receive. When this is done, some organs and tissues assume a greater importance, according to the circumstances under which they are irradiated. They are then said to be critical.

(27) In the case of more or less uniform irradiation of the *whole body*, the critical tissues are those tissues of the body that are most radiosensitive with respect to the ability of carrying out functions essential to the body as a whole. In this report these are taken to be the blood-forming organs, the gonads, and the lenses of the eyes. In previous reports the skin was listed as a critical organ in the case of whole body exposure. The presentation of the recommendations in the present report is simplified by not designating the skin as a critical organ.

(28) In the case of irradiation more or less limited to *portions of the* body, the critical tissue is that tissue most likely to be permanently damaged either because of its inherent radiosensitivity, or because of a combination of radiosensitivity and localized high dose.

Permissible Dose

(29) Any departure from the environmental conditions in which man has evolved may entail a risk of deleterious effects. It is therefore assumed that long continued exposure to ionizing radiation additional to that due to natural radiation involves some risk. However, man cannot entirely dispense with the use of ionizing radiations, and therefore the problem in practice is to limit the radiation dose to that which involves a risk that is not unacceptable to the individual and to the population at large. This is called a "permissible dose"

(30) The permissible dose for an *individual* is that dose, accumulated over a long period of time or resulting from a single exposure, which, in the light of present knowledge, carries a negligible probability of severe somatic or genetic injuries; furthermore, it is such a dose that any effects that ensue more frequently are limited to those of a minor nature that would not be considered unacceptable by the exposed individual and by competent medical authorities.

(31) Any severe somatic injuries (e.g. leukemia) that might result from exposure of individuals to the permissible dose would be limited to an exceedingly small fraction of the exposed group; effects such as shortening of life span, which might be expected to occur more frequently, would be very slight and would likely be hidden by normal biological variations. The permissible doses can therefore be expected to produce effects that could be detectable only by statistical methods applied to large groups.

(32) The permissible dose to the gonads for the *whole population* is limited primarily by considerations with respect to genetic effects (see paragraphs 58–65).

Categories of Exposure

(33) These recommendations are designed to limit not only somatic but also genetic effects; it is therefore necessary to reduce as much as possible the dose to the population as a whole, as well as to the individual. In general, doses resulting from all sources of ionizing radiation should be considered in the appraisal of possible biological damage. However practical considerations make it necessary to consider separately the doses resulting from two categories of exposure, namely:

(a) Exposure to natural background radiation.
(b) Exposure resulting from medical procedures.

(34) Natural background radiation varies considerably from locality to locality and the doses it contributes to the various organs are not well known. If maximum permissible limits recommended by the Commission included background radiation, the allowable contribution from man-made sources—which are the only ones that can be controlled—would be uncertain and would have to be different for different localities. Accordingly, doses resulting

from natural background radiation are excluded from all maximum permissible doses recommended in this report.

(35) In medical procedures, exposure of the patient to primary radiation is generally limited to parts of the body, but the whole body is exposed to some extent to stray radiation. The contributions to the doses in various organs and the part played in the over-all effects on the individual are practically impossible to evaluate at the present time. The Commission recognizes especially the importance of the *gonad* doses resulting from medical exposure and the attendant genetic hazard to the population. Accordingly, it recommends that the medical profession exercise great care in the use of ionizing radiation in order that the gonad dose received by individuals before the end of their reproductive periods be kept at the minimum value consistent with medical requirements. However, individual doses resulting from medical exposure are excluded from all maximum permissible doses recommended in this report.

(36) The recommendations cover the following categories of exposure. In principle both the exposure of *individuals* and averages over the whole *population* have to be considered, but recommendations with regard to individual exposure are given only for the groups A and B.

A. *Occupational exposure.*

B. *Exposure of special groups:*

(a) Adults who work in the vicinity of controlled areas (see paragraphs 71 and 72), but who are not themselves employed on work causing exposure to radiation.

(b) Adults who enter controlled areas occasionally in the course of their duties, but are not regarded as radiation workers.

(c) Members of the public living in the neighborhood of controlled areas.

C. *Exposure of the population at large.*

D. *Medical exposure.*

Occupational exposure

(37) Exposure of an *individual* who normally works in a controlled area constitutes occupational exposure. Maximum permissible doses are set for the individuals in the small portion of the population that can be occupationally exposed (paragraphs 46–52). The contribution from this group to the genetic dose to the *population* as a whole is discussed in paragraph 65.

Exposure of special groups

(38) Persons who only occasionally enter a controlled area and persons who work or reside in the vicinity of a controlled area may be exposed to radiation originating in the controlled area. They constitute groups that may include children and pregnant women as well as individuals subject to other hazards, and may in total constitute a large fraction of the whole population. For these reasons the maximum permissible dose to these persons as *individuals* is set lower than for persons occupationally exposed (paragraphs 53–57). The contribution from these groups to the genetic dose to the whole *population* is discussed in paragraph 65.

Exposure of the population at large

(39) Members of the population at large may be exposed to radiation that cannot be related to any specific controlled area; e.g. exposure from environmental contamination and widely distributed radiation sources such as wristwatches, TV-sets and various applications of radioactive materials to be expected as a result of future expansion in the atomic energy field. As such exposure is not easily controlled, it will be impossible to ensure that a recommended maximum permissible individual dose is not exceeded in any single case. Where large numbers are involved, it will not be possible to examine the habits of every individual. A reasonable procedure would be to study a sample of the group involved and to set the environmental level so that no individual in the sample receives any excessive exposure. There will always remain the possibility that someone of grossly different habits from those in the observed sample may receive a higher dose than the maximum in the sample.

(40) In order to facilitate planning for the anticipated increased uses of nuclear energy and other sources of radiation, it is desirable at this time to recommend a maximum for the genetic dose to the *population* (paragraph 64); this

maximum will determine what average gonad exposure could be allowed. Part of the recommended maximum genetic dose will have to be used for exposure of groups such as A and B and for medical exposure. The proper apportionment for exposure of the population at large must allow for both internal and external exposure (paragraph 65).

Medical exposure

(41) No recommendations are given with regard to the dose to the individual from medical exposure. (The contribution of medical exposure to the genetic dose is discussed in paragraphs 69–70.)

Reduction in Maximum Permissible Dose

(42) The new recommendations were introduced partly with the intention of limiting the genetically significant radiation exposure (see paragraph 63) of the population, and partly to limit the probability of somatic injury by reducing the lifetime dose. This reduction does not result from positive evidence of damage due to the use of the earlier permissible dose levels, but rather is based on the concept that biological recovery may be minimal at such low dose levels.

Time Interval over which Dose is to be Assessed

(43) The maximum permissible weekly doses recommended by the Commission in 1950 have been replaced by limits for the doses received over longer periods of time (paragraphs 47–49). In the case of occupational exposure the maximum permissible dose that may be accumulated at a certain time depends on the age of the worker. The dose to individuals in the population at large, or in special groups other than occupational, may be accumulated at a rate that is determined by a maximum permissible annual dose. The genetic dose to the whole population is assessed over the period between conception of the individual and conception of each child of the individual. (See paragraph 63 for method of evaluation.)

(44) These extended periods of time allow for some flexibility in the way in which radiation exposure may be received, and at the same time provide what is considered to be adequate protection for each group of the population.

C. MAXIMUM PERMISSIBLE DOSES

GENERAL

(45) It is emphasized that the maximum permissible doses recommended in this section are *maximum* values; the Commission recommends that all doses be kept as low as practicable, and that any unnecessary exposure be avoided.

EXPOSURE OF INDIVIDUALS

Occupational Exposure

(46) In any organ or tissue, the *total* dose due to occupational exposure shall comprise the dose contributed by external sources during working hours and the dose contributed by internal sources taken into the body during working hours. It shall not include any medical exposure or exposure to natural radiation.

Exposure of the gonads, the blood-forming organs and the lenses of the eyes

(47) The maximum permissible total dose accumulated in the gonads, the blood-forming organs and lenses of the eyes at any age over 18 years shall be governed by the relation

$$D = 5(N - 18)$$

where D is tissue dose in rems and N is age in years.

(48) For a person who is occupationally exposed at a constant rate from age 18 years, the formula implies a maximum weekly dose of 0.1 rem. It is recommended that this value be used for purposes of planning and design.

Rate of dose accumulation

(49) To the extent the formula permits, an occupationally exposed person may accumulate the maximum permissible dose at a rate not in excess of 3 rems during any period of 13 consecutive weeks (i.e. in no 13 consecutive weeks shall the dose exceed 3 rems). If necessary, the 3 rems may be received as a single dose, but as the scientific knowledge of the biological effects of differing dose rates is scant, single doses of the order of 3 rems should be avoided as far as practicable.

Application to special cases

(50) Setting permissible limits of exposure in terms of the dose accumulated up to a given age introduces certain practical complications. Thus, some workers (previously exposed at levels within the then permissible limits) may have already accumulated a dose in excess of the maximum permitted by the formula. There are also special cases in which exceptions in the application of the formula may be desirable for practical reasons and are justifiable within the context of paragraph 42. The following recommendations are intended to provide guidance on administrative policy, which may well vary according to circumstances at the local level. (It should be noted that this situation will obtain only during a relatively short transition period.)

(51a) *Previous exposure history unknown.* When the previous occupational exposure history of an individual is not definitely known, it shall be assumed that he has already received the full quota permitted by the formula.

(51b) *Persons exposed in accordance with the former maximum permissible weekly dose.* Persons who were exposed in accordance with the former maximum permissible weekly dose of 0.3 rem and who have accumulated a dose higher than that permitted by the formula, should not be exposed at a rate higher than 5 rems in any one year, until the accumulated dose at a subsequent time is lower than that permitted by the formula.

(51c) *Persons starting work at an age of less than 18 years.* When a person begins to be occupationally exposed at an age of less than 18 years, the dose shall not exceed 5 rems in any one year under age 18, and the dose accumulated to age 30 shall not exceed 60 rems. (The minimum age at which occupational exposure is legally permitted is lower than 18 years in some countries.)

(51d) *Accidental high exposure.* An accidental high exposure that occurs *only once in a lifetime* and contributes no more than 25 rems shall be added to the occupational dose accumulated up to the time of the accident. If the sum then exceeds the maximum value permitted by the formula, the excess need not be included in future calculations of the person's accumulated dose. Accidental exposure to doses higher than 25 rems must be regarded as being potentially serious, and shall be referred to competent medical authorities for appropriate remedial action and recommendations on subsequent occupational exposure. This is intended as an administrative guide to permit the continuation of work with radiation, following a bona fide accident ("once in a lifetime"), in cases in which interruption of such work, or curtailment of exposure, would handicap the individual in the pursuit of his career.

(51e) *Emergency exposure.* Emergency work involving exposure above permissible limits shall be planned on the basis that the individual will not receive a dose in excess of 12 rems. This shall be added to the occupational dose accumulated up to the time of the emergency exposure. If the sum then exceeds the maximum value permitted by the formula, the excess shall be made up by lowering the subsequent exposure rate so that within a period not exceeding 5 years, the accumulated dose will conform with the limit set by the formula. Women of reproductive age shall not be subjected to such emergency exposure.

Exposure of single organs other than the gonads, the blood-forming organs and the lenses of the eyes

(52) For exposure that is essentially restricted to portions or single organs of the body, with the exception of the gonads, the blood-forming organs and the lenses of the eyes, a higher dose than the one derived from the formula $D = 5(N - 18)$ is permitted. The following recommendations are made.

(52a) *A maximum dose of* 8 *rems*/13 *weeks for* *the skin.** The earlier recommended weekly maximum doses for exposure of the skin, namely 0.6 rem in connection with a whole body exposure and 1.5 rems for exposure with radiation of very low penetrating power, have been replaced by the recommendation that the dose in the skin, accumulated over any 13 consecutive weeks, shall not exceed 8 rems. This recommendation now applies to all exposure of the skin, except the skin of the hands and forearms, feet and ankles. As the 8 rems are derived from an average of 0.6 rem/week, the annual dose for a 50 week year is limited to 30 rems.

(52b) *A maximum dose of* 20 *rems*/13 *weeks for the hands and forearms, feet and ankles.* The earlier recommended weekly maximum of 1.5 rems for exposure of hands and forearms, feet and ankles has been replaced by the recommendation that the dose accumulated over any 13 consecutive weeks shall not exceed 20 rems. This recommendation applies to all tissues of the above-mentioned extremities. As the 20 rems are derived from an average of 1.5 rems/week, the annual dose for a 50 week year is limited to 75 rems.

(52c) *A maximum dose of* 4 *rems*/13 *weeks for limited exposure of internal organs other than the thyroid, the gonads and the blood-forming organs.* In the case of internal organs, limited exposure originates almost exclusively from radioisotopes within the body. As most planning of release of radioactive isotopes to the air and water supplies in controlled areas is made under conditions where occupational groups rather than single individuals are exposed, a formula corresponding to the one given in paragraph 47 cannot in general be applied to internal exposure. An average of 0.3 rem/week in the organ of interest (with some exceptions noted in the report of Committee II) is expected to be maintained under equilibrium conditions if the concentration in air *or* water of the relevant isotope is kept at levels given in the tables in the report of Committee II. Variations of the dose rate will occur in practice, and are permissible, provided that the dose accumulated over any 13 consecutive weeks does not exceed 4 rems. As this maximum is derived from a weekly average of 0.3 rem, the annual dose for a 50 week year is limited to 15 rems.

(52d) *Whole body exposure from uptake of several radioisotopes.* When the radioactive isotopes in a mixture are taken up by several organs and the resultant tissue doses in such organs are of comparable magnitude, the combined exposure is considered to constitute essentially whole body exposure. Accordingly, the permissible levels of exposure will be those applicable to the gonads, the blood-forming organs and the lenses of the eyes.

Exposure of Special Groups

(53) The total maximum permissible individual dose shall consist of the sum of the doses contributed by both external and internal sources. It shall not include any medical exposure or exposure to natural radiation.

Total annual dose to the gonads, the blood-forming organs and the lenses of the eyes

(54) For any individual in the groups B(a) and B(b) (see paragraph 36), the total annual dose, including contributions from external and internal sources, to the gonads, the blood-forming organs and the lenses of the eyes, due to operations within the controlled area shall not exceed 1.5 rems, nor shall the contribution from a mixture of isotopes whose combined exposure constitutes essentially whole body exposure, make the total annual dose exceed 1.5 rems. There is an exception in the case of the skin and the thyroid where an annual maximum of 3 rems is allowed.

(55) The group B(c) differs from the groups B(a) and B(b) in that it contains children for whom it is considered that a lower figure, namely 0.5 rem/year (in the gonads, the blood-forming organs and the lenses of the eyes), should apply. Accordingly the presence of children in the group B(c) will require the use of a value of 0.5 rem/year for this group for purposes of planning and design.

Internal exposure of single organs

(56) The *individual* maximum permissible annual dose will not be exceeded *from internal exposure* of any single organ, if the release of radioactive material is planned on the basis

* This also applies to the thyroid, see report of Committee II.

of $\frac{1}{10}$ of the maximum permissible concentration (MPC) in air *or* water as given for continuous occupational exposure ("168-hour week") in the tables in the report of Committee II.

Whole body exposure from uptake of several radioisotopes applicable to group B(c)

(57) When the radioactive isotopes in a mixture are taken up by several organs in such a way that the combined exposure constitutes essentially whole body exposure, a reduction of the maximum permissible concentrations based on the exposure of single organs (see report of Committee II) becomes necessary. The reduction should take into account the number and importance of the organs in question and the contribution to whole body exposure made by radioactive material in the circulating blood and in organs other than those in which it is assumed to concentrate. In this case the total body is considered to be the critical organ and the MPC values for the individual radioisotopes are reduced so that the MPC for the mixture corresponds to an average annual dose of 0.5 rem to the total body. For such mixtures of radioisotopes this is equivalent to a reduction in the MPC values of the individual radioisotopes in the mixture by a factor of $\frac{1}{3}$ or less in addition to the factor of $\frac{1}{10}$ recommended in paragraph 56.

EXPOSURE OF POPULATION

General

(58) Proper planning for nuclear power programs and other peaceful uses of atomic energy on a large scale requires a limitation of the exposure of whole populations, partly by limiting the individual doses and partly by limiting the number of persons exposed.

(59) This limitation necessarily involves a compromise between deleterious effects and social benefits. Consideration of genetic effects plays a major role in its evaluation. The problem has been discussed extensively in recent years and suggestions have been made by different national bodies. The Commission is aware of the fact that a proper balance between risks and benefits cannot yet be made, since it requires a more quantitative appraisal of the probable biological damage and the probable benefits than is presently possible. Furthermore, it must be realized that the factors influencing the balancing of risks and benefits will vary from country to country and that the final decision rests with each country.

(60) Because of the urgent need for guidance in this regard, the Commission in the following sections suggests an interim ceiling for the exposure of the whole population. The proposed level is essentially in accordance with suggestions by other scientific groups that have studied the problem and tried to evaluate the possible biological effects. It is felt that this level provides reasonable latitude for the expansion of atomic energy programs in the foreseeable future. It should be emphasized that the limit may not in fact represent the proper balance between possible harm and probable benefit, for reasons already mentioned.

(61) On the assumption that the genetic effects are linearly related to the gonad dose and provided that no threshold dose exists, it is possible to define a population dose average that is relevant to the assessment of genetic injury to the whole population (paragraphs 62–63). In the case of somatic effects no such dose can easily be defined although the annual per capita dose to certain tissues or to the whole body may be relevant on the assumption of a non-threshold, linear dose-effect relation.

Genetic Dose

Assessment of genetic dose

(62) The genetic dose to a population is the dose which, if it were received by each person from conception to the mean age of childbearing, would result in the same genetic burden to the whole population as do the actual doses received by the individuals. A permissible genetic dose is that dose, which if it were received by each person from conception to the mean age of childbearing, would result in an acceptable burden to the whole population.

(63) The genetic dose to a population can be assessed as the annual genetically significant dose multiplied by the mean age of child-bearing, which for the purpose of these recommendations is taken to be 30 years. The annual genetically significant dose to a population is the average of the individual gonad doses, each weighted for the expected number of children conceived subsequent to the exposure.

Maximum permissible genetic dose

(64) It is suggested that the genetic dose (see paragraph 63) to the whole population from all sources additional to the natural background should not exceed 5 rems plus the lowest practicable contribution from medical exposure. The background is excluded from the suggested value because it varies considerably from country to country. The contribution from medical exposure is considered separately for the same reason and also because the subject is being studied for the purpose of limiting such exposure to the minimum value consistent with medical requirements.

Apportionment of genetic dose

(65) The suggested maximum genetic dose of 5 rems in addition to the dose from medical procedures and natural background must not be used up by one single type of exposure. The proper apportionment of the total will depend upon circumstances which may vary from country to country, and the decision should therefore be made by national authorities.

Addendum to paragraph 65

(a) *Illustrative apportionment.* The Commission does not wish to make any firm recommendations as to the apportionment of the genetic dose of 5 rems but, for guidance, gives the following apportionment as an illustration.

(A) Occupational exposure	1.0 rem
(B) Exposure of special groups	0.5 rem
(C) Exposure of the population at large	2.0 rems
Reserve	1.5 rems

(b) *Fractions of population.* Assuming that the ratio of the total population to the reproductive population is the same in all groups, the largest fraction (ε) of the whole population that can be exposed to an average annual dose $\overline{D}_1^i$ is given by the equation:

$$\varepsilon \,.\, 30 \,.\, \overline{D}_1^i = D_{30}^i$$

where D_{30}^i is the apportionment of the genetic dose to the ith exposure group, and the average annual dose within the group can be expressed as a fraction of the maximum permissible individual annual dose; i.e. $\overline{D}_1^i = F_1 D_1^i$.

(c) *Occupational exposure.* Assigning 1.0 rem to occupational exposure would mean that 0.7 per cent of the whole population could accumulate the maximum permissible occupational gonad dose of 60 rems by age 30. It is very unlikely that such a figure will be approached in the foreseeable future. At the present time, the number of persons occupationally exposed in technologically developed countries is about 0.1–0.2 per cent of the population, and most of these persons receive doses which are considerably less than the maximum permissible doses.

(d) *Exposure of special groups.* Since the contribution from the special groups is largely due to group B(c) an apportionment of 0.5 rem for the special groups would imply that about 3 per cent could be exposed to the maximum permissible individual annual gonad doses for these groups. The allowable size of these groups varies inversely with the average dose within the groups. Thus, if this dose were only 10 per cent of the maximum individual doses, the groups could amount to 30 per cent of the whole population, which is very much larger than is likely to occur.

(e) *Exposure of the population at large.* The apportionment of 2.0 rems (with a long-term reserve of 1.5 rems for possible eventualities) for the genetic exposure of the population at large is intended for planning purposes in the development of nuclear energy programs (with the associated waste disposal problems) and more extensive uses of radiation sources. In the case of internal exposure, the radioisotopes of interest are those that contribute to the gonad dose directly (by local concentration) or indirectly (by radiation produced elsewhere in the body). In either case the maximum permissible concentrations in air and water of these isotopes recommended by Committee II for continuous occupational exposure ("168-hour week") are based on an average yearly dose of 5 rems in the gonads or the whole body. If for these isotopes the average concentrations in public air and water supplies are lower than the values recommended for continuous occupational exposure by a factor of 1/100, the genetic dose to the population would amount to 1.5 rems (5 × 1/100 rems/year in the gonads ×

30 years = 1.5 rems). In this case the contribution from external sources should be limited to 0.5 rem in order not to exceed the total of 2 rems.

Somatic Dose

(66) No specific recommendations are made at this time as to the maximum permissible "somatically" relevant dose to the population. However, it is expected that the maximum permissible limits of the *individual* total doses recommended in paragraphs 46–57 will keep the average dose in any tissue at such a level that the injuries that could possibly occur in a population would be well within acceptable limits. (See paragraph 31.)

(67) In the case of external exposure of the whole body to penetrating radiation the restriction imposed by the genetic dose to the population automatically reduces the doses to internal organs below the *individual* maximum permissible annual doses recommended in paragraphs 46–57. Thus the probability of somatic injury in these organs is considerably lower than indicated in paragraph 66. The same thing applies to internal exposure resulting from radioisotopes that directly or indirectly contribute to the gonad dose of a population. (See addendum to paragraph 65.)

(68) There remain for further consideration those isotopes that concentrate in specific organs (other than the gonads). In view of the existing uncertainty as to the dose-effect relationships for somatic effects, it is suggested that for planning purposes the average concentrations of such isotopes, or mixtures thereof, in air or water, applicable to the population at large, should not exceed one-thirtieth of the MPC values for continuous occupational exposure given in the report of Committee II.

Medical Exposure

(69) Estimates of the current annual genetically significant dose from medical procedures in various countries were surveyed in a report of a joint study group of the ICRP and ICRU to the United Nations Scientific Committee on the Effects of Atomic Radiation. The United Nations Scientific Committee gives the following summary statement in its 1958 report to the General Assembly:

"The contribution made by medical procedures to the radiation exposure of populations has only lately been estimated and has increased very rapidly in some countries in recent years, so that it is difficult to evaluate such genetic and somatic effects as are associated with an increasing employment of radiological procedures in medicine. No information is yet available for prediction of the future trend of medical exposures. It is expected that improvements in equipment and techniques may considerably reduce individual exposures, but the ever-expanding use of X-rays may well increase the world population dose. Precautions of the type described by the International Commissions on Radiological Protection and on Radiological Units and Measurements should make possible such reduction of exposure to radiation as is without detriment to the medical value of these procedures."

(70) Reported values of the annual genetically significant dose in various countries range up to about 150 mrems, corresponding to a genetic dose of 4.5 rems (from conception to age 30 years, averaged over the whole population). Even with the highest values reported (corresponding to the genetic dose of 4.5 rems), the total genetic dose from all types of exposure would not exceed 10 rems if the apportionment for the contributions from other exposure sources than medical is not exceeded. There are indications that the highest levels of medical exposure reported could be reduced significantly by careful attention to techniques. On the other hand, the use of X-rays may increase, although probably to a lesser degree in the countries which now report the most extensive use. A certain allowance for medical exposure of populations must be made and may be made in the near future as the subject is being studied for the purpose of limiting such exposure to the minimum value consistent with medical requirements.

D. GENERAL PRINCIPLES REGARDING WORKING CONDITIONS

Responsibility

The owner or the person in charge of a controlled area shall be responsible for the working conditions and for the instruction of all persons working in the area regarding radiation hazards and methods of control. He shall be responsible for maintaining radiation levels outside the controlled area resulting from operations within the area so that exposures do not exceed the maximum permissible doses recommended in paragraphs 53–57.

(71) A controlled area shall be established where persons occupationally exposed could receive doses in excess of 1.5 rems/year.

(72) A controlled area is an area in which the exposure of personnel to radiation or radioactive material is under the supervision of a radiation protection officer.

(73) A radiation protection officer is one who has the knowledge and responsibility to apply appropriate radiation protection regulations. He may be the owner or the person in charge of the controlled area or he may be a technically competent person appointed by the above.

(74) A qualified expert (or health physicist) is a person having the knowledge and training needed to measure ionizing radiations and to advise regarding radiation protection. The qualification should be of the type specified by a National Committee.

Radiation Surveys and Monitoring

Surveys prior to use of controlled areas

(76) In those instances where the operations in a controlled area may disturb or alter significantly the environment with respect to radiation hazards, adequate surveys should be made of the radioactivity of the air, soil, and water prior to the start of operations. This will provide a base line from which to judge the adequacy of radiation controls within the area.

(77) During and after installation, appropriate radiation surveys shall be made to ensure that the pertinent recommendations will be complied with when routine operations commence. Routine operations shall be deferred until such compliance is assured.

(78) When additional operations are planned in the area, a thorough survey should be made of the background radiation prior to the start of the new operations. This will aid in the identification of the operation responsible for any increase of the background radiation or the contamination in the area.

Routine surveys and monitoring

(79) Radiation surveys shall be made regularly, at a frequency dictated by the operations within the area, to determine the adequacy of safety procedures. This should include checks of the facilities, equipment (radiation warning devices, radiation shields, hoods, respirators, ventilating system etc.), and working techniques. When there is any reasonable probability of a radiation hazard existing, the vicinity of the controlled area should also be surveyed.

Special surveys

(80) Specific and detailed recommendations regarding radiation surveys applicable to some special cases will be given in the Reports of the Committees of ICRP.

Health Surveillance

Pre-employment examination

(81) All new personnel in radiation work shall have a pre-employment medical examination. Notes should be made of the family history, of the previous occupational history, and of previous X-ray diagnostic examination or radiation therapy. The examination shall include a complete blood count, with determination of erythrocyte and leukocyte levels and a differential white cell count. It should be recognized that the examination is directed toward determining the "normal" condition of the worker at the time of employment, and toward noting any abnormalities that might later be confused with radiation damage.

(82) In cases where there has been previous occupational exposure, the total accumulated dose shall be recorded (see paragraphs 47–51) and any appropriate additional medical examinations performed. These should include

ophthalmological examinations, with particular reference to changes in the lens in cases of exposure to neutrons and to heavy particles, and examinations of skin and nails in the case of partial external irradiation and external contamination.

Routine medical examinations

(83) Medical examinations should be performed at a frequency depending upon the conditions of the occupational exposure. Blood counts, although they are a part of a medical examination, are not to be considered as a method of radiation monitoring.

(84) Persons occupationally exposed to neutrons and to heavy particles of significant penetration should have ophthalmological examinations, with particular reference to changes in the lens. The frequency of the examination will depend upon the conditions of exposure.

PERSONNEL MONITORING

External radiation

(85) Doses received as a result of occupational exposures shall be systematically checked with appropriate instruments to ensure that the maximum permissible doses are not exceeded and to make it possible to keep individual cumulative dose records.

Internal radiation

(86) Tests should be performed to estimate the total body burden for workers who deal with unsealed radioactive isotopes that may give rise to levels of ingestion or inhalation in excess of the maximum permissible concentrations. Such tests should also be performed where radioisotopes may enter the body through the skin or through skin punctures and open wounds. These tests may require the monitoring of breath and excreta, and the direct determination of the body burden by means of a total body monitor, according to circumstances. The radiation doses delivered to the appropriate organs or tissues should be calculated and noted on the personal record, and the permitted doses of external radiation should be adjusted to allow for the "internal" doses.

RADIATION WARNING DEVICES

(87) An appropriate form of warning shall be provided to indicate the existence of a radiation hazard, even if the hazard is of a temporary nature only. In the latter case the warning device should be removed when the hazard no longer exists.

ADDENDUM TO ICRP PUBLICATION I (1958 RECOMMENDATIONS)

REPORT ON DECISIONS AT THE 1959 MEETING OF THE INTERNATIONAL COMMISSION ON RADIOLOGICAL PROTECTION (ICRP)

INTRODUCTION

The period since the Commission's last regular meeting in 1956 has been the most active in its history. Because of rapid developments in the field of nuclear energy and the more widespread use of radiation sources of all types, the scope of the work has increased beyond the field of medical radiology into all fields of radiation protection, including industrial uses as well as the exposure of the general public.

In 1955 the United Nations established a Scientific Committee on the Effects of Atomic Radiation to collect and evaluate information on radiation exposure and radiation effects. In addition, bodies such as the World Health Organization, the International Labour Office, the Food and Agriculture Organization and the International Atomic Energy Agency are actively interested in radiation protection problems and look to the International Commission on Radiological Protection for guidance. Although the primary responsibility of the Commission has been to the radiological profession, it has had to widen its scope and has accordingly been active not only during the last two international Congresses of Radiology but also in the intervening period.

Amendments to the 1953[1] Recommendations were reported to the Mexico Congress and published in 1957.[2] Revised Recommendations of the Main Commission were adopted in 1958 and printed early in 1959.[3] Reports of the various Committees exist at present in various stages of preparation. The Report of Committee II on internal radioactive substances is already in press.[4] A revised version of the Committee III Report, which is essentially a code of practice for the radiological profession, was approved during the 1959 meeting and will be published in the near future.[5] The Report of Committee IV on high-energy and heavy-particle radiation is undergoing a final revision. Committee V has prepared a report on the disposal of radioactive waste from hospitals and laboratories and is proceeding as rapidly as possible to prepare a further report on the disposal of waste from atomic energy establishments.

The Commission has an official relationship with the World Health Organization and the International Atomic Energy Agency. There has been close co-operation with the United Nations Scientific Committee on the Effects of Atomic Radiation, and the Commission, jointly with the International Commission on Radiological Units and Measurements, has on two occasions accepted its invitation to perform special studies. The results of the first study on the evaluation of gonad dose from medical procedures were published in 1957.[6] The second study, on the evaluation of exposure relevant to somatic damage, has been initiated and a report is to be prepared before the end of 1960.

The Commission also co-operates with the International Labour Office and the Food and Agriculture Organization and has invited them to send observers to future meetings. The Commission has been invited to send observers to appropriate meetings of the International Organization for Standardization and the United Nations Educational, Scientific and Cultural Organization.

During the 1959 meeting, the Commission discussed its basic Recommendations[3] and although no substantial changes were made, a number of explanatory statements were drafted. These statements which will be presented in the following text include such subjects as the irradiation of pregnant women, the maximum doses to individuals in the population at large, the interpretation to be placed on the paragraph dealing with the contamination of public air and water supplies, and the hours of work and vacation of radiation workers.

A grant from the Rockefeller Foundation made it possible for the Commission to invite a number of non-member experts on dose-effect relations to participate in the Munich discussions and be available for consultation.

During the preparation of this statement the ICRP has had the following composition.

1956–1959
(Including the Munich sessions)

R. M. Sievert, Chairman (Sweden)
G. Failla, Vice-Chairman (U.S.A.)
W. Binks, Secretary* (Great Britain)
L. Bugnard (France)
H. Holthusen (Germany)
J. C. Jacobsen (Denmark)
R. G. Jaeger (Germany)
W. V. Mayneord (Great Britain)
K. Z. Morgan (U.S.A.)
R. S. Stone (U.S.A.)
L. S. Taylor (U.S.A.)
E. A. Watkinson (Canada)
Sir Ernest Rock Carling, Chairman emeritus (Great Britain)

1959–
(Present composition)

R. M. Sievert, Chairman (Sweden)
E. E. Pochin, Vice-Chairman (Great Britain)
W. Binks (Great Britain)
L. Bugnard (France)
H. Holthusen (Germany)
J. C. Jacobsen (Denmark)
R. G. Jaeger (Germany)
J. F. Loutit (Great Britain)
K. Z. Morgan (U.S.A.)
H. J. Muller (U.S.A.)
R. S. Stone (U.S.A.)
L. S. Taylor (U.S.A.)
E. A. Watkinson (Canada)
Sir Ernest Rock Carling, Chairman emeritus (Great Britain)
G. Failla, Vice-Chairman emeritus (U.S.A.)
B. Lindell, Secretary (Sweden)

* Mr. Binks resigned as Secretary in 1957, for health reasons. After his resignation E. E. Smith (Great Britain) served as Acting Secretary, and since August 1, 1957, B. Lindell (Sweden) has served as Temporary Secretary.

EXPLANATORY STATEMENTS AND AMENDMENTS TO THE 1958 RECOMMENDATIONS

In the 1958[3] Recommendations all maximum permissible doses are expressed in rems without reference to the appropriate RBE values. Such reference will be given in the reports of the Committees concerning the application of the recommendations in various specified fields. The RBE values used in each of the Committee reports to be published are consistent with those published in 1955.[1]

The following statements refer to particular paragraphs in the 1958 Recommendations:

Explanatory statement of paragraph 46 (*see also paragraphs* 35 *and* 41)

It has been recommended that "medical exposure" be excluded from the calculation of the maximum permissible dose of those occupationally exposed. The Commission wishes to emphasize that "medical exposure" refers to the exposure of *patients* that is necessary for medical purposes and *not* to the exposure of the personnel conducting such procedure.

Interpretation of paragraph 49 (*see also paragraphs* 10, 14 *and* 52)

A calendar 13-week period may be used instead of a period of 13 consecutive weeks *if there is no reason to suppose that doses are being accumulated at grossly irregular rates.*

Addition to paragraph 49

The following words should be added at the end of the paragraph—"*especially in the case of women of reproductive age.*"

New paragraph to be added after paragraph 51e

"(51f) Where work involves exposure to β-rays of $E_{max} > 2.5$ MeV, eye shields or other suitable shielding may be necessary to keep the dose in the lens within permissible limits. In the case of exposure to β-rays of lower energy, if the provision of such shielding is impracticable, the small additional β-ray dose in the lens over the dose already permitted for more penetrating radiations, such as γ-rays or neutrons, is permissible, provided the dose in the skin is limited to the level recommended in paragraph 52a."

Additional paragraphs regarding the application of paragraphs 49, 51d *and* 51e *to cases of internal exposure*

With reference to paragraph 49:

"(52e) One or more short-term exposures to radioactive materials (together with any exposure to external radiation) within a period of 13 consecutive weeks is considered acceptable if the total intake of radioactive material during this period does not exceed the amount that would result from intake for 13 weeks at the maximum levels for occupational exposure to such radioactive materials permitted by the 1959 Report of Committee II. The dose to the critical organ during the following 50 years resulting from such an intake will not exceed the quarterly limit on dose stated in the 1958 Recommendations of ICRP. These limits are:

(1) for the whole body and the gonads: 3 rems,
(2) for the skin, thyroid and bone*: 8 rems,
(3) for other organs: 4 rems."

With reference to paragraph 51d:

"(52f) In the case of an accidental high exposure to radioactive materials where the total intake of radioactive material exceeds the amount that would result from intake for one year at the maximum levels for occupational exposure to such radioactive materials permitted by the 1959 Report of Committee II, an estimate of the intake resulting from the exposure shall be entered on the individual's record and he shall be referred to competent medical authorities for appropriate action."

With reference to paragraph 51e:

"(52g) Emergency work involving exposure above permissible limits to radioactive materials shall be planned on the basis that the total intake of radioactive material during the emergency period should not exceed the amount that would result from intake for one year at the maximum levels for occupational exposure to such radioactive materials permitted by the 1959 Report of Committee II. The dose to the critical organs during the following 50 years resulting from such an intake will not exceed the maximum yearly limit on dose stated in the 1958 Recommendations of ICRP. These limits are:

(1) for the whole body and the gonads: 12 rems,
(2) for the skin, thyroid and bone*: 30 rems,
(3) for other organs: 15 rems.

When such an exposure has occurred, an estimate of the intake shall be entered in the individual's record and measures shall be taken to prevent further exposure during the period of time it would take to accumulate this intake at the constant level of occupational exposure permitted by the 1959 Report of Committee II for such materials."

Explanatory statement of paragraphs 53 *to* 57 (*see also paragraphs* 15, 16, 38 *and* 39)

The size of a "group" or a "population" is a relative concept and it is often difficult to decide whether a group should be considered "large" and whether relatively small national populations should be referred to as the "whole" population with respect to exposures of which the importance depends on the size of the group exposed. The size of a group is irrelevant in the case of *individual* exposure, where groups are defined only to distinguish between individuals for whom the recommended maximum permissible doses are different for various reasons or for whom the membership of a certain group provides for more specific recommendations with regard to individual monitoring, medical examinations and surveys of the protection conditions. In the case of, for example, average exposure, however, the "*whole*" *population* is involved and the responsibility for the interpretation of this concept will rest with national and international administrative authorities responsible for the legal application of protection requirements.

Additional section regarding exposure of individual members of the population at large (*to follow after paragraph* 57)

A new section, under the heading "EXPOSURE OF THE POPULATION AT LARGE" should be added

* Based on body burden of 0·1 μc of Ra^{226} (see Report of Committee II).

after the section headed "EXPOSURE OF SPECIAL GROUPS" (paragraphs 53–57). The text to be added, referring to both external and internal exposure, reads: "The maximum total dose limit for *individuals* in the population at large (excluding those occupationally exposed and the special groups B (a) and B (b)) should be that recommended for members of the special group B (c) (cf. paragraph 55)."

Correction to paragraph 65

The figure "1.7" in paragraph 65, Addendum (c), is a misprint for "0.7".

Interpretation of paragraph 68

The basis for the limits of permissible exposure of populations to man-made sources of ionizing radiations is the dose received by the various organs of the body and not the MPC-values, or other criteria by which the dose is controlled. Nevertheless, for planning purposes some guidance as given in paragraph 68 must be available. The word "average" in paragraph 68 refers to the concentration of radioactive nuclides, averaged over a year, in the total intake to the average person of the population.

STATEMENTS ON ITEMS NOT INCLUDED IN THE 1958 RECOMMENDATIONS

Occupational exposure of pregnant women

With regard to occupational exposure of pregnant women the Commission notes that:

(1) It is especially in respect of somatic damage in foetal tissues that pregnant women present a "special-risk problem" in case of occupational exposure.

(2) Any special recommendations for pregnant women must in practice apply to all women of reproductive age.

Occupational working hours and length of vacation

The Commission considers that with the present maximum permissible exposure levels no special treatment of radiation workers with respect to working hours and length of vacation is required.

Emergency exposure of environmental populations

This subject was discussed extensively during the Munich meetings and the Commission considers that the British Report,[7] recommending criteria for acceptable levels under emergency conditions of I^{131}, Sr^{89}, Sr^{90} and Cs^{137} ingested in food or milk, constitutes a useful and sound approach to the subject.

REFERENCES

1. Recommendations of the International Commission on Radiological Protection (Revised December 1, 1954), *Brit. J. Radiol.* Suppl. 6 (1955).
2. Report on amendments during 1956 to the Recommendations of the International Commission on Radiological Protection, *Acta radiol., Stockh.* **48,** 493–495 (1957); *Radiology* **70,** 261–262 (1958); *Fortschr. Röntgenstr. Nuklearmed.* **88,** 500–502 (1958).
3. *Recommendations of the International Commission on Radiological Protection (Adopted September* 9, 1958). Pergamon Press, London (1959). (ICRP Publication 1.)
4. *Report of Committee* II *on Permissible Dose from Internal Radiation* (1959). Pergamon Press, London. In press. (ICRP Publication 2.)
5. *Report of Committee* III *on Protection Against X-rays up to Energies of* 3 MeV *and β- and γ-rays from Sealed Sources* (1959). Pergamon Press, London. In press. (ICRP Publication 3.)
6. Exposure of man to ionizing radiation arising from medical procedures. A report of the International Commission on Radiological Protection and International Commission on Radiological Units and Measurements. *Phys. in Med. Biol.* **2,** 107–151 (1957).
7. Report to the Medical Research Council by its Committee on protection against ionizing radiations (Chairman: E. E. POCHIN): Maximum permissible dietary contamination after the accidental release of radioactive material from a nuclear reactor, *Brit. Med. J.* **1,** 967–969 (1959).

REPORT OF COMMITTEE II ON PERMISSIBLE DOSE FOR INTERNAL RADIATION (1959)

I. INTRODUCTION

THE task of Committee II of the International Commission on Radiological Protection, ICRP, is to recommend values of maximum permissible body burden of radionuclides, q, and maximum permissible concentration of these nuclides, MPC, in air and in water (or food). These values are provided only for the more important radionuclides, and they are applicable primarily to occupational exposure. This Committee has recognized that such compilations are of limited usefulness unless periodically revised to incorporate the best available information and extended to include the values required by new developments and uses. It has worked closely with several of the national committees and in particular with the Internal Dose Committee of the United States National Committee on Radiation Protection, NCRP, in collecting these data and in making revisions of the earlier publications on internal dose published by the NCRP (1953)[1] and by the ICRP (1955).[2] In addition to revising and extending the earlier publications, the members of both committees hope that this publication will be a means of harmonizing and unifying the objectives and principles used by the international committee and by the various national committees in arriving at their decisions. The hope is expressed that the national internal dose committees will apply the same basic principles of radiation protection and will adopt the permissible exposure values recommended by the ICRP or will indicate the conditions and considerations which require their modification.

The basic recommendations concerning radiation exposure have been revised in recent years by the ICRP[3] and are reprinted in the present volume. Similar revisions have been made by the NCRP.[4] An examination of the 1958 Report of the ICRP reveals that the major changes of interest to Committee II are the following:

(1) Instead of a weekly limit, a quarterly limit is recommended thus giving greater flexibility for many operations.

(2) While the permissible quarterly rates are essentially comparable to former permissible rates, a limit on integrated dose is imposed in the case of exposure of the blood-forming organs and the gonads. The ICRP Recommendations[3] also apply the limit on integrated dose to the lenses of the eyes, but the relevant data are so inadequate the eyes are not considered as an organ of reference in this report.

(3) Explicit recommendations are given for some non-occupational groups and limits are suggested for the whole population.

A comparison of the present publication with earlier versions will reveal the very extensive modifications required by new data and methods of estimating internal dose, and will indicate that the number of radionuclides listed in the earlier publications has been increased by about a factor of three. All biological and physical data used in the earlier versions have been reviewed, and the permissible exposure values have been revised accordingly. Refinements in the calculations for the exposure of the gastrointestinal tract and for chains of radionuclides in the body have resulted in new values for many of the permissible limits. The power function model is discussed in the Appendix as an alternative method of estimating the body burden for certain long-lived radionuclides. The data in the tables are expressed in terms of the exponential or compartment model for retention and elimination, but the maximum permissible concentration (MPC) and body burden values listed in the tables were selected after careful consideration by the Committee of the values obtained by the use of both models. While it is clearly impossible to be completely abreast of the literature in such a rapidly developing field, this revision probably represents the most important findings through 1957 as well as those in a few early publications of 1958.

All MPC values are given for a 40 hr work week as well as for continuous exposure, i.e. a 168 hr week. Previous editions of the internal dose publications gave values based on continuous exposure, partly because these same values sometimes were used, with an appropriate factor, to apply to cases of continuous non-occupational exposure and also because of variations in the actual work week. The values based on a 40 hr work week are included because they are directly applicable to the standard working conditions existing in many countries.

The values listed for continuous occupational exposure are convenient in obtaining permissible levels for special groups and for the population at large in accordance with the Report of the ICRP.[3] The appropriate factors to be applied in obtaining permissible levels for these groups are discussed in Sections II.3 and II.4. Because the continuous exposure values listed neglect several important considerations, particularly differences between children and adults, it should be emphasized that, even when corrected by the above factors, these can only be regarded as interim values for non-occupational exposure. It is hoped that the term "continuous occupational exposure values" will emphasize the provisional nature of their use for other purposes.

Although the data on which the MPC values are based are very incomplete and in some cases uncertain, they embody the latest and best research of hundreds of scientists, and it is believed that these MPC values are the best now available. They should serve as a guide to indicate whether the operational procedures used in practice are adequate to insure that the dose delivered by internally deposited radioactive material does not exceed the pertinent permissible limit set by ICRP.

For many radionuclides the radiation exposure period may last for many months or even a lifetime, although the intake may have occurred in a relatively short time. When radioactive contaminants are deposited in the body, it is often difficult to make an accurate estimate of the total body burden or of its distribution in the body. In most cases, even when the fact is established that a person carries a large internal burden of a radionuclide, little can be done to hasten its elimination from the body. According to one theory, any dose of ionizing radiation, no matter how small, may produce some genetic or somatic damage, and thus, it is considered wise to avoid all unnecessary exposure to radionuclides. This has been pointed out, also, by several national[5] and international[6] organizations. However, in the light of present knowledge, occupational exposure for the working life of an individual at the maximum permissible values recommended in this report is not expected to entail appreciable risk of damage to the individual or to present a hazard more severe than those commonly accepted in other present day industries. The values given in this report are listed for occupational exposure and must be corrected by the application of appropriate factors for other uses, and in all cases the resultant tissue doses are intended to be in addition to those produced by the natural background and medical exposure.

II. BASIC STANDARDS OF MAXIMUM PERMISSIBLE INTERNAL EXPOSURE

1. Exposure categories. The ICRP[3] has made basic recommendations or suggestions concerning exposure to ionizing radiation for the following categories of exposure:

A. Occupational exposure.

B. Exposure of special groups:

(a) Adults who work in the vicinity of controlled areas (see paragraphs 71 and 72 of the ICRP Report,[3]) but who are not themselves employed on work causing exposure to radiation.

(b) Adults who enter controlled areas occasionally in the course of their duties, but are not regarded as radiation workers.

(c) Members of the public living in the neighborhood of controlled areas.

C. Exposure of the population at large.

In principle both the exposure of individuals and averages over the whole population have to be considered, but recommendations with regard to individual exposure are given only for the groups (A) and (B). Moreover, the ICRP considers that doses resulting from natural background radiation or individual doses resulting from medical and dental exposure are in addition to maximum permissible doses recommended in the report.

2. Occupational exposure (category (A). See paragraphs 46–52, *ICRP Report.*[3]) The basic rules concerned with occupational exposure due to internally deposited radionuclides are the following:

(a) The dose to the gonads or to the total body during any period of 13 consecutive weeks shall not exceed 3 rems. The dose to the gonads or to the total body at age N years shall not exceed $5(N-18)$ rems in case occupational exposure begins after age 18. If occupational exposure begins before age 18, the yearly dose before age 18 shall not exceed 5 rems and the dose to age 30 shall not exceed 60 rems.

(b) The effective RBE dose delivered to the bone from internal or external radiation during any 13 week period averaged over the entire skeleton shall not exceed the average RBE dose to the skeleton due to a body burden of 0.1 μc of Ra^{226}. This is considered to correspond to a dose rate of 0.56 rem/week in the case of Ra^{226} (derived from a dose rate of 0.06 rad/week, an RBE of 10 and $n = 1$). In computing the effective RBE dose to the skeleton, all absorbed energy shall be weighted by a relative damage factor, n. The relative damage factor, n, is taken as one for all energy absorbed from external radiation and for all internal emitters when the element taken into the body is an isotope of radium. If the isotope taken into the body is not an isotope of radium, the relative damage factor, n, is taken as 1 for all energy absorbed from X- or γ-radiation and as 5 for all other energy components, whether they originate from the parent or the daughters it produces in the body. The effective energy is listed in Table 5 as $\Sigma EF(\text{RBE})n$. For a more detailed discussion and examples, see Section IV.2 and V.1.

(c) The dose to any single organ of the body, excepting the gonads, bone, skin and thyroid, shall not exceed 4 rems in any 13 week period, or 15 rems in 1 year. The dose to skin and thyroid shall not exceed 8 rems in any 13 week period, or 30 rems in 1 year.

The decision of the ICRP[7] (1956) to set the average external occupational exposure at 5 rems/year (corresponding to 0.1 rem/week) is not applied to internal dose calculations except in the cases of radionuclides that are distributed rather uniformly throughout the body or are concentrated in the gonads. The purpose of limiting the average weekly total body dose (0.1 rem) to one-third of the former maximum weekly dose (0.3 rem) was to lessen the possible incidence of certain types of somatic damage, e.g. radiation induced leukemia and shortening of life span, which are considered to result primarily from total body exposure. Obviously, the reduction in the gonad dose was intended to lower the incidence of deleterious genetic mutations that will give rise to effects appearing in future generations.

Inasmuch as the restriction of integrated dose applies primarily to the total body and gonad dose, there is no basic change in the permissible RBE dose rate when individual organs[8] such as liver, spleen, bone, gastrointestinal (GI) tract and kidney are the critical body organs for reasons given in ICRP report paragraph 14.[3] It should be noted that the limits recommended here are maximal. In practice, the average occupationally exposed individual would receive a much lower dose.

Because the direct estimation of the body burden or of the dose to an organ or to the total body is generally difficult, and because in most cases measures to decrease the body burden are rather ineffective and difficult to apply, the only practical procedure for general protection of occupational workers is to limit the concentration of the various radionuclides in the water, food or air available for consumption. It is recommended, therefore, that:

(1) If there is no occupational external exposure, the concentration of a radionuclide or a mixture of radionuclides in air and in water which might be consumed by plant personnel during a 40 hr week be kept at levels not exceeding the appropriate MPC values given in this report. If there is occupational external exposure, the MPC values must be lowered to bring the total RBE doses within the limits prescribed by the basic rules. Thus, if D rem is the quarterly dose permitted to an organ by the basic rules and if external radiation delivers a dose E rem per quarter, then the MPC based on this organ must be reduced by the factor $(D-E)/D$. The calculation of an acceptable level for the case of a mixture of radionuclides is discussed in Section IV.8.

(2) Alternatively, over a period of 13 weeks, the concentrations of the various radionuclides present in air or in water may be allowed to vary, provided the total intake during any 13 week period does not exceed the total intake permitted by exposure at the constant levels indicated in subsection (1) above. It should be realized that while this method is in accordance with the basic recommendations its use is cumbersome, expensive and generally difficult, because it requires accurate and continuous monitoring of work areas and the keeping of detailed exposure histories for each individual. Its use is, therefore, only justified in exceptional cases.

The safest and simplest procedure to use in keeping within the basic limits (a), (b) and (c) in Section II.2 is to keep the level of contamination of the air, water or food consumed by plant personnel in the controlled area at or below the level indicated by the MPC values. These values are given for an exposure period of 40 hr/week and 168 hr/week. If a person's work assignments are such that he spends only 8 hr each week in the exposure area, the applicable MPC values are five times those listed for a 40 hr week in Table 1. However, this requires considerable care to determine that he is effectively unexposed during the remainder of his working week. If he spends 48 hr each week in the exposure area, the applicable MPC values are five-sixths of those listed for a 40 hr work week in Table 1. Similarly, when applied to food they generally will require modification to take account of the amount ingested. This is further discussed in Section IV.9.

Although the formula $5(N - 18)$ permits an average yearly dose to the total body and gonads of only 5 rems, the rules of the ICRP permit up to 3 rems during any interval (e.g. 1 min, 1 day, 1 week, etc.) provided that not more than 3 rems are received in any 13 consecutive weeks. Thus, an older person may receive up to 12 rems in a single year provided his dose does not exceed the limits prescribed by the formula $5(N - 18)$. Although flexibility is also allowed in principle for internal exposures, in practice it is risky and usually impractical to increase the MPC values much beyond those determined for operation over an extended period. The permissible levels do, however, take into account the exposure period (e.g. if the occupational exposures last for only 1 hr/week, the MPC values for a 40 hr week may be increased by a factor of 40), but if there are concurrent external exposures, the MPC must be reduced so that the total dose to any organ does not exceed the maximum permissible limits. In specific individual cases where sufficient monitoring is available (i.e. external monitoring meters, body fluid analyses, air surveys, etc.) and where no exposure has been received for the prior 13 week period, and if the restriction implied by the formula $5(N - 18)$ is not exceeded, a person may work for 1 hr where the concentration in air of an isotope with the total body as the critical organ is $40 \times 13 \times 12/5 = 1200 \times$ the $(MPC)_a$ values for the 40 hr week, but in such a case no further exposure shall be permitted in 13 weeks. This practice should be discouraged because of delays and inaccuracies in methods of estimating the body burden and dose to the organ from such an internally deposited radioactive material. However, if such exposures to contaminated air are unavoidable, the dose often may be reduced materially if appropriate and properly fitting masks are worn.

3. *Exposure of special groups* (*category* (*B*). *See paragraphs* 53–57, *ICRP Report.*[(3)]) The dose to the gonads or blood-forming organs of an individual belonging to either of the groups B(a) or B(b) shall not exceed 1.5 rems/year, and the corresponding limit for an individual of class B(c) is set at 0.5 rem/year. If no external radiation results due to operations within the controlled area, the corresponding MPC values for groups B(a) and B(b) are three-tenths of the occupational values for the 40 hr week, and for group B(c) are one-tenth of the occupational values for continuous exposure, i.e. for the 168 hr week. If external radiation results from operations within the controlled area and the dose due to this external radiation is E rems/year, then these values are to be reduced by the factor $(D-E)/D$ where $D = 1.5$ for groups B(a) and

B(b) and $D = 0.5$ for group B(c). The computation of the MPC for a mixture is discussed in Section IV.8.

If the radiation field (external and internal), does not irradiate significantly the gonads or the blood-forming organs, the MPC for an individual belonging to group B(c) shall be one-tenth the MPC value for continuous occupational exposure. Since the exposure of an individual belonging to group B(a) or group B(b) is directly related to his work in or near the controlled area, the MPC for such an individual shall be one-tenth the MPC for occupational exposure of an individual with the same work period per week. Thus, if the working period is 40 hr/week then the MPC for individuals of group B(a) and B(b) shall be one-tenth the MPC for the 40 hr week.

4. *Exposure of populations* (*category* (*C*). *See paragraphs* 58–68, *ICRP Report.*[3])

(a) Genetic and total body dose. The ICRP in its recent report[3] suggested limits on the *average* genetic dose to a population. These suggested limits are not considered as definitive but are offered for guidance in planning nuclear energy programs. Tentatively, allowing 2 rems to age 30 years for average genetic dose from man-made radiation (exclusive of medical exposures), 1.5 rems is suggested as a limit for internal dose and 0.5 rem as the limit for external dose to the gonads from such sources. Since the continuous occupational levels (168 hr/week) permit 5 rems/year $\times$ 30 years = 150 rems in 30 years to the gonads, such a continuous occupational MPC must be multiplied by a factor of 0.01 to give an equivalent constant level of exposure. The ICRP has suggested that the same dose limit (1.5 rems/30 years) and reduction factor (0.01) are to be applied when the total body is the critical organ. Except in a few cases, sufficient data for an estimate of gonad dose are lacking. In the absence of an MPC value based on the gonads, it is recommended that 0.01 of the MPC based on total body be used. The extent to which many of these nuclides contribute to the gonad dose is under investigation by the Committee.

(b) Somatic dose. For a radionuclide or mixture of radionuclides which does not have the total body or the gonads as critical organ, it is suggested that the average permissible level for large populations be one-thirtieth the continuous occupational value (168 hr/week) computed according to the basic rules (b) and (c) given in Section II.2 above. The Internal Dose Committee of ICRP and of several national organizations are studying the problem of the long-term effects of low-level exposure to the population at large with respect to somatic damage to the exposed individual, genetic damage to his children, ecological damage, etc.

III. MAXIMUM PERMISSIBLE VALUES FOR OCCUPATIONAL EXPOSURE

1. *Assumptions and restrictions applying to maximum permissible exposure values in Table 1.* The values of q and MPC for an individual will depend upon many factors such as his age, physical condition, eating habits and hygienic standards. They will depend also upon the physical and chemical properties of the radioactive material and the method of intake—by ingestion, by inhalation, through wounds or by absorption through the skin. The paucity of data concerning the effect of most of these factors does not warrant detailed treatment. To keep the required work and the size of this revision within manageable limits, and yet to meet the major needs of scientific and industrial users of isotopes, it has been necessary to limit severely the number

of factors considered. Therefore, MPC values are listed only for relatively insoluble and for the more common soluble compounds, and these compounds are specified only by the extent of solubility rather than by specific chemical structure. The only methods of intake considered are ingestion and inhalation except in a few cases—where submersion presents the greatest hazard criterion. All calculations are based on a "standard man" and thus do not provide for individual variations. The standard man is specified in Tables 6 through 11 and is a somewhat modified version of the standard man defined at the Chalk River Conference[9] (September 1949). This standard man is designed to represent a typical or average adult who is exposed occupationally.

Ideally, maximum permissible body burden, q, and maximum permissible concentration, MPC, should be based on studies of humans who have been exposed to and who have consumed a particular radionuclide under working conditions and over an extended period of time approximating those which are typical of the average occupational exposure. However, human data are very scarce and only in the case of radium does one have an accumulation of human experience for as long as 50 years, which is the minimum for selecting values for chronic exposure to man. Studies using total and partial body counters have been made recently to determine the uptake, distribution, and elimination of trace quantities of some radionuclides in the human body. In a few cases, certain radionuclides have been administered to humans therapeutically, and in some cases, accidents have occurred in which radionuclides have been taken into the body. The data from these cases of human exposure have been studied carefully and, where possible, such data are substituted in this report for earlier data based on animal experiments. For the majority of radionuclides, human data are lacking, and in such cases data from animal experiments must be extrapolated to man. Sometimes even animal data are not available and estimates are made from comparison with elements having similar chemical behavior. Recent studies of trace and minor stable element distribution in the human body[10] have been particularly helpful in these revisions. It is assumed that the normal stable element distribution in the various body organs is typical of the distribution that would result from chronic human exposure to radionuclides of these same elements and that the chemical form is similar. Likewise, a study of the metabolic balance between the trace and minor elements in the food, water, urine and feces of man has yielded direct evidence for the MPC of radionuclides of these elements. Because of the many assumptions and approximations made in applying much of the data in this publication, it is concluded that detailed refinements in the calculations generally are unwarranted.

In Table 1 are the recommended values of maximum permissible total body burden, q, and maximum permissible concentration in air, $(MPC)_a$, and in water, $(MPC)_w$, for about 240 radionuclides. The daily intake of water used in calculating $(MPC)_w$ includes the water content of food, and thus, consideration of the intake of a radionuclide in food is necessary only in case it concentrates in the food during processing or enters the food from other sources. In such cases the $(MPC)_w$ values of Table 1 converted to microcuries per gram are applicable when corrected for daily intake, i.e. to take account of the total intake of radionuclides in the complete diet. This publication includes values for all the radionuclides listed in the previous publications of NCRP[1] (1953) and of ICRP[2] (1955) together with others for which a need has arisen and for which the necessary biological data are available. With few exceptions (e.g. certain daughter radionuclides and isomeric states), radionuclides with radioactive half-lives shorter than 1 hr are not considered in Table 1. The following are the principal assumptions and conditions which are the bases of the calculations.

(a) In all cases the values are listed both for soluble and for insoluble compounds (an exception is the case of some of the inert gases for which values are given only for the submersion of a person in the inert gas). The lowest values of $(MPC)_a$ and $(MPC)_w$ obtained are in bold-face type both for the soluble and insoluble forms of the isotope. The organs on which these values are based are termed the critical organs and are printed in bold-face type in Table 1.

(b) In all cases the values are computed for occupational exposure at the rate of 40 hr/week, 50 weeks/year for a continuous work period of 50 years, as well as for 50 years of continuous exposure, i.e. 168 hr/week.

(c) In all cases the calculated dose rate which determines the MPC takes into account the actual amounts of the radionuclide in the body or critical organ rather than an assumed state of equilibrium. The MPC values based on a critical organ are set by the requirement that the dose rate (rems/week) after 50 years of occupational exposure shall not exceed the values specified in (a), (b) and (c) of Section II.2. During a 50 year exposure period, equilibrium is reached for the vast majority of the radionuclides because the effective half-life is short compared to this work period (i.e. the term $e^{-0.693t/T}$ in equations (7) and (8) is approximately zero for $t = 50 \times 365$ days). Exceptions to this rule are listed in Table 2. Column 5 of Table 2 gives the effective half-life, and column 6 gives the percentage of equilibrium the body burden attains over a period of occupational exposure lasting 50 years. Most of these exceptions are in the 5 *f* type rare earth group of elements which are assigned a biological half-life of 200 years. The extreme case is represented by ten of these radionuclides which reach only 16 per cent of equilibrium in the body in 50 years of occupational exposure.

(d) In the case of a radionuclide which decays to form radioactive daughters, the calculation assumes that only the parent radionuclide enters the body, but the estimated dose rate includes all the energy released by the daughter elements formed in the body. There are two exceptional cases, Rn^{220} and Rn^{222}, where a state of equilibrium typical of that attained in ordinary air is assumed. These cases are discussed further below. In all other cases, it is assumed that only the parent element enters the body. Because the various daughter elements generally have different effective half-lives, the percentage of equilibrium attained is generally not the same for all elements of a chain. Also, the effective energies, i.e. the weighted energy absorbed per disintegration, are not the same for different members of the chain, so that the dose rate after 50 years exposure will generally not be the same percentage of the dose rate resulting from an equilibrium body burden as the figure shown in Table 2. Thus, for radionuclides which decay to form radioactive daughters these percentages give only a rough indication of the percentage of equilibrium dose rate attained at the end of 50 years.

(e) The assumptions and formulas are presented in terms of a compartment model, i.e. each organ is assigned a biological half-life, and the radionuclide that accumulates in the organ is considered to be eliminated at a constant rate. In general, this is a drastic oversimplification of the situation since the organ retention usually requires several exponentials, or perhaps a power function, for its mathematical representation. Unfortunately, the biological information available generally does not yield detailed information on organ retention, particularly for the conditions and periods of exposure of interest here. In selecting MPC and body burden values, the Committee has considered both multiple exponential and power function models for retention when such information is available, and the values finally selected are in some cases chosen between those calculated by these models. In view of the large measure of uncertainty in many of these cases, and in the interest of uniformity and economy of presentation the biological data in the Tables are given in terms of a single compartment model for each organ considered, with a biological half-life for each. The values of these are selected to produce in 50 years of constant level exposure the retention indicated by the more detailed model, and thus may not represent accurately the situation for short-term exposure. A discussion of the power function model and a table of the necessary parameters for its use are given in the Appendix.

(f) If occupational exposure continues beyond 50 years, the dose rate will continue to rise in the case of the radionuclides listed in Table 2 because they are not in a state of equilibrium under the assumed conditions, but for the radionuclides not listed in Table 2 the maximum permissible dose rate would not be exceeded. However, since the period of occupational exposure probably will not greatly exceed 50 years, and since the maximum permissible body burden, q, would be reached only after 50 years of occupational exposure at the MPC values given in Table 1, the average dose rate over the working life of the individual will be well below the maximum permissible dose rate, even for the isotopes in Table 2. While noteworthy, this observation does not alter the fact that the terminal dose rates would be in violation of the criteria adopted in (a), (b) and (c) of Section II.2, although the integrated dose undoubtedly would be considerably less than that permitted for many radionuclides not listed in Table 2. In the previous publications,[1, 2] the calculations were based on a 70-year exposure. Although this change to an exposure period of 50 years has had very little effect on the MPC values (i.e. a maximum increase of 27 per cent in the MPC values for some of the radionuclides in Table 2), it is believed that this change should be made in the calculations because, for most workers in atomic installations, the working period extends from age 18 to age 65 or less.

(g) The average breathing rate is 10^7 cm³ per 8 hr work day; this is one-half the air breathed in 24 hr.

2×10⁷ cm³/day

(h) The average rate of water consumption is 1100 cm³ per 8 hr work day; this is one-half the water consumed in 24 hr.

(i) The dose from inert gases with radiation of sufficient energy to penetrate the minimal epidermal layer (7 mg/cm²) results from external exposure to the surrounding cloud of radioactive gas rather than from the amount of gas in the body.

(j) In general, chemical toxicity is not considered in estimating the body burden or MPC values. However, in the case of uranium, the chemical toxicity has been considered and is the limiting criterion for the longer-lived nuclides of uranium.

2. *Units of ionizing radiation used in Table 1.* In Table 1 the units are the microcurie (μc) and microcurie per cubic centimeter ($\mu c/cm^3$) for maximum permissible quantities of the various radionuclides in the total body, q, and for the maximum permissible concentrations, $(MPC)_a$ and $(MPC)_w$, in air and in water, respectively. One curie is a quantity of a radioactive nuclide in which the number of disintegrations per second is 3.700×10^{10}; the microcurie then, is one-millionth of this amount. In accordance with long established usage, however, the curie of natural uranium is considered to correspond to 3.7×10^{10} dis./sec from U^{238}, 3.7×10^{10} dis./sec from U^{234}, and 1.7×10^{9} dis./sec from U^{235}. Also, the curie of natural thorium is considered to correspond to 3.7×10^{10} dis./sec from Th^{232} and 3.7×10^{10} dis./sec from Th^{228}. The rem is the unit of RBE dose of ionizing radiation in tissue. When a dose is expressed in rems it is superfluous to call it RBE dose. Therefore the unqualified term "dose" alone is used in such cases. The rem corresponds to the dose in tissue which results in biological damage equivalent to that produced per rad of X-radiation (of about 200 kV) having a linear energy transfer, LET, to water of 3.5 keV/μ, i.e., rem = RBE $\times$ rad. The rad corresponds to an energy absorption of ionizing radiation of 100 ergs/g in any medium. In this case the energy absorption is in tissue. The relative biological effectiveness, RBE, in this report is taken as one for β-, γ- and X-radiation, and conversion electrons (for low energy β-emitters, i.e. $E_m \leqslant 0.03$ MeV, the RBE = 1.7), 10 for α-particles, and 20 for recoil atoms. The reader is referred to the Handbook by the International Commission on Radiological Units for detailed information on units.[11]

3. *Critical body organ.* The values of body burden, q, in column 3 of Table 1 are based on that amount of the radionuclide which is deposited in the total body and produces the maximum permissible RBE dose rate to the body organ listed in column 2. The concentration values in water (columns 4 and 6) and in air (columns 5 and 7) are in turn based on the intake by the standard man who accumulates this body burden as a consequence of occupational exposure for a period of 50 years. In most cases, significantly different values of body burden result when effects on different organs are considered. The critical organ is considered to be that organ of the body whose damage by the radiation results in the greatest damage to the body. It is readily apparent that many factors must be considered in determining which affected organ will cause the body to suffer the greatest damage. Criteria of prime importance are: (a) the organ that accumulates the greatest concentration of the radioactive material; (b) the essentialness or indispensability of the organ to the well-being of the entire body; (c) the organ damaged by the route of entry of the radionuclide into the body; and (d) the radio-sensitivity of the organ, e.g. the organ damaged by the lowest dose. Theoretically all of these considerations are taken into account through the use of the RBE factors and the basic standards (a), (b) and (c) of Section II.2, but it is apparent that the information they represent does not embody much detail on most of the above criteria. Actually, except for a few radionuclides, case (a) above is the determining factor in choosing the critical body organ. For this revision, each radionuclide was studied individually. For some radionuclides as many as twelve reasonable choices of a critical organ were made with the corresponding permissible body burden and concentration values calculated for each organ. These

are listed in Table 1 with the critical organ (or organs in the case of identical MPC values) and minimal MPC values in bold-face type. For each isotope the MPC values are listed first for soluble materials and then for insoluble materials. The values for soluble materials are ranked according to magnitude of $(MPC)_w$ so that the first line in this group designates the critical organ determined solely on the basis of $(MPC)_w$. The values for insoluble materials are ranked according to the magnitude of $(MPC)_a$. The rankings based on $(MPC)_a$ and on $(MPC)_w$ may differ in some cases, so the smallest MPC in each group is in bold-face type to indicate it as a maximum permissible occupational exposure level for plant operation under the stated conditions. The MPC values for other additional organs (termed organs of reference in Table 1) are given primarily as an aid in estimating MPC values for mixtures of radionuclides, and thus, are not permissible levels for the single radionuclide unless in bold-face type.

The total body is listed as an organ of reference for all nuclides except a few of the inert gases. These values are included primarily as an aid in computing MPC values for mixtures, and as a check on the oversimplified model used. As mentioned in (e) on p. 8, this one compartment model is selected to represent the long-term retention in the critical organ and may not represent adequately the situation in other organs. For example, radium and strontium are long-term bone-seekers, but during the first day or two following ingestion appreciable amounts are present in the plasma and soft tissues. This amount is negligible so far as the 50 year accumulation in the bone is concerned, but a check is necessary to determine that the whole body limit is not exceeded by the amount present in the plasma and soft tissues. When present in a mixture, perhaps with other isotopes that concentrate primarily in the soft tissues, the dose delivered by this component of the total retention should not be neglected. The MPC based on total body also supplies a ready means of estimating the integrated dose, i.e. the dose to the body as a whole. While the basic rules do not directly limit the integrated dose except in the case of whole body irradiation, it is of considerable interest. Because the total body limit for constant level exposure is based on 5 rems/year (0.1 rem/week), the total body is sometimes the critical organ. Because the GI tract often receives a greater absorbed dose than any other body organ, and is frequently the critical organ for exposure to mixed fission products, it is with few exceptions included as an organ of reference for the radionuclides in Table 1.

IV. CALCULATION OF MAXIMUM PERMISSIBLE EXPOSURE VALUES

1. Basis for estimating maximum permissible exposure values. As indicated in the above discussion of the basic standards for maximum permissible internal exposure, two somewhat different criteria commonly are used in determining maximum permissible exposure values: (a) for bone-seeking radionuclides such as Sr^{90}, Pu^{239}, etc., which emit significant amounts of particulate radiation, the estimate is based on a comparison with Ra^{226} and daughter products; and (b) for all other radionuclides, the MPC and body burden values are set to limit the weekly RBE dose received by the various organs of the body*, e.g. 0.1 rem/week to the gonads and total body, 0.6 rem/week to the skin and thyroid, and 0.3 rem/week to all other soft tissues. Thus, for a

* In the case of long-lived radionuclides of uranium, the toxic effects set the limiting body burden.

bone-seeker, such as Sr^{85}, which emits only γ- or X-rays, the calculation must be based on 0.3 rem/week since the adjacent soft tissues are also irradiated to approximately the same extent as bone. The first method is the result of a calculation designed to determine, (i) the amount (μc) deposited in the bone that will deliver the same effective RBE dose as delivered by 0.1 μc of Ra^{226} and its daughter products and (ii) the amount (μc) deposited in the bone that will result in damage comparable to that observed from known deposits of Ra^{226} in the bone. In some cases, this first method rests on rather extensive clinical experience or studies of biological damage, either with the particular radionuclide, or with another radionuclide having similar chemical properties and similar metabolic behavior in the body. The method based on RBE dose rate is used generally when bone is not the critical organ or when direct experience is not available. The biological evidence supporting the limits on RBE dose to the various organs of the body is less direct than clinical observation or studies of biological damage, but is consistent with general experience involving radiation from both external and internal sources.

2. *Body burden based on comparison with radium.* In the case of α- and β-emitting radionuclides that localize in the bone, the maximum permissible body burden, q, is determined from a direct comparison with Ra^{226}. In 1941 an advisory committee[12] to the National Bureau of Standards first established the maximum permissible body burden for radium at 0.1 μg ($\sim$ 0.1 μc). Man has had years of experience with radium, which is the basis of reference in choosing the maximum permissible body burden of similar radionuclides that are deposited in the bone. The radium dial painters, patients treated medically with radium and persons using public water supplies relatively rich in radium[13] have furnished the best source of continuous human exposure from which to observe the effects of an internally deposited radionuclide. From autoradiographic studies[14] of human autopsy material, radium is known to be unevenly distributed in the bone, but other bone-seeking radionuclides may be even less uniformly distributed.[15] From animal experiments[16] it is known that some bone-seeking radionuclides produce greater damage to the bone than Ra^{226} for the same RBE dose. This greater damage is attributed to several factors, some of which are (a) non-uniform distribution, (b) greater radiosensitivity of the portion of bone in which the isotope is deposited, and (c) greater essentialness of the damaged tissue. Therefore a relative damage factor, n, is introduced into the MPC calculation to make some allowance both for the greater relative effectiveness of some radionuclides as well as for the fact that many have a more heterogeneous distribution in bone than radium. The relative damage factor, n, in the formula for effective energy, $\Sigma E_i F_i (\mathrm{RBE})_i n_i$ is taken as one provided (a) the parent element of the chain considered is an isotope of radium, or (b) if the energy component considered originates as X- or γ-radiation. The relative damage factor is taken as 5 in all other cases, i.e. if the parent element of the chain is not an isotope of radium and if the energy component considered originates as α-, β^--, β^+-, e^-- radiation or from a recoil atom. Thus, the first two elements in the Th^{228} chain are $Th^{228} \xrightarrow{\alpha,\gamma} Ra^{224} \xrightarrow{\alpha,\gamma}$ and the value of n is 5 for the energies of both these α-particles. In the chain $Ra^{228} \xrightarrow{\beta} Ac^{228} \xrightarrow{\beta,\gamma} Th^{228} \xrightarrow{\alpha,\gamma} Ra^{224} \xrightarrow{\alpha,\gamma}$ the same two α-energies are weighted with $n = 1$. The γ-energy is always weighted with $n = 1$.

When the necessary data are available, the maximum permissible body burden, q, of a radionuclide may be determined by a comparative study of the clinical findings and biological damage produced by various quantities of Ra^{226} and the radionuclide under study. Studies of chronic exposure(17)—a few of which have been started—should furnish the most direct and reliable values of q. Until these studies have been completed, it will be necessary to continue to determine values of q by a direct comparison of the energy deposited in bone by the particular radionuclide with the energy deposited by 0.1 μc of Ra^{226} and its daughter products (with an RBE of 10), modified by the factor, n. In this case, the value of q is given by the equation

$$q = \frac{q^{Ra} f_2^{Ra}}{f_2} \times \frac{\varepsilon^{Ra}}{\varepsilon} = \frac{0.1\ (0.99)}{f_2} \times \frac{110}{\varepsilon} = \frac{11}{f_2 \varepsilon} \qquad (1)$$

in which

$q^{Ra} = 0.1\ \mu c$ is the maximum permissible body burden of Ra^{226};
f_2 = fraction of radionuclide in the skeleton of that in the total body;
$f_2^{Ra} = 0.99$ is the value of f_2 for radium;
ε = effective absorbed energy per disintegration of a radionuclide = $\Sigma EF(\mathrm{RBE})n$; $\varepsilon^{Ra} = 110$ is the value of ε for radium;
E = energy (MeV) deposited in skeleton per disintegration;
RBE = relative biological effectiveness = 1 for X, γ, β^-, β^+, e^-, (it is set equal to 1.7 if the maximum energy, $E_m \leqslant 0.03$ MeV for β^-, β^+ or e^-), 10 for α and 20 for recoil atoms;
F = ratio of disintegrations of daughter to disintegrations of parent. See Section V.1.

It is assumed that 99 per cent of the radium in the body is in the skeleton, and the total energy deposited in the skeleton per disintegration of Ra^{226} plus 30 per cent of its daughter products(18, 19) is 11 MeV, and thus the effective energy deposited in the skeleton is $\Sigma EF(\mathrm{RBE})n = 110$*. For other radionuclides which are localized in the bone, the effective absorbed energy is found from $\Sigma EF(\mathrm{RBE})n$.

Thus, 0.1 μc of Ra^{226} and its daughter products in the body corresponds to an average absorbed dose rate to the bone of 0.06 rad/week or an average dose rate to the bone of 0.56 rem/week. As indicated above, the factor, n, was set equal to 1 in arriving at these dose rates for Ra^{226}. The distribution of radium in bone is not uniform,(14) and, for example, if there are portions of the bone in which radium is concentrated, the dose rate in these areas might be many times the average values. These values of RBE dose rate are based on the assumption that $(\mathrm{RBE})_\alpha = 10$. Many experiments(20) indicate that $(\mathrm{RBE})_\alpha$ is much smaller than 10 for biological damage resulting from acute exposure—perhaps as small as 1.4—but for biological damage from chronic exposures much higher applicable values have been reported.(21) Therefore, until more data from chronic exposures are available it would be unwise to use a value of $(\mathrm{RBE})_\alpha < 10$. Occupational and medical experience with radium offers much more justification for accepting the 0.1 μc of Ra^{226} and for the RBE dose

* This value was given as 162 MeV in the 1955 ICRP report(2) but is changed to 110 MeV in this 1958 edition. The reduction to 110 MeV is the result of using the more recent data of Norris(18) which indicate a bone retention of 30 per cent of the daughter products of Ra^{226}. The earlier data of Evans (19) which assumed 55 per cent retention of the daughter products of Ra^{226} had been used to obtain the 162 MeV. Details of calculation of this effective absorbed energy are given in Section V.1.

it delivers to the bone as a basic reference for permissible occupational exposure than any arbitrarily chosen dose rate to individual organs. At this time, it would be difficult to say which is more harmful to man, (a) the dose rate to the total body of 0.1 rem/week, or (b) the dose rate to the bone resulting from a body burden of 0.1 μc of Ra^{226}. Certainly, if a major portion of the hematopoietic system were irradiated, e.g. concurrently from the spleen-seeking Po^{210} and from the bone-seeking Ra^{226}, the biological damage would be greater than if only a part of it were irradiated. It has been shown[8] that in some cases a synergistic effect results when several organs of the body are irradiated simultaneously. Thus, it is rather certain that 0.1 rem/week to the bone is less harmful than 0.1 rem/week to the total body but, at present, sufficient quantitative data are lacking to indicate whether or not an average dose rate of 0.56 rem/week (involving, perhaps, a much higher local dose rate) to the bone produces greater or less damage than 0.1 rem/week to the entire body.

The development of bone tumors many years after exposure (from 10 to 35 years) has been the principal hazard to patients given large medical doses of radium and to the radium dial painters. Although tumors have not been observed in persons with body burdens of radium as low as 0.1 μc, the factor of safety may not be as large as 10 because tumors have occurred in persons having a body burden less than 1μc of radium at the time the tumor was first detected. However, in all these cases the original body burden had been greater than it was when the tumor was first detected. Furthermore, in most cases the integrated absorbed dose received by the radium dial painters had been much enhanced because a large amount of mesothorium (Ra^{228}) was in the ingested material. There is an additional factor of safety in the MPC values for the long-lived radionuclides in Table 1 in that the maximum permissible body burden is reached only after an extended exposure at the MPC level (see Section III.1). For the radionuclides (Table 2) with a long effective half-life, e.g. Ra^{226}, Th^{230}, Th^{232}, Np^{237}, Pu^{239}, Am^{243}, Cm^{246}, etc., the maximum permissible body burden is not reached until after 50 years of continuous occupational exposure. Several workers[22] have described changes in skeletal density and/or histopathological changes in the bone of patients who have 0.1 μc or less of radium, and more pathological changes may be expected as these individuals become older. This problem will be kept constantly under advisement, and as more data are accumulated on the chronic effects of radium and other bone-seeking radionuclides, it may be desirable at a later date to lower the basic reference of 0.1 μc of Ra^{226}. However, at the present time, this change does not seem to be warranted for reasons as follows: (a) radium does not irradiate the entire hematopoietic system; (b) body burdens of 0.1 μc of Ra^{226} probably produce detectable changes in the bone but are not known to have caused serious damage (demonstrable harm to the individual); (c) the principal recognizable damage from Ra^{226} is the production of bone tumors, but the lowest body burden that has resulted in a tumor is 0.5 μc;[23] (d) all radium-produced tumors have occurred in persons whose original body burdens had been much greater than at the time the tumors were discovered; (e) most bone tumors arising in radium dial painters may be attributed to Ra^{226} + Ra^{228} in which the integrated RBE dose was much greater than would be indicated by the Ra^{226} burden at the time the tumors were discovered; and (f) the maximum permissible body burden of a bone-seeking radionuclide corresponding to 0.1 μc of Ra^{226} is not reached except following continuous occupational exposure at the MPC values. For the more dangerous bone-seeking radionuclides, this requires continuous occupational exposure for 50 years at the MPC level.

3. *Body burden based on a permissible RBE dose rate to the critical body organ.* Because specific experimental information is lacking for assessing values of safe body burdens of the radionuclides that are not localized in the bone, the MPC and q values were calculated on the premise that a maximum permissible body burden is that amount distributed throughout the body that will result in a maximum permissible RBE dose rate to the critical organ. The maximum RBE dose rates permitted to the various body organs are listed in Section II.2. It should be emphasized that these maximum permissible RBE dose rates are values averaged during a quarter. Variations of these rates over shorter intervals may be expected and are permissible. As explained in Section II, the average dose rate of 0.1 rem/week and corresponding MPC values for occupational exposure of the gonads or total body may be increased over a 13 week period by a factor as large as 2.4, provided the dose at any age N does not exceed that given by the formula $5(N-18)$ and provided adequate monitoring is used to insure that the dose in a 13 week period does not exceed 3 rems.

In the following discussion, the distribution of the isotope in the body is characterized by the following parameters:

f_1 = the fraction of ingested radionuclides reaching the blood;
f_2' = the fraction of the nuclide in the blood that reaches the organ of reference;
$f_w = f_1 f_2'$, see Section V.3;
f_a = the fraction of inhaled radionuclide reaching the organ of reference, see Section V.3;
f_2 = the fraction of the body burden in the organ of reference, see Section V.3.

The equation for maximum permissible body burden, q, based on a maximum permissible dose rate R rem/week is

$$q = \frac{100\, mR}{3.7 \times 10^4 \times 1.6 \times 10^{-6} \times 6.05 \times 10^5 f_2 \varepsilon} \tag{2}$$

$$q = \frac{2.8 \times 10^{-3}\, m\, R}{f_2\, \varepsilon} \tag{3}$$

and when $R = 0.3$ rem/week

$$q = \frac{8.4 \times 10^{-4}\, m}{f_2 \varepsilon} \tag{4}$$

where 3.700×10^4 = dis/sec per μc;
1.6×10^{-6} = ergs/MeV;
6.05×10^5 = sec/week;
100 = ergs/g per rad;
m = mass of the organ of reference (g);
and ε is defined as for equation (1).

4. Concentrations in air and water—based on exponential model—critical organs other than gastrointestinal (GI) tract. Maximum permissible concentrations in air and in water in Table 1 were calculated for most of the radionuclides on the assumption that the radioactive material is taken into the critical body organ at the rate of P μc/day and that the biological elimination from the critical organ follows a simple exponential law. This relationship is expressed by the equation;

$$\frac{d(qf_2)}{dt} + \lambda(qf_2) = P \tag{5}$$

The solution with $qf_2 = 0$ when $t = 0$ is

$$qf_2 = P(1 - e^{-\lambda t})/\lambda \tag{6}$$

in which qf_2 = burden of the radionuclide in the critical body organ (μc);

f_2 = fraction of radionuclide in critical organ of that in total body;
λ = effective decay constant = $0.693/T$;
T = effective half-life $(T_r T_b)/(T_r + T_b)$ (days);
T_r = radioactive half-life (days);
T_b = biological half-life (days);
t = period of exposure; for occupational exposure $t = 50$ years (in the previous publications of NCRP(1) and ICRP(2) t was set to equal 70 years);
P = rate of uptake of the radionuclide by the critical body organ (μc/day) = $(M)S$, where M is the concentration (μc/cm^3) of the radionuclide in water or in air taken into the body, and S is the product of the average rate of intake (cm^3/day) of water or of air and the fraction of the microcuries arriving in the critical body organ. For occupational exposure at the maximum permissible concentration (MPC) of the radionuclide in water, $M = (\text{MPC})_w$ and in air, $M = (\text{MPC})_a$. In a 24 hr day, the standard man (see Section V.2 for a discussion of the standard man) consumes 2200 cm^3 of water and breathes 2×10^7 cm^3 of air. Because of his greater activity during an 8 hr work day, it is assumed that half of this body intake occurs during the work period, viz. 1100 cm^3 of water and 10^7 cm^3 of air. The work schedule for the standard man is 8 hr/day, 5 days/week and 50 weeks/year. Therefore for the average occupational exposure, $S = 1100 \times 5/7 \times 50/52 f_w = 750\ f_w$ cm^3 of water per day and $S = 10^7 \times 5/7 \times 50/52 f_a = 6.9 \times 10^6 f_a$ cm^3 of air per day.

The formulas that follow in this section are all based on a 40 hr/week exposure period whenever specific time data are involved. For continuous occupational exposure the MPC values should be divided by $2 \times 365/(5 \times 50) = 2.92$ except for submersion where they should be divided by $3 \times 365/(5 \times 50) = 4.38$. Substituting the above values for P and λ in equation (6) the MPC values are determined by

$$(\text{MPC})_a = \frac{10^{-7}\, q f_2}{T f_a \,(1 - e^{-0.693\, t/T})}\ \mu\text{c/cm}^3 \tag{7}$$

and

$$(\text{MPC})_w = \frac{9.2 \times 10^{-4}\, q f_2}{T f_w \,(1 - e^{-0.693\, t/T})}\ \mu\text{c/cm}^3 \tag{8}$$

T = effective half-life (days);
t = period of exposure (days).

If the radionuclide disintegrates into one or more daughter radionuclides, proper account must be taken of the contribution to the RBE dose by the daughter radionuclides that are produced in the body. Formulas (7) and (8) may be modified so that they remain correct for a chain of parent–daughter radionuclides. This can be done by simply augmenting the effective energy of the parent by the effective energy of each daughter weighted by the frequency of the daughter disintegrations per disintegration of parent. This ratio defines the factor F_i, i.e.

$$F_i = \frac{\mu\text{c of } i\text{th daughter in the organ}}{\mu\text{c of parent in the organ}}$$

Thus in the case[24] of a single intake, if P μc of the parent radionuclide reaches the critical organ at time $t = 0$, the organ burden $(q f_2)_i^s$ of the ith daughter product at time t is given by the equation

$$(q f_2)_0^s = P\, e^{-\lambda_0 t}$$

$$(q f_2)_1^s = P\, \lambda_1^r \left[\frac{e^{-\lambda_0 t}}{\lambda_1 - \lambda_0} + \frac{e^{-\lambda_1 t}}{\lambda_0 - \lambda_1}\right]$$

$$(q f_2)_2^s = P\, \lambda_1^r \lambda_2^r \left[\frac{e^{-\lambda_0 t}}{(\lambda_1 - \lambda_0)(\lambda_2 - \lambda_0)} + \frac{e^{-\lambda_1 t}}{(\lambda_0 - \lambda_1)(\lambda_2 - \lambda_1)} + \frac{e^{-\lambda_2 t}}{(\lambda_0 - \lambda_2)(\lambda_1 - \lambda_2)}\right]$$

The general formula is

$$(q f_2)_i^s = P\left[\prod_{j=1}^{i} \lambda_j^r\right] \sum_{h=0}^{i} \frac{e^{-\lambda_h t}}{\prod\limits_{\substack{p=0\\ p \neq h}}^{i} (\lambda_p - \lambda_h)} \tag{9}$$

In this formula $\left[\prod_{j=1}^{i} \lambda_j^r\right]$ denotes the product $\lambda_1^r \times \lambda_2^r \times \ldots \times \lambda_i^r$.

If it is understood that when $i = 0$ the empty product $\left[\prod_{j=1}^{0} \lambda_j^r\right]$ is equal to 1, this general formula (9) is applicable to the total body burden of the parent as well as the daughter radionuclides. In the following discussion, the subscript, 0, as in $\lambda_0^r = 0.693/T_0^r$, etc., always refers to the parent isotope while the subscript i indicates the decay constants of the ith daughter.

When there is continuous intake of the parent radionuclide so that P μc/day of the parent radionuclide reaches the critical organ, the organ burden $(qf_2)_i$ of the ith daughter product at time t is given by the equation:

$$(qf_2)_0 = P(1 - e^{-\lambda_0 t})/\lambda_0$$

$$(qf_2)_1 = P\,\lambda_1^r \left[\frac{(1 - e^{-\lambda_0 t})}{\lambda_0(\lambda_1 - \lambda_0)} + \frac{(1 - e^{-\lambda_1 t})}{\lambda_1(\lambda_0 - \lambda_1)}\right]$$

$$(qf_2)_2 = P\,\lambda_1^r\lambda_2^r\left[\frac{(1 - e^{-\lambda_0 t})}{\lambda_0(\lambda_1 - \lambda_0)\,(\lambda_2 - \lambda_0)} + \frac{(1 - e^{-\lambda_1 t})}{\lambda_1(\lambda_0 - \lambda_1)\,(\lambda_2 - \lambda_1)} + \frac{(1 - e^{-\lambda_2 t})}{\lambda_2(\lambda_0 - \lambda_2)\,(\lambda_1 - \lambda_2)}\right]$$

The general formula is

$$(qf_2)_i^s = \int_0^t (qf_2)_i^s\,dt = P\left[\prod_{j=1}^{i} \lambda_j^r\right]\sum_{h=0}^{i} \frac{1 - e^{-\lambda_h t}}{\lambda_h \prod_{\substack{p=0\\p\neq h}}^{i} (\lambda_p - \lambda_h)} \qquad (10)$$

It is to be noted that equation (10) includes equation (6) as a special case if it is understood that when $i = 0$ the empty product is replaced by 1. The dose rate in rems/week to the critical body organ resulting from the continuous body intake and deposition of the parent radionuclide and from the growth of the daughter radionuclides in the critical body organ is given by the equation:

$$R = \sum_{i=0}^{k} (qf_2)_i \frac{3.7\times 10^4 \times 24 \times 3600 \times 7 \times 1.6 \times 10^{-6}\, E_i\,(\mathrm{RBE})_i n_i}{100\, m} \text{ rems/week} \qquad (11)$$

in which m is the mass of the critical organ, and $E_i\,(\mathrm{RBE})_i n_i$ is the effective energy corresponding to one disintegration of an ith daughter atom. The factor P is taken as $6.9 \times 10^6 \times (\mathrm{MPC})_a f_a$ for inhalation and as $750\,(\mathrm{MPC})_w f_w$ for ingestion, and since the factor P occurs in each of the (qf_2) terms in equation (11), and since $(qf_2)_0 = P(1 - e^{-\lambda_0 t})/\lambda_0$

$$(\mathrm{MPC})_a = \frac{4.1 \times 10^{-10}\, m\, R}{f_a \sum_{i=0}^{k} (qf_2)_i\, E_i\,(\mathrm{RBE})_i n_i/P}\ \mu\mathrm{c/cm^3} = \frac{4.1 \times 10^{-10}\, m\, R\, \lambda_0}{f_a(1 - e^{-\lambda_0 t}) \sum_{i=0}^{k} E_i F_i (\mathrm{RBE})_i n_i}\ \mu\mathrm{c/cm^3} \qquad (12)$$

$$(\text{MPC})_w = \frac{3.7 \times 10^{-6}\, mR}{f_w \sum_{i=0}^{k} (qf_2)_i E_i (\text{RBE})_i n_i / P}\ \mu\text{c/cm}^3 = \frac{3.7 \times 10^{-6}\, m\, R\, \lambda_0}{f_w (1 - e^{-\lambda_0 t}) \sum_{i=0}^{k} E_i F_i (\text{RBE})_i n_i}\ \mu\text{c/cm}^3 \quad (13)$$

with $F_0 = 1$ and $F_i = (qf_2)_i/(qf_2)_0$. In equations (12) and (13) R is the permissible dose rate to the organ in rems/week. Thus if particulate radiation is involved $R=0.56$ when bone is the critical organ and $R = 0.3$ for all other organs except thyroid and skin, in which cases $R = 0.6$ or for total body and gonads where $R = 0.1$. The weighted sum of chain energies $\Sigma E_i F_i$ $(\text{RBE})_i n_i$ and the fractions F_i are listed in Table 5(a). In all organs other than bone n_i is taken as 1. Equations (12) and (13) are based on the 40 hr week. The corresponding formulas for the 168 hr week, i.e. continuous exposure, are obtained by replacing the constants 4.1×10^{-10} and 3.7×10^{-6} by 1.4×10^{-10} and 1.3×10^{-6}, respectively.

5. Concentrations in air and water based on RBE dose delivered to various segments of the GI tract. When the critical organ considered is the gastrointestinal (GI) tract, the amount (μc) of the ith daughter present at time t is given by formulas similar to equation (9), but since the material moves along the intestines at somewhat different rates, formula (11) also needs adjustment. If τ is the total time spent in a section of the GI tract, e.g. the upper large intestine, then during a time interval $d\tau$ the fraction of the total contents which moves by a given site is, on the average, $d\tau/\tau$. The mass of this material is thus $d\tau/\tau \times m$, where m is the total mass of the contents of the section being considered. The energy is, to a first approximation, absorbed in this mass. Thus if there is continuous intake of P μc/day, then the dose rate in rems/week to the walls of the GI tract near the site is given by

$$R = \sum_{i=0}^{k} (qf_2)_i^{\text{total}} \frac{3.7 \times 10^4 \times 24 \times 3600 \times 7 \times 1.6 \times 10^{-6} \varepsilon_i\, d\tau}{2 \times 100\, m \times d\tau/\tau}\ \text{rems/week} \quad (14)$$

In the case of an isotope with no daughters, the value of $(\text{MPC})_a$ is

$$(\text{MPC})_a = \frac{8.2 \times 10^{-10}\, m\, R}{f_a \tau \varepsilon_0 e^{-\lambda_0 t}}\ \mu\text{c/cm}^3 \quad (15)$$

and the value of $(\text{MPC})_w$ is

$$(\text{MPC})_w = \frac{7.4 \times 10^{-6}\, m\, R}{\tau \varepsilon_0 e^{-\lambda_0 t}}\ \mu\text{c/cm}^3 \quad (16)$$

If the radionuclide considered is the parent of a chain of k daughters, the corresponding formula for $(\text{MPC})_a$ is

$$(\text{MPC})_a = \frac{8.2 \times 10^{-10}\, m\, R}{\tau f_a \sum_{i=0}^{k} \frac{(qf_2)_i^{\text{total}}}{P} \varepsilon_i}\ \mu\text{c/cm}^3 \quad (15')$$

and the value of $(MPC)_w$ is

$$(MPC)_w = \frac{7.4 \times 10^{-6}\, m\, R}{\tau \sum_{i=0}^{k} \frac{(q f_2)_i^{\text{total}}}{P}\, \varepsilon_i}\ \mu c/cm^3 \qquad (16')$$

The values of the biological constants used for the different sections of the GI tract are listed in Table 11. Since daughter elements also enter the small intestine and the large intestine, each subdaughter is the parent for a subchain and $(q f_2)_i^s$ must be computed by equation (9) for all such subchains and the results added to give the amount of ith daughter in the organ. This will be denoted by $(q f_2)_i^{\text{total}}$. A factor of $\frac{1}{2}$ has been included in formulas (14) through (19′) to take account of the fact that the dose to the intestinal wall is, on the average, only half the dose to the contents of the GI tract. In equations (15′) and (16′) $(q f_2)_i^{\text{total}}$ represents the amount of the ith isotope (μc) (equation (9)), and the formulas were computed in this form. Thus the factors F_i are not needed and since the relative damage factor $n_i = 1$ for the GI tract, the effective energy reduces to $\varepsilon_i = \Sigma E$ (RBE) which is tabulated in Tables 5 and 5(a). Experiments[25] have shown that α-particles fail to penetrate the mucosa to an appreciable extent. Therefore, the Committee has decided to include only 1 per cent of the energy of the α-particles in computing the effective energies, $\Sigma\varepsilon_i$, for the GI tract. In calculating $(q f_2)_i^{\text{total}}$ it is assumed that there is no absorption of the material from the large intestine, and thus $\lambda_i^b = 0$ and $\lambda_i = \lambda_i^r$ in these sections of the tract. The same is assumed for the stomach. In the small intestine a fraction f_1 is absorbed and a value of λ_i^b is chosen so that absorption at this constant rate during the time of passage amounts to a total absorption of a fraction f_1 of the material. Equations (15) and (16) are applied when the critical portion of the GI tract is the small intestine, SI, upper large intestine, ULI, or the lower large intestine, LLI. Since the upper large intestine and the lower large intestine have the same diameter, the effective energy is the same for these two sections. This common value is listed in Tables 5 and 5(a) as the value for the large intestine, LI. The calculations for the stomach, S, are somewhat different since it is assumed that the ingested material remains in the stomach for 1 hr. Thus, the dose to the stomach is given by

$$R = \sum_{i=0}^{k} \int_0^{1/24} \frac{(q f_2)_i^s \times 3.7 \times 10^4 \times 24 \times 3600 \times 7 \times 1.6 \times 10^{-6}\, \varepsilon_i\, d\tau}{2 \times 100\, m}\ \text{rems/week} \qquad (17)$$

In the case of an isotope with no daughters the value of $(MPC)_a$ is

$$(MPC)_a = \frac{2.5 \times 10^{-10}\, m\, \lambda_0}{f_a\, \varepsilon_0\, (1 - e^{-\lambda_0/24})}\ \mu c/cm^3 \qquad (18)$$

and the value of $(MPC)_w$ in this case is

$$(MPC)_w = \frac{2.2 \times 10^{-6}\, m\, \lambda_0}{\varepsilon_0\, (1 - e^{-\lambda_0/24})}\ \mu c/cm^3 \qquad (19)$$

If the radionuclide considered is the parent of a chain of k daughters and the stomach is the critical tissue, the corresponding formula for $(\mathrm{MPC})_a$ is

$$(\mathrm{MPC})_a = \frac{2.5 \times 10^{-10}\, m}{f_a \sum_{i=0}^{k} \varepsilon_i \left[\prod_{j=1}^{i} \lambda_j^r\right] \sum_{h=0}^{i} \frac{(1 - e^{-\lambda_h/24})}{\lambda_h \prod_{\substack{p=0 \\ p\neq h}}^{i} (\lambda_p - \lambda_h)}}\ \mu\mathrm{c/cm}^3 \qquad (18')$$

and the value of $(\mathrm{MPC})_w$ when the stomach is the critical tissue is

$$(\mathrm{MPC})_w = \frac{2.2 \times 10^{-6}\, m}{\sum_{i=0}^{k} \varepsilon_i \left[\prod_{j=1}^{i} \lambda_j^r\right] \sum_{h=0}^{i} \frac{(1 - e^{-\lambda_h/24})}{\lambda_h \prod_{\substack{p=0 \\ p\neq h}}^{i} (\lambda_p - \lambda_h)}}\ \mu\mathrm{c/cm}^3 \qquad (19')$$

The notation in formulas (18) through (19′) is chosen in agreement with the notation of formula (10) on which these are based. However, as explained above, no absorption occurs in the stomach so that $\lambda_i^b = 0$ and thus λ_i in formulas (18) through (19′) is equal to λ_i^r, i.e. $\lambda_i = \lambda_i^r + \lambda_i^b = \lambda_i^r + 0 = \lambda_i^r$. For some isotopes the dose rate to the intestinal wall passes through a maximum value during the time of passage through the GI tract, and thus it is necessary to determine this maximum and equate it to 0.3 rem/week in determining the maximum permissible intake. The use of the single intake formulas for $(qf_2)_i^s$ and $(qf_2)_i^{\text{total}}$ in equations (14) through (19′) instead of continuous intake formulas for the organ burden as in equations (10) through (13) follows from the fact that by our assumption of continuous movement at a uniform rate through each section of the tract the isotope never accumulates in the GI tract, and thus the dose at a position reached at time t after ingestion of material is entirely independent of what material was ingested before time $t = 0$ or following time $t = 0$. This is, of course, an oversimplification since there is some irradiation of one portion of the GI tract by any γ-radiation in the body and, perhaps, by some β-rays emitted in other portions of the tract. To a large extent this is taken into account in computing the effective energies, ε_i, which are calculated for each section of the tract as a whole and not merely for a very small portion of the tract.

6. *Maximum permissible concentration of radionuclides of noble gases and other relatively inert gases.* In dealing with inert gases, such as A^{41} and Xe^{135}, the calculations are not based on the dose delivered by the concentration of the radioactive material inside the body, but rather on the dose the person would receive if he were surrounded by a semispherical infinite cloud of radioactive gas. In this case, one would expect the radiation from the radioactive cloud to deliver a much higher dose than that from the gas held in the lungs or other body organs. It follows that the body is assumed to be irradiated from half the solid angle by this radioactive cloud of large volume.

The maximum permissible concentration of an inert gas under these conditions is,

$$(MPC)'_a = \frac{0.024\,R}{\Sigma\,(E)}\,\rho_a\,P_a/P_t\,\mu c/cm^3 \qquad (20)$$

When the maximum permissible dose rate R is 0.1 rem/week,

$$(MPC)'_a = \frac{2.6 \times 10^{-6}}{\Sigma\,(E)}\,\mu c/cm^3 \qquad (21)$$

in which ρ_a = density of air (= 0.0012 g/cm³);

P_a/P_t = stopping power of air relative to tissue; $P_a/P_t = 1/1.13$ for β and secondary electrons produced by X- and γ-radiation;

$\Sigma\,(E)$ = effective energy per disintegration (MeV); in this case RBE = 1 and $n = 1$;

$(MPC)'_a$ = maximum permissible concentration ($\mu c/cm^3$) in a large cloud of gas that will deliver a dose at the rate of 0.1 rem/week.*

Equation (21) is applied only in the case of large clouds of noble gases or other relatively inert gases that emit γ or high energy β-radiation ($E_m \geqslant 0.1$ MeV). This equation is applicable to occupational exposure (i.e. 40 hr/week) and for the case where a person is surrounded by an infinite semispherical cloud of radioactive material that emits γ-, X- or β-radiation of sufficient energy to constitute essentially a total body exposure and necessitate limiting the dose rate to 0.1 rem/week.

The above formula was not used for noble gases that are principally α-emitters, e.g. Rn^{222} and Rn^{220}, or for other relatively inert gases that emit low energy ($\leqslant 0.1$ MeV) β-radiation, e.g. H_2^3, because the radiation would not penetrate the protective epidermal layer of skin surrounding the body. In the case of such low energy radiation formula (20) still applies but with $R = 0.6$ rem/week. Such cases are listed in Table 1 with "submersion skin" as the organ of reference. Experiments have shown that when HTO vapor is present in air, approximately equal amounts enter the body by inhalation and absorption through the skin. Thus the value computed by equation (7) must be halved in this case.

In 1941 the United States Advisory Committee on X-ray and Radium Protection(12) set 10^{-8} $\mu c/cm^3$ as the value of $(MPC)_a$ for occupational exposure (40/hr week) to Rn^{222} plus its daughter products. However, the ICRP(2) gave an $(MPC)_a$ value of 10^{-7} $\mu c/cm^3$ for continuous exposure (168 hr/week). Despite the wide disparity of these values and the long record of experience with radon, there are few, if any, well-established cases of serious damage from exposures at these levels. Nevertheless, calculations indicate that an air concentration of 10^{-7} $\mu c/cm^3$ might lead to an excessively large dose to the bronchi, and the NCRP(1) previously had recommended the value of 10^{-8} $\mu c/cm^3$ as $(MPC)_a$ for Rn^{222} plus daughters (168 hr/week).

* In the previous publication of this report,(2) the exposure rate was taken as 0.3 rem/week rather than 0.1 rem/week, and the radioactive cloud was assumed to comprise an infinite sphere rather than an infinite semisphere about the body. Also, the equations were given for continuous exposure rather than for the typical week of work. Therefore, previously published MPC values have been increased by three factors, viz. $1/3 \times 2 \times 4.4 = 2.9$. The new assumptions are thought to be sufficiently conservative in all practical cases.

Recent studies[26] have indicated that when radon and its daughters are present in ordinary air the free ions of RaA constitute only about 10 per cent of the total number of RaA atoms that would be present at equilibrium and these unattached atoms deliver all but a small fraction of the dose to the bronchi. Based on these measured dose rates the $(MPC)_a$ for exposure to radon and daughter products is found to be $3 \times 10^{-6}/(1 + 1000f)$ where f is the fraction of the equilibrium amount of RaA ions which are unattached to nuclei.

For Rn^{220} the major portion of the dose to the bronchi is due to free ions of ThB which reach only 1/2000 of the equilibrium number in ordinary unfiltered air. Because of this and energy considerations the $(MPC)_a$ value will be higher and is recommended as $6 \times 10^{-6}/(1 + 40000f)$ if the free ions of ThB constitute a fraction f of the equilibrium number of such atoms. The values given here for radon and daughters and for thoron and daughters are for the 40 hr week.

7. *Maximum permissible concentration of unidentified radionuclides (MPCU)*. The identity of the radioactive contaminants in air, water and food must be established before appropriate MPC values can be applied either for occupational exposure or for exposure to population outside of controlled areas. In many cases there is no question regarding the identity of a radionuclide because the operation involves only one radionuclide. Sometimes, however, preliminary surveys reveal the presence of radioactive contamination, and considerable uncertainty exists as to which radionuclides are the major contributors. When a laboratory is using a number of radionuclides, e.g. mixed fission products, an air sample may furnish only a few clues as to the identity of the radionuclide. By using the simplest of equipment and techniques, the level of air contamination may be established in a matter of minutes, but hours or even days may be required to conduct the radiochemical analyses necessary to identify the one or more radionuclides that are present in the air. Fortunately, in such cases it usually is not necessary to go through a tedious, time consuming and expensive radiochemical analysis. If it is determined that certain of the more dangerous radionuclides are not present, i.e. the concentration of the more dangerous is small compared with the MPC values in Table 1, the operation may be continued safely regardless of the radionuclide or mixture of radionuclides, provided the concentration does not exceed the values for MPC of unidentified (MPCU) radionuclides as listed in Table 3 for water or in Table 4 for air. These MPCU values are applicable to continuous occupational exposure (168 hr/week), and should be multiplied by one-tenth if they are to be applied as interim values outside of and in the neighborhood of the controlled exposure area. It should be pointed out that the use of MPCU values may save an immense amount of effort and expense if they are applied properly to avoid unnecessary radionuclide analyses in areas where the air, water and food contamination is usually less than the appropriate MPCU values. On the other hand, they can impose a needless penalty if improperly applied. For example, if initial measurements indicate a negligible amount of Ra^{226} and Ra^{228} in the drinking water of a small community near an atomic energy laboratory, and if it is determined by daily gross α-, β- and γ-sample counting that the activity does not exceed the MPCU value ($\frac{1}{10} \times 1 \times 10^{-6}\,\mu c/cm^3 = 1 \times 10^{-7}\,\mu c/cm^3$) it would seem foolish to carry out a daily radiochemical analysis of this water. If, on the other hand,

the level ranged between 10^{-5} and 2×10^{-5} $\mu c/cm^3$, it would be unwise to shut down the plant or to instigate an expensive modification of the operation without first identifying the radionuclides, for it might be that the contamination in the water is from Na^{24} and P^{32}. In this case, the appropriate MPC value for application in the neighborhood of the plant is $\frac{1}{10} \times 2 \times 10^{-3} = 2 \times 10^{-4}$ and $\frac{1}{10} \times 2 \times 10^{-4} = 2 \times 10^{-5}$, respectively (see Table 1).

8. *Maximum permissible concentration of known mixtures of radionuclides.* Suppose a person is exposed to concentrations $\rho_{aA}, \rho_{aB}, \ldots \rho_{wA}, \rho_{wB} \ldots$ $\mu c/cm^3$ of isotopes $A, B, \ldots$ in air and in water, respectively, and also to external sources of γ and neutron radiations. Assume further that the external sources give doses R^x_γ, R^x_n to a given organ x for γ and neutron radiation, respectively. If L^x rem is the average weekly dose permitted to organ x by the basic rules, then the total dose to organ x is

$$\left[\frac{\rho_{aA}}{(\mathrm{MPC})^x_{aA}} + \frac{\rho_{aB}}{(\mathrm{MPC})^x_{aB}} + \cdots + \frac{\rho_{wA}}{(\mathrm{MPC})^x_{wA}} + \frac{\rho_{wB}}{(\mathrm{MPC})^x_{wB}} + \cdots\right] L^x + R^x_\gamma + R^x_n \quad (22)$$

This does not exceed L^x provided

$$\frac{\rho_{aA}}{(\mathrm{MPC})^x_{aA}} + \frac{\rho_{aB}}{(\mathrm{MPC})^x_{aB}} + \cdots + \frac{\rho_{wA}}{(\mathrm{MPC})^x_{wA}} + \frac{\rho_{wB}}{(\mathrm{MPC})^x_{wB}} + \cdots + \frac{R^x_\gamma}{L^x} + \frac{R^x_n}{L^x} \leqslant 1 \quad (23)$$

and thus provides a criterion for assessing whether or not the exposure is in excess of that permitted by the basic rules. If organ x is not listed as an organ of reference in Table 1, and if an independent estimate of the corresponding MPC values is not available, the MPC based on total body may be used with the correction factor $L^x/0.1$, i.e. $L^x(\mathrm{MPC})^{T.B.}_a/0.1$ may be substituted for $(\mathrm{MPC})^x_a$ in such cases. In general it will be necessary to calculate the dose for all the organs for which the dose may reasonably be considered to be in excess of the prescribed limits. Often this may include the total body even though no one of the radionuclides irradiates a major portion of the body. Assuming that a major portion of the body is being irradiated at somewhat comparable rates, the calculation is essentially as before except that the MPC values based on total body are to be used. Thus the criterion is

$$\frac{\rho_{aA}}{(\mathrm{MPC})^{T.B.}_{aA}} + \frac{\rho_{aB}}{(\mathrm{MPC})^{T.B.}_{aB}} + \cdots + \frac{\rho_{wA}}{(\mathrm{MPC})^{T.B.}_{wA}} + \frac{\rho_{wB}}{(\mathrm{MPC})^{T.B.}_{wB}} + \cdots + \frac{R^{T.B.}_\gamma}{0.1} + \frac{R^{T.B.}_n}{0.1} \leqslant 1 \quad (24)$$

In effect this limits the average dose rate over the body to 0.1 rem/week. There may be some organs in which the dose rate exceeds 0.1 rem/week, but this is considered permissible so long as such organs do not constitute a major portion of the body. Of course, the criteria for these organs must also be considered, and the application of equation (23) will prevent any particular organ from exceeding the permissible limit set for that organ. However, it would seem too conservative and contrary to the intent of the basic rules to limit the dose to any portion of the body to a maximum rate of 0.1 rem/week merely because the entire body is receiving some dose, though it may be very small in most of the body and only be at the rate of 0.1 rem/week in a small portion. The values of $(MPC)^{T.B.}$ as given in Table 1 and as applied in equation (24) were derived on the assumption that the total body dose of interest in this case is the gram-rem dose or the total weighted energy delivered to the total body. On this basis the total body burden was obtained from equation (3) by setting m equal to the mass of the total body ($m = 70{,}000$ g), $f_2 = 1$, ε equal to the weighted absorbed energy, $n = 1$ and $R = 0.1$ rem/week.

The application of these criteria may be illustrated by the following example: Suppose the mixture consists of Sr^{90}, Pu^{239} and Na^{24}, and that an external γ-source is also present, and that the measured intensities are those indicated in Table *A*.

Table A. Calculation of MPC of a mixture of radionuclides

Example of Concurrent Exposure to Several Radionuclides (in Soluble Form) Present in Air and Water and to an External Source of Radiation

Source of exposure	Body organ exposed	In air*	In water*
Sr^{90}	Bone	$\dfrac{\rho_{aA}}{(MPC)^{x}_{aA}} = \dfrac{1.8\times10^{-11}\ \mu c/cm^3}{3\times10^{-10}\ \mu c/cm^3}$ 0.06	$\dfrac{\rho_{wA}}{(MPC)^{x}_{wA}} = \dfrac{1.5\times10^{-7}\ \mu c/cm^3}{4\times10^{-6}\ \mu c/cm^3}$ 0.038
	Total body	$\dfrac{\rho_{aA}}{(MPC)^{T.B.}_{aA}} = \dfrac{1.8\times10^{-11}\ \mu c/cm^3}{9\times10^{-10}\ \mu c/cm^3}$ 0.02	$\dfrac{\rho_{wA}}{(MPC)^{T.B.}_{wA}} = \dfrac{1.5\times10^{-7}\ \mu c/cm^3}{1\times10^{-5}\ \mu c/cm^3}$ 0.015
Pu^{239}	Bone	$\dfrac{\rho_{aB}}{(MPC)^{x}_{aB}} = \dfrac{4\times10^{-13}\ \mu c/cm^3}{2\times10^{-12}\ \mu c/cm^3}$ 0.2	$\dfrac{\rho_{wB}}{(MPC)^{x}_{wB}} = \dfrac{1.3\times10^{-5}\ \mu c/cm^3}{1\times10^{-4}\ \mu c/cm^3}$ 0.13
	Total body	$\dfrac{\rho_{aB}}{(MPC)^{T.B.}_{aB}} = \dfrac{4\times10^{-13}\ \mu c/cm^3}{1\times10^{-11}\ \mu c/cm^3}$	$\dfrac{\rho_{wB}}{(MPC)^{T.B.}_{wB}} = \dfrac{1.3\times10^{-5}\ \mu c/cm^3}{1\times10^{-3}\ \mu c/cm^3}$
Na^{24}	Total body	0.1 $\dfrac{\rho_{aC}}{(MPC)^{T.B.}_{aC}} = \dfrac{2\times10^{-7}\ \mu c/cm^3}{2\times10^{-6}\ \mu c/cm^3}$	0.2 $\dfrac{\rho_{wC}}{(MPC)^{T.B.}_{wC}} = \dfrac{2\times10^{-3}\ \mu c/cm^3}{1\times10^{-2}\ \mu c/cm^3}$
γ†		Bone $\dfrac{R^{x}_{\gamma}}{L^{x}} = \dfrac{0.065\ \text{rem/week}}{0.56\ \text{rem/week}}$ 0.12	
		Total body $\dfrac{R^{T.B.}_{\gamma}}{L^{T.B.}} = \dfrac{0.065\ \text{rem/week}}{0.1\ \text{rem/week}}$ 0.65	

* The ratios given for Sr^{90}, Pu^{239} and Na^{24} are the ($\mu c/cm^3$ present in air)/$(MPC)^{x}_{aA}$ where $(MPC)^{x}_{aA}$ is the $(MPC)_a$ for element *A* (Sr^{90}) and organ *x* (bone), etc.

† The ratio given for γ is the (actual RBE dose rate)/(maximum permissible RBE dose rate).

The concentrations have been chosen to illustrate the case of a mixture which is below the permissible limit for one of the criteria (bone), but is barely in excess of the limit determined by another of the criteria (total body).

Criterion (23) applied to bone gives

$$\frac{\rho_{aA}}{(\mathrm{MPC})^x_{aA}} + \frac{\rho_{wA}}{(\mathrm{MPC})^x_{wA}} + \frac{\rho_{aB}}{(\mathrm{MPC})^x_{aB}} + \frac{\rho_{wB}}{(\mathrm{MPC})^x_{wB}} + \frac{0.1}{0.56}\left[\frac{\rho_{aC}}{(\mathrm{MPC})^{TB}_{aC}} + \frac{\rho_{wC}}{(\mathrm{MPC})^{TB}_{wC}}\right] + \frac{R^x_\gamma}{L^x}$$

$$= 0.06 + 0.038 + 0.2 + 0.13 + \frac{0.1}{0.56}(0.1 + 0.2) + \frac{0.065}{0.56} = 0.60 < 1.$$

Thus the average dose rate to the bone is about $0.60 \times 0.56 = 0.34$ effective rem/week and is therefore within the limits set for bone.

Criterion (24) for total body gives

$$\frac{\rho_{aA}}{(\mathrm{MPC})^{T.B.}_{aA}} + \frac{\rho_{wA}}{(\mathrm{MPC})^{T.B.}_{wA}} + \frac{\rho_{aB}}{(\mathrm{MPC})^{T.B.}_{aB}} + \frac{\rho_{wB}}{(\mathrm{MPC})^{T.B.}_{wB}} + \frac{\rho_{aC}}{(\mathrm{MPC})^{T.B.}_{aC}} + \frac{\rho_{wC}}{(\mathrm{MPC})^{T.B.}_{wC}} + \frac{R^{T.B.}_\gamma}{L^{T.B.}} =$$

$$0.02 + 0.015 + 0.04 + 0.013 + 0.1 + 0.2 + 0.65 = 1.038$$

and thus the calculation indicates that the mixture is slightly, though not significantly, in excess of the permissible limit for total body.

If the γ-source is removed, the dose rate to the bone becomes $0.48 \times 0.56 = 0.27$ rem/week while the dose rate to the total body is $0.39 \times 0.1 = 0.039$ rem/week. These dose rates are 48 per cent and 39 per cent of the corresponding limits, and thus the bone is now the critical organ. In this situation any or all of the concentrations could be increased by as much as a factor of 2 without exceeding the permissible limits.

9. *Modifications required for other applications.* The MPC values listed in Table 1 are intended primarily for occupational exposure and for the indicated types of exposure. Nevertheless, they are frequently used for a variety of other purposes. In most cases the conditions of exposure will not strictly conform to the conditions assumed for the calculation of these values. Thus great care and judgment should be used to insure that the departure from the conditions of occupational exposure assumed here are not so great as to completely invalidate the use of these values; some of the more common discrepancies that may often lead to large inaccuracies are mentioned.

A 50 year exposure period is assumed here and the exposure level is assumed to be constant. Thus a transient situation, e.g. fallout shortly after a nuclear detonation or a major reactor accident where the level of activity is rapidly decreasing, and even the relative abundance of the different radionuclides may be changing, presents a hazard widely different from the constant level 50 year occupational exposure which is assumed. The measure of discrepancy is here so large that to attempt to correct for it amounts to a new calculation.

The $(MPC)_w$ values listed here may be applied to foods, but to use the $(MPC)_w$ for the 168 hr week without correction amounts to assuming that 2200 g of the individual's food, i.e. substantially all his food, is contaminated at this level and that this situation will persist for 50 years, or until equilibrium is reached in the body. Obviously, a correction factor to take account of the intake is needed, but to naïvely use the ratio of 2200 g to the gram intake of a particular food, e.g. butter, per day as correction factor amounts to assuming no other foods or beverages are contaminated. Again, the total situation must be considered and great judgment must be used in making such corrections.

Frequently the MPC values are used to obtain estimates of dose from large single intakes of a radionuclide. In many cases this is warranted, but there may well be many cases where the distribution in the body following an acute exposure to the nuclide is markedly different from the distribution pattern reached following chronic, low-level exposure. For example, many nuclides concentrate in bone with a long biological half-life which leads to a large bone burden of the nuclide after many years of exposure. Then the bone is the critical organ, although the fraction of the daily intake reaching the bone may be much smaller than that passing through the GI tract. For an acute single dose the GI tract may be the critical organ.

Many other factors may have a large effect in determining the proper value for a maximum permissible limit. The relative abundance or scarcity in the diet of other nuclides with similar chemical properties, the wide range of physiological differences as well as differences in habits, age and sex, and the chemical form of the radionuclide or the size of the particle to which it is attached, may account for large changes in the value of the MPC in some cases. Many of these factors as well as others are being carefully studied at the present time, and we may expect that our knowledge of their influence on the permissible levels will be more precise. In the present state of our knowledge, the modification or adaption of the values listed here for application to other situations than those specified by the exposure categories of the basic rules requires the careful consideration and mature judgment of competent experts in this field.

V. FACTORS NEEDED FOR CALCULATION OF MPC EQUATIONS

1. Effective energy. The effective energy term used in the formulas for calculating the values listed in Table 1 takes various forms as needed for the particular problem, i.e. $\Sigma E(\text{RBE})$, $\Sigma E(\text{RBE})n$, $\Sigma EF(\text{RBE})n$, and sometimes simply ΣE. In these equations E is the total energy absorbed in the body organ per disintegration of the radionuclide. In these cases, all of the energy absorbed in the tissue in the process of radioactive decay (i.e. X, γ, α, β^-, β^+, e^- and atomic recoils) was included in the effective energy term with exception of the neutrino energy which is assumed to escape from the body. For β-radiation it was assumed that all the energy of each β is dissipated in the critical body organ. Except for very small organs this is justified since it is generally the maximum dose that is of interest. Various methods have been developed for determining the distribution of β-ray energies and for finding the effective energy, but all are tedious and time consuming and a relatively simple empirical equation that gives results that are in most cases accurate within about 5 per cent was found.[27]

For β^--radiation the equation is

$$E = 0.33\, E_m f\left(1 - \frac{Z^{\frac{1}{2}}}{50}\right)\left(1 + \frac{E_m^{\frac{1}{2}}}{4}\right), \tag{25}$$

in which

Z = atomic number of the radionuclide emitting the β-ray;
f = fraction of the disintegrations of the type considered;
E_m = maximum energy (MeV) of the type considered.

For β^+-radiation the equation is,

$$E = 0.33\, E_m f\left(1 + \frac{E_m^{\frac{1}{2}}}{4}\right) + 2f\,(0.51)\,(1 - e^{-\sigma x}) \tag{26}$$

where

x = effective radius (cm) of the body organ containing the radionuclide (values are given in Table 8);
σ = total coefficient of absorption minus Compton scattering coefficient in cm^{-1} for the given photon energy;
2(0.51) arises from the energy of two 0.51 MeV gammas resulting from the annihilation process.

For other types of radiation, the following equations were used:

For γ-radiation $$E = E_m f\,(1 - e^{-\sigma x}) \tag{27}$$

For α-radiation $$E = E_m f \tag{28}$$

with E_m as the energy of the photon or α-particle.

For internal conversion, e^-

$$E = f\left[(E_\gamma - \eta)\left(\frac{\alpha_K}{1+\alpha_K}\right) + (\eta)\left(\frac{\alpha_K}{1+\alpha_K}\right)(1 - e^{-\sigma x}) + E_\gamma\left(\frac{1 - e^{-\sigma x}}{1+\alpha_K}\right)\right] \tag{29}$$

where

α_K = internal conversion coefficient for the K shell, etc.;
η = binding energy of the daughter element;
E_γ = γ-energy (MeV) of type considered.

For K and L capture X-radiation, the simplification is made that

$$E = f\eta(1 - e^{-\sigma x}) \tag{30}$$

For atomic recoils following α-emission

$$E = f\frac{(\text{energy of } \alpha\text{-particle})\ (\text{mass of } \alpha\text{-particle})}{\text{mass of recoiling daughter nucleus}} \tag{31}$$

RBE = relative biological effectiveness of the radiation; RBE is taken as 1 for β^--, β^+-, γ- and X-radiation and conversion electrons (it is set equal to 1.7 if the maximum energy $E_m \leqslant 0.03$ MeV for β^-, β^+ or e^-), 10 for α-particles, and 20 for recoil atoms;

n = relative damage factor for radionuclides deposited in the bone. The relative damage factor, n, is defined in basic rule (b) and, a detailed discussion of its use, with examples, is given in Section IV.2;

F_i = the ratio at time t of the number of disintegrations per unit time of daughter atoms to the number of disintegrations per unit time of parent atoms in the critical organ. It is a factor that can be multiplied by the energy of the ith daughter so that it may be added to the energy of the other daughters and of the parent in order to obtain the weighted energy of a chain of radionuclides which is equivalent to that absorbed in the critical body organ by a single radionuclide. For the ith daughter,

$$F_i = \frac{\prod_{j=1}^{i} T_j/T_j^r}{1 - e^{-\lambda_0 t}} \sum_{n=0}^{i} \frac{T_n^i\,(1 - e^{-\lambda_n t})}{\prod_{\substack{p=0\\ p\neq n}}^{i} (T_n - T_p)} \tag{32}$$

in which

λ_0 = total decay coefficient of the parent ($= 0.693/T_0$); the subscript, zero, refers to the parent isotope;
λ_i = total decay coefficient of the ith daughter;
T_i = total half-life of the ith daughter;
T_i^r = radioactive half-life of the ith daughter;
t = occupational exposure time (50 years).

In order to explain the meaning of the notation in the previous equations, equation (32) is expanded. For the parent $F_0 = 1$, for the first daughter

$$F_1 = \frac{T_1/T_1^r}{1 - e^{-\lambda_0 t}}\left[(1 - e^{-\lambda_0 t})\frac{T_0}{T_0 - T_1} + (1 - e^{-\lambda_1 t})\frac{T_1}{T_1 - T_0}\right] \tag{33}$$

and for the second daughter,

$$F_2 = \frac{T_1\,T_2/T_1^r\,T_2^r}{1 - e^{-\lambda_0 t}}\left[\frac{(1 - e^{-\lambda_0 t})\,T_0^2}{(T_0 - T_1)\,(T_0 - T_2)} + \frac{(1 - e^{-\lambda_1 t})\,T_1^2}{(T_1 - T_0)\,(T_1 - T_2)} + \frac{(1 - e^{-\lambda_2 t})\,T_2^2}{(T_2 - T_0)\,(T_2 - T_1)}\right] \tag{34}$$

etc., for all daughters of the chain. The appearance of these factors in the MPC equations is discussed in Section IV.4. In the case of radium isotopes which are daughters of a thorium isotope, recent experimental work has indicated that the radium daughter behaves as though it is absorbed into the blood. In these cases the factor f'_2 for radium was included in the formula for F_1, F_2, etc.

The effective energy can be found by simply summing the component terms of $\Sigma\, EF(\mathrm{RBE})n$,

$$\Sigma\, EF(\mathrm{RBE})n = \Sigma_i F_i \Big[(\mathrm{RBE})_j f^i_j E^i_j + (\mathrm{RBE})_k f^i_k E^i_k n^i_k + (\mathrm{RBE})_s f^i_s E^i_s n^i_s + (\mathrm{RBE})_m f^i_m E^i_m n^i_m + (\mathrm{RBE})_v f^i_v E^i_v n^i_v + (\mathrm{RBE})_p f^i_p E^i_p + (\mathrm{RBE})_r f^i_r E^i_r n^i_r\Big] \quad (35)$$

where the subscripts j, k, s, m, v, p and r refer to γ, negatron, positron, α, internal conversion, electron capture, and α-recoil, respectively. The RBE of these radiations is specified above.

Effective energies[28] used for making the permissible exposure calculations of Table 1 are given in Tables 5 and 5(a). In Table 5(a) all the daughter nuclides are listed individually following the parent nuclide. The detailed listing is necessary here because the formulas for the GI tract require individual energies for each daughter nuclide. Also, the F_i factors necessitate separate listings for the entire chain, so that with the complete data as given, values for MPC and body burden for any mixture of parent and daughter radionuclides can be calculated easily.

2. *Standard man data.* In order that all MPC values be calculated on a common biological basis the so-called "standard man" or "average man" was defined.[29, 30] The first committee values were stipulated at the Chalk River Conference,[9] but later modified at the Sixth International Congress of Radiology,[31] the Harriman Conference on Permissible Dose,[32] and the Seventh International Congress of Radiology.[33] The values for the GI tract[34] (Table 11) and the chemical composition of the individual organs (Table 7) are further additions to the standard man. In Table 12 a few references have been listed, but it must be emphasized that these are only a few of those which were consulted. For a detailed study the reader should consult the references cited in *Bibliography for Biological Data** and the references listed below.[35–39]

3. *Other biological and related physical terms.* Other relevant biological and related physical terms that were used in the preparation of Table 1 appear in Table 12. For each element and radionuclide, the many distribution fractions, the concentration in the critical organs, the biological half-lives, etc., were gleaned from a voluminous amount of experimental data: data which, though great in mass, yielded in many cases a sparse amount of information concerning the specific quantities needed. Ideally, to establish satisfactory MPC values for occupational exposure, data are needed of lifetime exposure of humans to each of the radionuclides. However, not only are such data almost non-existent for man (see Section III for detailed

* *Health Physics*, Vol. 2, No. 3, 1959.

discussion) but they are extremely scarce for animals. As stated earlier, many of the biological factors used for the continuous exposure calculations of Table 1 were not obtained directly from continuous exposure animal data but of necessity were taken from single exposure data. Exploratory experiments(40) have indicated that extrapolation from single dose studies to the situation corresponding to continuous exposure is fairly satisfactory, if the single exposure data of retention in the critical body organ yield a curve having a long straight portion when plotted as a function of time on semilogarithmic paper. In general, the radionuclide does not seem to be uniformly bound in an organ and the retention curve is represented as a sum of exponentials. The component of longest half-life is generally the most significant for the long-term exposure case, and this is obtained by extrapolating back to time $t = 0$ the straight portion mentioned above. It sometimes happens that no data—not even data from single exposure of animals—are available for an element. When this is the case, it may be possible to obtain some of the desired information by assuming the existence of an equilibrium condition between the stable isotopes of the element in the critical body organ and in the food, water and air taken into the body from the environment,(10) i.e. set the amount ingested and deposited in the critical organ per day equal to the amount eliminated from it per day. For other cases where experimental data are not found, direct comparisons sometimes are made with elements that are chemically similar. Many equations and approximations—some of which are listed in this section—were used to check and cross-check the values given in these tables.

(a) I = average daily ingestion of an element (g/day).

(b) f_1 = fraction of the radionuclide passing from GI tract to blood.

(c) C = average concentration of the element in the critical organ (grams of element per gram of wet tissue).

(d) f_2' = fraction of the radionuclide passing from blood to critical body organ; in some cases this is chosen to represent only the component of longest biological half-life as mentioned above.

(e) f_2 = fraction of the radionuclide in the critical organ of that in total body. This fraction is required in the calculation of the maximum permissible body burden, q. The fraction f_2 is unusually difficult to find from limited experimental data, so it is fortunate that f_2 is not required for the calculation of MPC values. Various methods employing more easily measured fractions are often utilized for arriving at f_2; they are enumerated as follows:

(i) Under conditions of continuous exposure where equilibrium has been reached

$$f_2^x = \frac{q^x}{q^x+q^y+q^z+\ldots} = \frac{q^x}{q} \quad (36)$$

in which the superscripts x, y, z, etc., refer to different body organs, e.g. $q^x = \mu c$ in organ x, $q^y = \mu c$ in organ y, etc., and $q = \mu c$ in total body.

(ii) In cases where f_w and T can be found from single exposure data, f_2 can be determined by

$$f_2^x = \frac{T^x f_w^x}{T^x f_w^x + T^y f_w^y + T^z f_w^z + \ldots} \tag{37}$$

Sometimes when a long time has elapsed since the radionuclide was administered as a single exposure the biological half-lives for the various organs become approximately equal. In such cases

$$f_2^x = \frac{f_w^x}{f_w^x + f_w^y + f_w^z + \ldots} \tag{38}$$

(iii) For intravenous single exposure data equation (38) can be used by setting $f_w^x = f_1 f_2'^x$, $f_w^y = f_1 f_2'^y$ etc. Then,

$$f_2^x = \frac{f_2'^x}{f_2'^x + f_2'^y + f_2'^z + \ldots} \tag{39}$$

Equations (38) and (39) also apply in all cases where $T_r \ll T_b$ for organs x, y, z, etc.

(iv) For single exposure data

$$f_2^x = \frac{T^x f_w^x}{T^t(f_1 - f_w^u)} = \frac{T^x f_w^x}{T^t(f_w^x + f_w^y + f_w^z + \ldots)} = \frac{T^x f_2'^x}{T^t(f_2'^x + f_2'^y + f_2'^z \ldots)} \tag{40}$$

in which the superscript, t, refers to total body and f_w^u = fraction of that ingested that goes rapidly to the urine. Where data are not available for f_w^u, the following approximations may be used;

$$f_2^x \geqslant \frac{T^x f_w^x}{T^t f_1} \tag{41}$$

$$f_2^x \geqslant \frac{T^x f_a^x}{T^t f_a^t} \tag{42}$$

(v) In the case of stable isotopes or radionuclides, where $T_r \gg T_b$,

$$f_2^x = \frac{m^x C^x}{m^t C^t}$$

Equations (37), (41) and (42) can be modified for this case so that

$$f_2^x = \frac{T_b^x f_w^x}{T_b^x f_w^x + T_b^y f_w^y + T_b^z f_w^z \ldots} \tag{43}$$

and

$$f_2^x = \frac{T_b^x f_w^x}{T_b^t f_1} \tag{44}$$

$$f_2^x = \frac{T_b^x f_a^x}{T_b^t f_a^t} \tag{45}$$

(f) f_a = fraction of that taken into the body by inhalation that arrives in the critical organ. For soluble material

$$f_a = (0.25 + 0.5 f_1) f_2' \tag{46}$$

When the fraction f_2', is unknown, it is replaced by f_2. It is sometimes convenient to write f_a in the form $f_a = (0.5 + 0.25/f_1) f_w$. MPC values are given in Table 1 for inhalation of insoluble and slightly soluble materials and in these cases a portion of the GI tract or the lung is usually the critical organ. Unless data are available for the inhalation of specific radioactive, insoluble dust particles, it is assumed in the case of the lungs that $f_a = 0.12$. Some of the inhaled radioactive material is swallowed, so that it irradiates the GI tract. In the case in which a portion of the GI tract is the critical tissue, the value of f_a is given by the equation, $f_a = 0.62$ for insoluble material and $f_a = 0.5$ for soluble.

(g) f_w = fraction of that taken into the body by ingestion that is retained in the critical organ. For ingestion of soluble compounds

$$f_w = f_1 f_2' \tag{47}$$

f_2 is sometimes used instead of f_2' if no better information is available. For ingestion of insoluble compounds a portion of the GI tract is the critical tissue.

(h) T_b = biological half-life or the time required for half of the element or radionuclide to be eliminated by biological processes. When T_b cannot be found from experimental data for a particular radionuclide, the assumption is made that the radionuclide has the same biological elimination time as the stable element. Assuming the existence of an equilibrium condition between the stable element in the food and water and the stable element in the critical body organ, the grams eliminated per day may be set equal to the grams deposited per day. It follows then that for a stable element

$$T_b = \frac{0.693\, m\, C}{I f_w} \tag{48}$$

In the above equation f_w may be replaced by f_a if inhalation rather than ingestion is responsible for the deposition of the stable element in the body. For insoluble material in the lungs, T_b is taken as 120 days for all radionuclides except plutonium and thorium, in which case $T_b =$ 1 year and $T_b = 4$ years, respectively, were used.

(i) $T_r =$ radioactive half-life.

(j) $T =$ effective half-life. Because by definition the total decay coefficient is equal to the sum of the biological and physical decay coefficients, i.e. $\lambda = \lambda_r + \lambda_b$,

$$T = \frac{T_b\, T_r}{T_b + T_r} \tag{49}$$

For a radionuclide equation (48) becomes

$$T = \frac{0.693\, m\, C}{I f_w} \tag{50}$$

in which $C =$ grams of radionuclide per gram of organ. If $T_r \gg T_b$, C for the stable element is approximately equal to C for the radioelement.

As explained previously, single exposure data can be used satisfactorily to find biological constants for chronic exposure if the retention data plotted on a semi-logarithmic graph as a function of time of exposure yield a curve with a long straight portion following the initial rapid elimination. If the data are not corrected for radioactive decay, the effective half-life in such cases is related to the ordinate b of the curve, taken at the beginning of the straight portion and ordinate c taken at some later time by the expression

$$T = \frac{0.693\, t}{\ln b/c} \tag{51}$$

in which $t =$ time interval between b and c

In any two organs x and y,

$$\frac{f_2^x}{f_2^y} = \frac{m^x\, C^x}{m^y\, C^y} \tag{52}$$

and,

$$\frac{T^x}{T^y} = \frac{f_2^x f_w^x}{f_2\, f_w^y} \tag{53}$$

As indicated earlier, the critical body organ is that organ receiving the radionuclide that results in the greatest body damage. However, in most cases it is the body organ that accumulates the greatest concentration of the radionuclide. Having selected the critical body organ, it is useful to make a check to determine whether or not this organ has an above average concentration. If the concentration in organ x is greater than the average concentration in the rest of the body

$$\frac{m(1 - f_2^x)}{(70{,}000 - m) f_2^x} \leqslant 1 \qquad (54)$$

APPENDIX

Concentrations in air and in water based on a power function model. Although the formulas used to calculate the maximum permissible concentrations assume that the biological elimination follows a simple exponential function, i.e. the fraction of organ burden eliminated per day is constant, cognizance is taken of the fact that many data[41] support the view that the fraction of the body burden excreted per day varies inversely with the time and could best be represented by a power function. Following a single injection of certain bone-seeking radionuclides, the body burden has been expressed by

$$R(t) = A\, t^{-n} \qquad t \geqq 1 \qquad (55)$$

where $R(t)$ = fractional retention t days after injection;
A = normalized fraction of injected dose retained at end of unit time;
n = a constant.

Ingested or inhaled material may not be retained to the same degree, therefore a factor, f_1, should be included to designate the fraction of ingested radionuclide which reaches the blood stream. If the radionuclide is long-lived so that radioactive decay can be neglected, then the body burden after an amount, a, has been ingested per day for T days is given by

$$q = A\, a f_1 \int_0^T (T - \tau)^{-n}\, d\tau = \frac{A\, a f_1}{1 - n} T^{1-n}\ \mu c \qquad (56)$$

This equation assumes n is not close to 1. Otherwise the integration should extend from 1 day to T days and the contribution of the first day added. In terms of the previous notation $a = P/f_w = 750$ M $= 750\,(\mathrm{MPC})_w$ for ingestion or $a = P/f_a = 6.9 \times 10^6\ (\mathrm{MPC})_a$ for inhalation, and T is the period of occupational exposure which is set at 50 years for the values recorded in Table 1.

If the radioactive half-life of the radionuclide is of the same order as T, it may be taken into account also. If the body burden following a single intravenous injection, $R(t)$, is a power function, the fraction eliminated per day is given by

$$\frac{dR}{dt}/R = -\frac{n}{t} \qquad (57)$$

which represents only the biological elimination of the radionuclide because experiments determining the best values for A and n are generally of short duration as compared to the radioactive half-life of the radionuclides here considered (Sr, Ra, Pu and U); thus, including radioactive decay

$$dR/dt = -\frac{n}{t} R(t) - \lambda^r R(t) \tag{58}$$

where λ^r is the radioactive decay constant of the radionuclide in days.

The integral of this equation with $R(1) = A$ readily is found to be

$$R(t) = A\, t^{-n}\, e^{-\lambda^r(t-1)} \quad t > 1 \tag{59}$$

Hence, if the radionuclide is undergoing appreciable radioactive decay while it is being eliminated from the body according to a power function, the body burden under the same conditions as before is given by

$$q = a\, A f_1 \int_0^T (T-\tau)^{-n}\, e^{-\lambda^r(T-\tau-1)} = a\, A f_1 \int_0^T u^{-n}\, e^{-\lambda^r(u-1)}\, du \ \mu c \tag{60}$$

or

$$(\mathrm{MPC})_a = \frac{q}{6.9 \times 10^6\, A f_1 \int_0^T u^{-n}\, e^{-\lambda^r(u-1)}\, du}\ \mu c/\mathrm{cm}^3 \tag{61}$$

and

$$(\mathrm{MPC})_w = \frac{q}{750\, A f_1 \int_0^T u^{-n}\, e^{-\lambda^r(u-1)}\, du}\ \mu c/\mathrm{cm}^3 \tag{62}$$

This integral may be evaluated with the help of a table of the incomplete γ-function.(42)

In case the radionuclide has daughters which must be taken into account, the power function estimate of elimination still may be applied. In principle, the daughter elements might be eliminated at rates quite different from those of the parent, i.e. the constant n may be different for different elements of the chain. In such cases the value of n would vary from element to element in the chain. The formulas for this case would be similar to those given above.

For example, in the case of Ra^{228} it seems desirable to consider the elements of a chain. Because all these elements are held very tenaciously in the body, the daughter elements with radioactive half-lives of a few hours or days may be considered to decay immediately and thus only the case of a chain of two radionuclides is discussed. Also the same value of n is assumed for each of these radionuclides.

Letting $R_0(t)$ and $R_1(t)$ denote the body burden (μc) of the parent and the daughter radionuclide, respectively, at time t days following injection of 1 μc of the parent, the differential equations governing the changes with time are:

$$\frac{dR_0}{dt} = \frac{-n}{t} R_0(t) - \lambda_0^r R_0(t) \tag{63}$$

$$\frac{dR_1}{dt} = \frac{-n}{t} R_1(t) - \lambda_1^r R_1(t) + \lambda_1^r R_0(t) \tag{64}$$

The solution which gives an amount A for the parent and 0 for the daughters at $t = 1$ is given by,

$$R_0(t) = A\, t^{-n}\, e^{-\lambda_0^r (t-1)} \tag{65}$$

$$R_1(t) = \frac{A\, \lambda_1^r\, t^{-n}}{\lambda_1^r - \lambda_0^r}\left[e^{-\lambda_0^r (t-1)} - e^{-\lambda_1^r (t-1)}\right] \tag{66}$$

Except for the presence of the factor $A\, t^{-n}$ these equations are identical with the expanded form of equation (9). This solution is valid only if $n \; 1 \ll$ but this is true in all the practical cases considered here. The choice of the solution where $R_0(1) = A$ and $R_1(1) = 0$ neglects the formation of the daughter radionuclides during the first day. Because it is only applied here to radionuclides of rather long radioactive half-life, and because the power function does not represent adequately the behavior of the radionuclide for short periods of time after injection, this neglect seems justified.

If an amount, a μc, enters the blood per day during a period of T days, the body burden of the ith isotope at the end of T days is given by

$$a \int_0^T R_i(T - t)\, dt \tag{67}$$

and this leads to an incomplete γ-function which may be evaluated as before. From these estimates of body burden, the $(\mathrm{MPC})_a$ and $(\mathrm{MPC})_w$ can be estimated by the method used in deriving equations (61) and (62).

At present the use of a power function is possible in only a few cases. There is some indication that it does not represent precisely the true situation since the exponent n has been found to vary with time.[43] However, for the radionuclides with long physical half-lives, the power function does seem to represent adequately the available long-term data. Unfortunately, its metabolic significance remains unexplained, and it does not seem desirable to extrapolate an empirical formula far beyond the range where it has been verified experimentally. For comparison, MPC values have been computed both according to the exponential model and the power law for the radionuclides of Sr, Ra, Pu and U which have an effective half-life exceeding 20 days. In these cases, the Committee has considered the MPC values obtained both by the power function as well as by the exponential method in selecting the values listed in Table 1. The values of the constants considered and the MPC values obtained in the case of the more important isotopes of these four elements are listed in Table *B*. These values were selected by a Subcommittee on the Power Function.*

Table B. MPC values as calculated by the power function model
(168 hr/week)

Radionuclides and retention constants	$(MPC)_w$ ($\mu c/cm^3$)	$(MPC)_a$ ($\mu c/cm^3$)	Critical organ
Strontium			
$A = 0.65$, $n = 0.35$			
Sr^{85}	6×10^{-3}	5×10^{-7}	Bone
Sr^{89}	4×10^{-4}	4×10^{-8}	Bone
Sr^{90}	8×10^{-6}	7×10^{-10}	Bone
Strontium			
$A = 0.95$, $n = 0.25$			
Sr^{85}	3×10^{-3}	2×10^{-7}	Bone
Sr^{89}	2×10^{-4}	2×10^{-8}	Bone
Sr^{90}	6×10^{-6}	5×10^{-10}	Bone
Radium			
$A = 0.54$, $n = 0.52$			
Ra^{226}	1×10^{-6}	1×10^{-10}	Bone
Ra^{228}	2×10^{-6}	1×10^{-10}	Bone
Uranium			
$A = 0.72$, $n = 0.80$			
U^{238}	8×10^{-4}	4×10^{-11}	Kidney
U–nat	8×10^{-4}	4×10^{-11}	Kidney
Plutonium			
$A = 0.99$, $n = 0.01$			
Pu^{238}	5×10^{-5}	6×10^{-13}	Bone
Pu^{239}	4×10^{-5}	5×10^{-13}	Bone
Pu^{240}	4×10^{-5}	5×10^{-13}	Bone
Pu^{241}	2×10^{-3}	3×10^{-11}	Bone
Pu^{242}	5×10^{-5}	6×10^{-13}	Bone

In the cases considered, the power function method seems to yield a higher estimate of the MPC values than does the exponential method. Since, in principle, the retention data can be fitted with a multiple exponential curve, this undoubtedly is in large part due to conservatism in assigning a long biological half-life and a rather large value to the fraction of material in the blood that has the long half-life, i.e. to f_2'. While the MPC values listed in the accompanying table were considered by the

* The data in Table *B* were developed and agreed upon by a special subcommittee which was organized to evaluate the application of the power function in obtaining MPC values. The members were: W. H. Langham, Chairman, E. C. Anderson, P. Harris, J. W. Healy, W. P. Norris and W. S. Snyder.

Committee in making their final decision, they are not to be considered as recommended values. They are listed to indicate that the Committee has considered carefully this method of estimation and to stimulate research concerning the interpretation and validity of this model. The presentation of the biological data in Table 12 on the basis of the exponential model is in large part dictated by the desire to give a unified and economical presentation of the material.

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18. See references Br–44 and No–7.
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20. See references Bv–1, Ln–22 and Lr–5.
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43. See reference War–2.

Table 1. Maximum permissible body burdens and maximum permissible concentrations of radionuclides in air and in water for occupational exposure

Radionuclide and type of decay	Organ of reference* (critical organ **bold face**)	Maximum permissible burden in total body q(μc)	Maximum permissible concentrations: For 40 hr week $(MPC)_w$ ($\mu c/cm^3$)	For 40 hr week $(MPC)_a$ ($\mu c/cm^3$)	For 168 hr week $(MPC)_w$ ($\mu c/cm^3$)	For 168 hr week $(MPC)_a$ ($\mu c/cm^3$)
$_1H^3$(HTO or H_2^3O) β^- [(sol.)	**Body tissue**	10^3	**0.1**	**5×10^{-6}**	**0.03**	**2×10^{-6}**
	Total body	2×10^3	0.2	8×10^{-6}	0.05	3×10^{-6}
(H_2^3) (submersion)	**Skin**			**2×10^{-3}**		**4×10^{-4}**
$_4Be^7$ (sol.) ϵ, γ	**GI (LLI)**		**0.05**	10^{-5}	**0.02**	4×10^{-6}
	Total body	600	6	**6×10^{-6}**	2	**2×10^{-6}**
	Kidney	800	9	8×10^{-6}	3	3×10^{-6}
	Liver	800	9	8×10^{-6}	3	3×10^{-6}
	Bone	2×10^3	20	2×10^{-5}	7	6×10^{-6}
	Spleen	4×10^3	50	4×10^{-5}	20	2×10^{-5}
(insol.)	**Lung**			**10^{-6}**		**4×10^{-7}**
	GI (LLI)		**0.05**	9×10^{-6}	**0.02**	3×10^{-6}
$_6C^{14}(CO_2)$ (sol.) β^-	**Fat**	300	**0.02**	**4×10^{-6}**	**8×10^{-3}**	**10^{-6}**
	Total body	400	0.03	5×10^{-6}	0.01	2×10^{-6}
	Bone	400	0.04	6×10^{-6}	0.01	2×10^{-6}
(submersion)	**Total body**			**5×10^{-5}**		**10^{-5}**
$_9F^{18}$ (sol.) β^+	**GI (SI)**		**0.02**	**5×10^{-6}**	**8×10^{-3}**	**2×10^{-6}**
	Bone and teeth	20	0.2	3×10^{-5}	0.06	9×10^{-6}
	Total body	20	0.3	4×10^{-5}	0.09	10^{-5}
(insol.)	**GI (ULI)**		**0.01**	**3×10^{-6}**	**5×10^{-3}**	**9×10^{-7}**
	Lung			2×10^{-5}		6×10^{-6}
$_{11}Na^{22}$ (sol.) β^+, γ	**Total body**	10	**10^{-3}**	**2×10^{-7}**	**4×10^{-4}**	**6×10^{-8}**
	GI (LLI)		0.01	2×10^{-6}	3×10^{-3}	7×10^{-7}
(insol.)	**Lung**			**9×10^{-9}**		**3×10^{-9}**
	GI (LLI)		**9×10^{-4}**	2×10^{-7}	**3×10^{-4}**	5×10^{-8}
$_{11}Na^{24}$ (sol.) β^-, γ	**GI (SI)**		**6×10^{-3}**	**10^{-6}**	**2×10^{-3}**	**4×10^{-7}**
	Total body	7	0.01	2×10^{-6}	4×10^{-3}	6×10^{-7}
(insol.)	**GI (LLI)**		**8×10^{-4}**	**10^{-7}**	**3×10^{-4}**	**5×10^{-8}**
	Lung			8×10^{-7}		3×10^{-7}

* The abbreviations GI, S, SI, ULI and LLI refer to gastrointestinal tract, stomach, small intestine, upper large intestine, and lower large intestine, respectively.

Radionuclide and type of decay		Organ of reference (critical organ **bold face**)	Maximum permissible burden in total body $q(\mu c)$	Maximum permissible concentrations: For 40 hr week $(MPC)_w$ $(\mu c/cm^3)$	For 40 hr week $(MPC)_a$ $(\mu c/cm^3)$	For 168 hr week $(MPC)_w$ $(\mu c/cm^3)$	For 168 hr week $(MPC)_a$ $(\mu c/cm^3)$
$_{14}Si^{31}$	(sol.)	**GI (S)**		**0.03**	**6×10^{-6}**	**9×10^{-3}**	**2×10^{-6}**
β^-, γ		Lung	10	0.1	2×10^{-5}	0.05	7×10^{-6}
		Adrenal	30	0.3	4×10^{-5}	0.1	10^{-5}
		Total body	30	0.3	4×10^{-5}	0.1	2×10^{-5}
		Testis	40	0.4	5×10^{-5}	0.1	2×10^{-5}
		Ovary	60	0.6	8×10^{-5}	0.2	3×10^{-5}
		Skin	100	1	2×10^{-4}	0.5	7×10^{-5}
	(insol.)	**GI (ULI)**		**6×10^{-3}**	**10^{-6}**	**2×10^{-3}**	**3×10^{-7}**
		Lung			10^{-5}		4×10^{-6}
$_{15}P^{32}$	(sol.)	**Bone**	6	**5×10^{-4}**	**7×10^{-8}**	**2×10^{-4}**	**2×10^{-8}**
β^-		Total body	30	3×10^{-3}	4×10^{-7}	9×10^{-4}	10^{-7}
		GI (LLI)		3×10^{-3}	6×10^{-7}	9×10^{-4}	2×10^{-7}
		Liver	50	5×10^{-3}	6×10^{-7}	2×10^{-3}	2×10^{-7}
		Brain	300	0.02	3×10^{-6}	8×10^{-3}	10^{-6}
	(insol.)	**Lung**			**8×10^{-8}**		**3×10^{-8}**
		GI (LLI)		**7×10^{-4}**	10^{-7}	**2×10^{-4}**	4×10^{-8}
$_{16}S^{35}$	(sol.)	**Testis**	90	**2×10^{-3}**	**3×10^{-7}**	**6×10^{-4}**	**9×10^{-8}**
β^-		Total body	400	7×10^{-3}	10^{-6}	3×10^{-3}	4×10^{-7}
		Bone	800	0.02	2×10^{-6}	5×10^{-3}	8×10^{-7}
		Skin	3×10^3	0.07	10^{-5}	0.02	3×10^{-6}
		GI (LLI)		0.2	4×10^{-5}	0.05	10^{-5}
	(insol.)	**Lung**			**3×10^{-7}**		**9×10^{-8}**
		GI (LLI)		**8×10^{-3}**	10^{-6}	**3×10^{-3}**	5×10^{-7}
$_{17}Cl^{36}$	(sol.)	**Total body**	80	**2×10^{-3}**	**4×10^{-7}**	**8×10^{-4}**	**10^{-7}**
β^-		GI (LLI)		0.04	8×10^{-6}	0.01	3×10^{-6}
	(insol.)	**Lung**			**2×10^{-8}**		**8×10^{-9}**
		GI (LLI)		**2×10^{-3}**	3×10^{-7}	**6×10^{-4}**	10^{-7}
$_{17}Cl^{38}$	(sol.)	**GI (S)**		**0.01**	**3×10^{-6}**	**4×10^{-3}**	**9×10^{-7}**
β^-, γ		Total body	9	0.3	4×10^{-5}	0.1	2×10^{-5}
	(insol.)	**GI (S)**		**0.01**	**2×10^{-6}**	**4×10^{-3}**	**7×10^{-7}**
		Lung			10^{-5}		5×10^{-6}
$_{18}A^{37}$ ϵ	(submersion)	**Skin**			**6×10^{-3}**		**10^{-3}**
$_{18}A^{41}$ β^-, γ	(submersion)	**Total body**			**2×10^{-6}**		**4×10^{-7}**

Radionuclide and type of decay	Organ of reference (critical organ **bold face**)	Maximum permissible burden in total body $q(\mu c)$	Maximum permissible concentrations: For 40 hr week $(MPC)_w$ $(\mu c/cm^3)$	For 40 hr week $(MPC)_a$ $(\mu c/cm^3)$	For 168 hr week $(MPC)_w$ $(\mu c/cm^3)$	For 168 hr week $(MPC)_a$ $(\mu c/cm^3)$
$_{19}K^{42}$ (sol.) β^-, γ	**GI (S)**		**9×10^{-3}**	**2×10^{-6}**	**3×10^{-3}**	**7×10^{-7}**
	Total body	10	0.02	3×10^{-6}	8×10^{-3}	10^{-6}
	Brain	20	0.04	6×10^{-6}	0.01	2×10^{-6}
	Spleen	20	0.04	6×10^{-6}	0.01	2×10^{-6}
	Muscle	20	0.04	6×10^{-6}	0.02	2×10^{-6}
	Liver	50	0.08	10^{-5}	0.03	4×10^{-6}
(insol.)	**GI (LLI)**		**6×10^{-4}**	**10^{-7}**	**2×10^{-4}**	**4×10^{-8}**
	Lung			9×10^{-7}		3×10^{-7}
$_{20}Ca^{45}$ (sol.) β^-	**Bone**	30	**3×10^{-4}**	**3×10^{-8}**	**9×10^{-5}**	**10^{-8}**
	Total body	200	2×10^{-3}	3×10^{-7}	7×10^{-4}	9×10^{-8}
	GI (LLI)		0.01	3×10^{-6}	4×10^{-3}	10^{-6}
(insol.)	**Lung**			**10^{-7}**		**4×10^{-8}**
	GI (LLI)		**5×10^{-3}**	9×10^{-7}	**2×10^{-3}**	3×10^{-7}
$_{20}Ca^{47}$ (sol.) β^-, γ	**Bone**	5	**10^{-3}**	**2×10^{-7}**	**5×10^{-4}**	**6×10^{-8}**
	GI (LLI)		2×10^{-3}	5×10^{-7}	8×10^{-4}	2×10^{-7}
	Total body	10	4×10^{-3}	5×10^{-7}	2×10^{-3}	2×10^{-7}
(insol.)	**GI (LLI)**		**10^{-3}**	**2×10^{-7}**	**3×10^{-4}**	**6×10^{-8}**
	Lung			**2×10^{-7}**		**6×10^{-8}**
$_{21}Sc^{46}$ (sol.) β^-, γ	**GI (LLI)**		**10^{-3}**	**2×10^{-7}**	**4×10^{-4}**	**8×10^{-8}**
	Liver	**10**	6	**2×10^{-7}**	2	**8×10^{-8}**
	Kidney	10	6	3×10^{-7}	2	9×10^{-8}
	Total body	20	6	3×10^{-7}	2	10^{-7}
	Bone	60	20	10^{-6}	8	4×10^{-7}
(insol.)	**Lung**			**2×10^{-8}**		**8×10^{-9}**
	GI (LLI)		**10^{-3}**	2×10^{-7}	**4×10^{-4}**	7×10^{-8}
$_{21}Sc^{47}$ (sol.) β^-, γ	**GI (LLI)**		**3×10^{-3}**	**6×10^{-7}**	**9×10^{-4}**	**2×10^{-7}**
	Liver	50	100	6×10^{-6}	50	2×10^{-6}
	Kidney	60	200	8×10^{-6}	60	3×10^{-6}
	Bone	60	200	8×10^{-6}	60	3×10^{-6}
	Total body	80	200	10^{-5}	80	3×10^{-6}
(insol.)	**GI (LLI)**		**3×10^{-3}**	**5×10^{-7}**	**9×10^{-4}**	**2×10^{-7}**
	Lung			10^{-6}		3×10^{-7}
$_{21}Sc^{48}$ (sol.) β^-, γ	**GI (LLI)**		**8×10^{-4}**	**2×10^{-7}**	**3×10^{-4}**	**6×10^{-8}**
	Total body	9	50	2×10^{-6}	20	7×10^{-7}
	Liver	9	50	2×10^{-6}	20	7×10^{-7}
	Kidney	10	80	3×10^{-6}	30	10^{-6}
	Bone	30	200	8×10^{-6}	60	3×10^{-6}

Radionuclide and type of decay	Organ of reference (critical organ **bold face**)	Maximum permissible burden in total body $q(\mu c)$	Maximum permissible concentrations: For 40 hr week $(MPC)_w$ $(\mu c/cm^3)$	For 40 hr week $(MPC)_a$ $(\mu c/cm^3)$	For 168 hr week $(MPC)_w$ $(\mu c/cm^3)$	For 168 hr week $(MPC)_a$ $(\mu c/cm^3)$
(insol.)	**GI (LLI)**		8×10^{-4}	10^{-7}	3×10^{-4}	5×10^{-8}
	Lung			4×10^{-7}		10^{-7}
$_{23}V^{48}$ (sol.) $\beta^+, \epsilon, \gamma$	**GI (LLI)**		9×10^{-4}	2×10^{-7}	3×10^{-4}	6×10^{-8}
	Kidney	8	0.03	3×10^{-7}	0.01	9×10^{-8}
	Total body	10	0.04	4×10^{-7}	0.02	10^{-7}
	Spleen	20	0.06	5×10^{-7}	0.02	2×10^{-7}
	Liver	20	0.09	8×10^{-7}	0.03	3×10^{-7}
	Bone	60	0.2	2×10^{-6}	0.08	7×10^{-7}
(insol.)	**Lung**			6×10^{-8}		2×10^{-8}
	GI (LLI)		8×10^{-4}	10^{-7}	3×10^{-4}	5×10^{-8}
$_{24}Cr^{51}$ (sol.) ϵ, γ	**GI (LLI)**		0.05	10^{-5}	0.02	4×10^{-6}
	Total body	800	6	10^{-5}	2	4×10^{-6}
	Lung	10^3	10	2×10^{-5}	4	8×10^{-6}
	Prostate	2×10^3	20	3×10^{-5}	5	10^{-5}
	Thyroid	4×10^3	30	6×10^{-5}	10	2×10^{-5}
	Kidney	8×10^3	60	10^{-4}	20	4×10^{-5}
(insol.)	**Lung**	60		2×10^{-6}		8×10^{-7}
	GI (LLI)		0.05	8×10^{-6}	0.02	3×10^{-6}
$_{25}Mn^{52}$ (sol.) $\beta^+, \epsilon, \gamma$	**GI (LLI)**		10^{-3}	2×10^{-7}	3×10^{-4}	7×10^{-8}
	Pancreas	5	0.01	4×10^{-7}	4×10^{-3}	2×10^{-7}
	Liver	6	0.01	5×10^{-7}	4×10^{-3}	2×10^{-7}
	Total body	9	0.02	8×10^{-7}	7×10^{-3}	3×10^{-7}
(insol.)	**Lung**			10^{-7}		5×10^{-8}
	GI (LLI)		9×10^{-4}	2×10^{-7}	3×10^{-4}	5×10^{-8}
$_{25}Mn^{54}$ (sol.) ϵ, γ	**GI (LLI)**		4×10^{-3}	8×10^{-7}	10^{-3}	3×10^{-7}
	Liver	20	0.01	4×10^{-7}	4×10^{-3}	10^{-7}
	Total body	40	0.02	8×10^{-7}	8×10^{-3}	3×10^{-7}
	Pancreas	50	0.02	9×10^{-7}	9×10^{-3}	3×10^{-7}
(insol.)	**Lung**			4×10^{-8}		10^{-8}
	GI (LLI)		3×10^{-3}	6×10^{-7}	10^{-3}	2×10^{-7}
$_{25}Mn^{56}$ (sol.) β^-, γ	**GI (LLI)**		4×10^{-3}	8×10^{-7}	10^{-3}	3×10^{-7}
	Pancreas	2	0.2	6×10^{-6}	0.05	2×10^{-6}
	Liver	5	0.4	10^{-5}	0.1	5×10^{-6}
	Total body	10	0.9	3×10^{-5}	0.3	10^{-5}
(insol.)	**GI (LLI)**		3×10^{-3}	5×10^{-7}	10^{-3}	2×10^{-7}
	Lung			5×10^{-6}		2×10^{-6}

Radionuclide and type of decay	Organ of reference (critical organ **bold face**)	Maximum permissible burden in total body $q(\mu c)$	Maximum permissible concentrations: For 40 hr week $(MPC)_w$ $(\mu c/cm^3)$	For 40 hr week $(MPC)_a$ $(\mu c/cm^3)$	For 168 hr week $(MPC)_w$ $(\mu c/cm^3)$	For 168 hr week $(MPC)_a$ $(\mu c/cm^3)$
$_{26}Fe^{55}$ (sol.) ϵ	**Spleen**	10^3	**0.02**	**9×10^{-7}**	**8×10^{-3}**	**3×10^{-7}**
	Liver	2×10^3	0.04	2×10^{-6}	0.01	5×10^{-7}
	Total body	3×10^3	0.06	2×10^{-6}	0.02	8×10^{-7}
	Lung	4×10^3	0.07	3×10^{-6}	0.03	9×10^{-7}
	GI (LLI)		0.08	2×10^{-5}	0.03	6×10^{-6}
	Bone	7×10^3	0.1	5×10^{-6}	0.04	2×10^{-6}
(insol.)	**Lung**			**10^{-6}**		**3×10^{-7}**
	GI (LLI)		**0.07**	10^{-5}	**0.02**	4×10^{-6}
$_{26}Fe^{59}$ (sol.) β^-, γ	**GI (LLI)**		**2×10^{-3}**	4×10^{-7}	**6×10^{-4}**	10^{-7}
	Spleen	20	4×10^{-3}	**10^{-7}**	10^{-3}	**5×10^{-8}**
	Total body	20	5×10^{-3}	2×10^{-7}	2×10^{-3}	7×10^{-8}
	Liver	30	6×10^{-3}	2×10^{-7}	2×10^{-3}	7×10^{-8}
	Lung	100	0.02	8×10^{-7}	7×10^{-3}	3×10^{-7}
	Bone	100	0.03	10^{-6}	0.01	4×10^{-7}
(insol.)	**Lung**			**5×10^{-8}**		**2×10^{-8}**
	GI (LLI)		**2×10^{-3}**	3×10^{-7}	**5×10^{-4}**	9×10^{-8}
$_{27}Co^{57}$ (sol.) ϵ, γ, e^-	**GI (LLI)**		**0.02**	**3×10^{-6}**	**5×10^{-3}**	**10^{-6}**
	Total body	200	0.07	6×10^{-6}	0.03	2×10^{-6}
	Pancreas	700	0.2	2×10^{-5}	0.08	7×10^{-6}
	Liver	10^3	0.4	2×10^{-5}	0.1	6×10^{-6}
	Spleen	2×10^3	0.7	6×10^{-5}	0.2	2×10^{-5}
	Kidney	3×10^3	0.9	8×10^{-5}	0.3	3×10^{-5}
(insol.)	**Lung**			**2×10^{-7}**		**6×10^{-8}**
	GI (LLI)		**0.01**	2×10^{-6}	**4×10^{-3}**	7×10^{-7}
$_{27}Co^{58m}$ (sol.) $\beta^+, \epsilon, \gamma$	**GI (LLI)**		**0.08**	**2×10^{-5}**	**0.03**	**6×10^{-6}**
	Total body	200	2	10^{-4}	0.6	5×10^{-5}
	Pancreas	800	6	5×10^{-4}	2	2×10^{-4}
	Liver	10^3	9	4×10^{-4}	3	10^{-4}
	Spleen	2×10^3	20	10^{-3}	5	4×10^{-4}
	Kidney	3×10^3	20	2×10^{-3}	8	6×10^{-4}
(insol.)	**Lung**			**9×10^{-6}**		**3×10^{-6}**
	GI (LLI)		**0.06**	10^{-5}	**0.02**	4×10^{-6}
$_{27}Co^{58}$ (sol.) β^+, ϵ	**GI (LLI)**		**4×10^{-3}**	**8×10^{-7}**	**10^{-3}**	**3×10^{-7}**
	Total body	30	0.01	10^{-6}	4×10^{-3}	**3×10^{-7}**
	Pancreas	200	0.06	5×10^{-6}	0.02	2×10^{-6}
	Liver	200	0.08	4×10^{-6}	0.03	10^{-6}
	Spleen	400	0.1	10^{-5}	0.05	4×10^{-6}
	Kidney	600	0.2	2×10^{-5}	0.07	6×10^{-6}

Radionuclide and type of decay	Organ of reference (critical organ **bold face**)	Maximum permissible burden in total body $q(\mu c)$	Maximum permissible concentrations: For 40 hr week $(MPC)_w$ $(\mu c/cm^3)$	For 40 hr week $(MPC)_a$ $(\mu c/cm^3)$	For 168 hr week $(MPC)_w$ $(\mu c/cm^3)$	For 168 hr week $(MPC)_a$ $(\mu c/cm^3)$
(insol.)	**Lung**	2.9		**5×10^{-8}**		**2×10^{-8}**
	GI (LLI)		**3×10^{-3}**	5×10^{-7}	**9×10^{-4}**	2×10^{-7}
$_{27}Co^{60}$ (sol.) β^-, γ	**GI (LLI)**		**10^{-3}**	**3×10^{-7}**	**5×10^{-4}**	**10^{-7}**
	Total body	10	4×10^{-3}	4×10^{-7}	10^{-3}	**10^{-7}**
	Pancreas	70	0.02	2×10^{-6}	7×10^{-3}	6×10^{-7}
	Liver	90	0.03	10^{-6}	9×10^{-3}	5×10^{-7}
	Spleen	200	0.05	4×10^{-6}	0.02	2×10^{-6}
	Kidney	200	0.07	6×10^{-6}	0.03	2×10^{-6}
(insol.)	**Lung**	1.2		**9×10^{-9}**		**3×10^{-9}**
	GI (LLI)		**10^{-3}**	2×10^{-7}	**3×10^{-4}**	6×10^{-8}
$_{28}Ni^{59}$ (sol.) ϵ	**Bone**	10^3	**6×10^{-3}**	**5×10^{-7}**	**2×10^{-3}**	**2×10^{-7}**
	Total body	3×10^3	0.01	10^{-6}	4×10^{-3}	3×10^{-7}
	Liver	4×10^3	0.02	10^{-6}	6×10^{-3}	5×10^{-7}
	GI (LLI)		0.08	2×10^{-5}	0.03	6×10^{-6}
(insol.)	**Lung**			**8×10^{-7}**		**3×10^{-7}**
	GI (LLI)		**0.06**	10^{-5}	**0.02**	3×10^{-6}
$_{28}Ni^{63}$ (sol.) β^-	**Bone**	200	**8×10^{-4}**	**6×10^{-8}**	**3×10^{-4}**	**2×10^{-8}**
	Total body	900	4×10^{-3}	4×10^{-7}	2×10^{-3}	10^{-7}
	Liver	10^3	6×10^{-3}	5×10^{-7}	2×10^{-3}	2×10^{-7}
	GI (LLI)		0.03	6×10^{-6}	0.01	2×10^{-6}
(insol.)	**Lung**			**3×10^{-7}**		**10^{-7}**
	GI (LLI)		**0.02**	4×10^{-6}	**7×10^{-3}**	10^{-6}
$_{28}Ni^{65}$ (sol.) β^-, γ	**GI (ULI)**		**4×10^{-3}**	**9×10^{-7}**	**10^{-3}**	**3×10^{-7}**
	Bone	4	0.1	10^{-5}	0.04	3×10^{-6}
	Total body	10	0.4	3×10^{-5}	0.1	10^{-5}
	Liver	20	0.5	4×10^{-5}	0.2	10^{-5}
(insol.)	**GI (ULI)**		**3×10^{-3}**	**5×10^{-7}**	**10^{-3}**	**2×10^{-7}**
	Lung			5×10^{-6}		2×10^{-6}
$_{29}Cu^{64}$ (sol.) $\beta^-, \beta^+, \epsilon$	**GI (LLI)**		**0.01**	**2×10^{-6}**	**3×10^{-3}**	**7×10^{-7}**
	Spleen	10	0.08	6×10^{-6}	0.03	2×10^{-6}
	Kidney	30	0.2	2×10^{-5}	0.07	5×10^{-6}
	Total body	80	0.5	4×10^{-5}	0.2	10^{-5}
	Liver	100	0.6	5×10^{-5}	0.2	2×10^{-5}
	Heart	200	0.9	7×10^{-5}	0.3	3×10^{-5}
	Brain	600	4	3×10^{-4}	1	10^{-4}
(insol.)	**GI (LLI)**		**6×10^{-3}**	**10^{-6}**	**2×10^{-3}**	**4×10^{-7}**
	Lung			7×10^{-6}		3×10^{-6}

Radionuclide and type of decay		Organ of reference (critical organ **bold face**)	Maximum permissible burden in total body $q(\mu c)$	Maximum permissible concentrations: For 40 hr week $(MPC)_w$ $(\mu c/cm^3)$	For 40 hr week $(MPC)_a$ $(\mu c/cm^3)$	For 168 hr week $(MPC)_w$ $(\mu c/cm^3)$	For 168 hr week $(MPC)_a$ $(\mu c/cm^3)$
$_{30}Zn^{65}$ $\beta^-, \epsilon, \gamma$	(sol.)	**Total body**	60	3×10^{-3}	10^{-7}	10^{-3}	4×10^{-8}
		Prostate	70	4×10^{-3}	10^{-7}	10^{-3}	4×10^{-8}
		Liver	80	4×10^{-3}	10^{-7}	10^{-3}	5×10^{-8}
		Kidney	100	6×10^{-3}	2×10^{-7}	2×10^{-3}	7×10^{-8}
		GI (LLI)		6×10^{-3}	10^{-6}	2×10^{-3}	4×10^{-7}
		Pancreas	200	7×10^{-3}	3×10^{-7}	3×10^{-3}	9×10^{-8}
		Muscle	200	0.01	4×10^{-7}	4×10^{-3}	10^{-7}
		Ovary	300	0.01	5×10^{-7}	4×10^{-3}	2×10^{-7}
		Testis	400	0.02	6×10^{-7}	6×10^{-3}	2×10^{-7}
		Bone	700	0.04	10^{-6}	0.01	4×10^{-7}
	(insol.)	**Lung**			6×10^{-8}		2×10^{-8}
		GI (LLI)		5×10^{-3}	9×10^{-7}	2×10^{-3}	3×10^{-7}
$_{30}Zn^{69m}$ γ, e^-, β^-	(sol.)	**GI (LLI)**		2×10^{-3}	4×10^{-7}	7×10^{-4}	2×10^{-7}
		Prostate	0.7	0.01	4×10^{-7}	4×10^{-3}	10^{-7}
		Pancreas	5	0.07	3×10^{-6}	0.02	9×10^{-7}
		Liver	8	0.1	5×10^{-6}	0.05	2×10^{-6}
		Kidney	10	0.2	8×10^{-6}	0.07	3×10^{-6}
		Ovary	10	0.2	8×10^{-6}	0.07	3×10^{-6}
		Total body	30	0.5	2×10^{-5}	0.2	6×10^{-6}
		Testis	30	0.5	2×10^{-5}	0.2	6×10^{-6}
		Bone	40	0.6	2×10^{-5}	0.2	7×10^{-6}
		Muscle	100	2	8×10^{-5}	0.7	3×10^{-5}
	(insol.)	**GI (LLI)**		2×10^{-3}	3×10^{-7}	6×10^{-4}	10^{-7}
		Lung			2×10^{-6}		8×10^{-7}
$_{30}Zn^{69}$ β^-	(sol.)	**GI (S)**		0.05	10^{-5}	0.02	4×10^{-6}
		Prostate	0.8	0.2	7×10^{-6}	0.07	2×10^{-6}
		Pancreas	5	1	5×10^{-5}	0.5	2×10^{-5}
		Liver	10	3	10^{-4}	1	4×10^{-5}
		Ovary	20	4	10^{-4}	1	5×10^{-5}
		Kidney	20	4	2×10^{-4}	2	5×10^{-5}
		Testis	30	9	3×10^{-4}	3	10^{-4}
		Bone	40	10	4×10^{-4}	3	10^{-4}
		Total body	50	10	5×10^{-4}	5	2×10^{-4}
		Muscle	200	60	2×10^{-3}	20	7×10^{-4}
	(insol.)	**GI (S)**		0.05	9×10^{-6}	0.02	3×10^{-6}
		Lung			5×10^{-5}		2×10^{-5}
$_{31}Ga^{72}$ β^-, γ	(sol.)	**GI (LLI)**		10^{-3}	2×10^{-7}	4×10^{-4}	8×10^{-8}
		Liver	5	9	4×10^{-6}	3	10^{-6}
		Total body	10	20	8×10^{-6}	6	3×10^{-6}
		Bone	10	20	10^{-5}	8	3×10^{-6}
		Spleen	10	20	10^{-5}	8	4×10^{-6}

Radionuclide and type of decay	Organ of reference (critical organ **bold face**)	Maximum permissible burden in total body $q(\mu c)$	Maximum permissible concentrations			
			For 40 hr week		For 168 hr week	
			$(MPC)_w$ $(\mu c/cm^3)$	$(MPC)_a$ $(\mu c/cm^3)$	$(MPC)_w$ $(\mu c/cm^3)$	$(MPC)_a$ $(\mu c/cm^3)$
	Kidney	10	20	10^{-5}	8	4×10^{-6}
(insol.)	**GI (LLI)**		**10^{-3}**	**2×10^{-7}**	**4×10^{-4}**	**6×10^{-8}**
	Lung			10^{-6}		4×10^{-7}
$_{32}Ge^{71}$ (sol.) ϵ	**GI (LLI)**		**0.05**	**10^{-5}**	**0.02**	**4×10^{-6}**
	Kidney	100	10	5×10^{-5}	4	2×10^{-5}
	Liver	10^{3}	100	6×10^{-4}	50	2×10^{-4}
	Total body	2×10^{3}	200	9×10^{-4}	70	3×10^{-4}
(insol.)	**Lung**			**6×10^{-6}**		**2×10^{-6}**
	GI (LLI)		**0.05**	8×10^{-6}	**0.02**	3×10^{-6}
$_{33}As^{73}$ (sol.) ϵ, γ	**GI (LLI)**		**0.01**	3×10^{-6}	**5×10^{-3}**	10^{-6}
	Total body	300	0.2	**2×10^{-6}**	0.06	**7×10^{-7}**
	Kidney	600	0.3	4×10^{-6}	0.1	10^{-6}
	Liver	10^{3}	0.5	6×10^{-6}	0.2	2×10^{-6}
(insol.)	**Lung**			**4×10^{-7}**		**10^{-7}**
	GI (LLI)		**0.01**	2×10^{-6}	**5×10^{-3}**	8×10^{-7}
$_{33}As^{74}$ (sol.) β^-, β^+, ϵ, γ	**GI (LLI)**		**2×10^{-3}**	**3×10^{-7}**	**5×10^{-4}**	**10^{-7}**
	Total body	40	0.07	8×10^{-7}	0.02	3×10^{-7}
	Kidney	80	0.1	2×10^{-6}	0.05	6×10^{-7}
	Liver	100	0.2	3×10^{-6}	0.08	10^{-6}
(insol.)	**Lung**			**10^{-7}**		**4×10^{-8}**
	GI (LLI)		**2×10^{-3}**	3×10^{-7}	**5×10^{-4}**	9×10^{-8}
$_{33}As^{76}$ (sol.) β^-, γ	**GI (LLI)**		**6×10^{-4}**	**10^{-7}**	**2×10^{-4}**	**4×10^{-8}**
	Total body	20	0.4	5×10^{-6}	0.1	2×10^{-6}
	Kidney	20	0.6	8×10^{-6}	0.2	3×10^{-6}
	Liver	40	1	10^{-5}	0.4	5×10^{-6}
(insol.)	**GI (LLI)**		**6×10^{-4}**	**10^{-7}**	**2×10^{-4}**	**3×10^{-8}**
	Lung			6×10^{-7}		2×10^{-7}
$_{33}As^{77}$ (sol.) β^-, γ	**GI (LLI)**		**2×10^{-3}**	**5×10^{-7}**	**8×10^{-4}**	**2×10^{-7}**
	Total body	80	2	2×10^{-5}	0.5	7×10^{-6}
	Kidney	100	2	2×10^{-5}	0.7	8×10^{-6}
	Liver	200	4	5×10^{-5}	1	2×10^{-5}
(insol.)	**GI (LLI)**		**2×10^{-3}**	**4×10^{-7}**	**8×10^{-4}**	**10^{-7}**
	Lung			2×10^{-6}		6×10^{-7}
$_{34}Se^{75}$ (sol.) ϵ, γ	**Kidney**	90	**9×10^{-3}**	**10^{-6}**	**3×10^{-3}**	**4×10^{-7}**
	Total body	100	**0.01**	**10^{-6}**	**3×10^{-3}**	**5×10^{-7}**

Radionuclide and type of decay	Organ of reference (critical organ **bold face**)	Maximum permissible burden in total body $q(\mu c)$	Maximum permissible concentrations: For 40 hr week $(MPC)_w$ $(\mu c/cm^3)$	For 40 hr week $(MPC)_a$ $(\mu c/cm^3)$	For 168 hr week $(MPC)_w$ $(\mu c/cm^3)$	For 168 hr week $(MPC)_a$ $(\mu c/cm^3)$
	Liver	100	0.01	2×10^{-6}	4×10^{-3}	5×10^{-7}
	Spleen	200	0.02	3×10^{-6}	8×10^{-3}	10^{-6}
	GI (LLI)		0.07	2×10^{-5}	0.03	6×10^{-6}
(insol.)	**Lung**			**10^{-7}**		**4×10^{-8}**
	GI (LLI)		**8×10^{-3}**	10^{-6}	**3×10^{-3}**	5×10^{-7}
$_{35}Br^{82}$ (sol.) β^-, γ	**Total body**	10	**8×10^{-3}**	**10^{-6}**	**3×10^{-3}**	**4×10^{-7}**
	GI (SI)		**8×10^{-3}**	2×10^{-6}	**3×10^{-3}**	6×10^{-7}
(insol.)	**GI (LLI)**		**10^{-3}**	**2×10^{-7}**	**4×10^{-4}**	**6×10^{-8}**
	Lung			6×10^{-7}		2×10^{-7}
$_{36}Kr^{85m}$ (submersion) β^-, γ	**Total body**			**6×10^{-6}**		**10^{-6}**
$_{36}Kr^{85}$ (submersion) β^-	**Total body**			**10^{-5}**		**3×10^{-6}**
$_{36}Kr^{87}$ (submersion) β^-, γ	**Total body**			**10^{-6}**		**2×10^{-7}**
$_{37}Rb^{86}$ (sol.) β^-, γ	**Total body**	30	**2×10^{-3}**	**3×10^{-7}**	**7×10^{-4}**	**10^{-7}**
	Pancreas	30	**2×10^{-3}**	**3×10^{-7}**	**7×10^{-4}**	**10^{-7}**
	Liver	40	3×10^{-3}	4×10^{-7}	10^{-3}	**10^{-7}**
	Spleen	50	3×10^{-3}	5×10^{-7}	10^{-3}	2×10^{-7}
	Muscle	70	5×10^{-3}	7×10^{-7}	2×10^{-3}	2×10^{-7}
	GI (LLI)		0.01	3×10^{-6}	5×10^{-3}	10^{-6}
(insol.)	**Lung**			**7×10^{-8}**		**2×10^{-8}**
	GI (LLI)		**7×10^{-4}**	10^{-7}	**2×10^{-4}**	4×10^{-8}
$_{37}Rb^{87}$ (sol.) β^-	**Pancreas**	200	**3×10^{-3}**	**5×10^{-7}**	**10^{-3}**	**2×10^{-7}**
	Total body	200	4×10^{-3}	6×10^{-7}	2×10^{-3}	**2×10^{-7}**
	Liver	200	5×10^{-3}	7×10^{-7}	2×10^{-3}	**2×10^{-7}**
	Muscle	400	7×10^{-3}	10^{-6}	2×10^{-3}	4×10^{-7}
	Spleen	400	7×10^{-3}	10^{-6}	2×10^{-3}	4×10^{-7}
	GI (LLI)		0.1	2×10^{-5}	0.03	8×10^{-6}
(insol.)	**Lung**			**7×10^{-8}**		**2×10^{-8}**
	GI (LLI)		**5×10^{-3}**	9×10^{-7}	**2×10^{-3}**	3×10^{-7}
$_{38}Sr^{85m}$ (sol.) ϵ, γ	**GI (SI)**		**0.2**	**4×10^{-5}**	**0.07**	**10^{-5}**
	Total body	50	3	2×10^{-4}	1	8×10^{-5}

Radionuclide and type of decay	Organ of reference (critical organ **bold face**)	Maximum permissible burden in total body $q(\mu c)$	Maximum permissible concentrations: For 40 hr week $(MPC)_w$ $(\mu c/cm^3)$	For 40 hr week $(MPC)_a$ $(\mu c/cm^3)$	For 168 hr week $(MPC)_w$ $(\mu c/cm^3)$	For 168 hr week $(MPC)_a$ $(\mu c/cm^3)$
	Bone	70	5	4×10^{-4}	2	10^{-4}
(insol.)	**GI (SI)** Lung		**0.2**	**3×10^{-5}** 9×10^{-5}	**0.07**	**10^{-5}** 3×10^{-5}
$_{38}Sr^{85}$ (sol.) ϵ, γ	**Total body** Bone GI (LLI)	60 70	**3×10^{-3}** 4×10^{-3} 7×10^{-3}	**2×10^{-7}** 4×10^{-7} 2×10^{-6}	**10^{-3}** 2×10^{-3} 2×10^{-3}	**8×10^{-8}** 10^{-7} 5×10^{-7}
(insol.)	**Lung** **GI (LLI)**		**5×10^{-3}**	**10^{-7}** 9×10^{-7}	**2×10^{-3}**	**4×10^{-8}** 3×10^{-7}
$_{38}Sr^{89}$ (sol.) β^-	**Bone** GI (LLI) Total body	4 40	**3×10^{-4}** 10^{-3} 2×10^{-3}	**3×10^{-8}** 3×10^{-7} 2×10^{-7}	**10^{-4}** 4×10^{-4} 7×10^{-4}	**10^{-8}** 9×10^{-8} 6×10^{-8}
(insol.)	**Lung** **GI (LLI)**		**8×10^{-4}**	**4×10^{-8}** 10^{-7}	**3×10^{-4}**	**10^{-8}** 5×10^{-8}
$_{38}Sr^{90}$ (sol.) β^-	**Bone** Total body GI (LLI)	2 20	**4×10^{-6}** 10^{-5} 10^{-3}	**3×10^{-10}** 9×10^{-10} 3×10^{-7}	**10^{-6}** 4×10^{-6} 5×10^{-4}	**10^{-10}** 3×10^{-10} 10^{-7}
(insol.)	**Lung** **GI (LLI)**		**10^{-3}**	**5×10^{-9}** 2×10^{-7}	**4×10^{-4}**	**2×10^{-9}** 6×10^{-8}
$_{38}Sr^{91}$ (sol.) β^-, γ	**GI (LLI)** Bone Total body	 3 9	**2×10^{-3}** 0.02 0.07	**4×10^{-7}** 2×10^{-6} 6×10^{-6}	**7×10^{-4}** 7×10^{-3} 0.02	**2×10^{-7}** 5×10^{-7} 2×10^{-6}
(insol.)	**GI (LLI)** Lung		**10^{-3}**	**3×10^{-7}** 10^{-6}	**5×10^{-4}**	**9×10^{-8}** 4×10^{-7}
$_{38}Sr^{92}$ (sol.) β^-, γ	**GI (ULI)** Bone Total body	 2 8	**2×10^{-3}** 0.05 0.2	**4×10^{-7}** 4×10^{-6} 2×10^{-5}	**7×10^{-4}** 0.02 0.07	**2×10^{-7}** 2×10^{-6} 6×10^{-6}
(insol.)	**GI (ULI)** Lung		**2×10^{-3}**	**3×10^{-7}** 3×10^{-6}	**6×10^{-4}**	**10^{-7}** 10^{-6}
$_{39}Y^{90}$ (sol.) β^-	**GI (LLI)** Bone Total body	 3 20	**6×10^{-4}** 10 80	**10^{-7}** 5×10^{-7} 3×10^{-6}	**2×10^{-4}** 4 30	**4×10^{-8}** 2×10^{-7} 10^{-6}
(insol.)	**GI (LLI)** Lung		**6×10^{-4}**	**10^{-7}** 3×10^{-7}	**2×10^{-4}**	**3×10^{-8}** 10^{-7}

2.44 µc/Q ← 0.76 µc Sr+Y .15 µc/Q inhaled

Radionuclide and type of decay		Organ of reference (critical organ **bold face**)	Maximum permissible burden in total body $q(\mu c)$	Maximum permissible concentrations: For 40 hr week $(MPC)_w$ $(\mu c/cm^3)$	For 40 hr week $(MPC)_a$ $(\mu c/cm^3)$	For 168 hr week $(MPC)_w$ $(\mu c/cm^3)$	For 168 hr week $(MPC)_a$ $(\mu c/cm^3)$
$_{39}Y^{91m}$	(sol.)	**GI (SI)**		**0.1**	**2×10^{-5}**	**0.03**	**8×10^{-6}**
β^-, γ		Bone	5	10^3	6×10^{-5}	400	2×10^{-5}
		Total body	20	6×10^3	2×10^{-4}	2×10^3	8×10^{-5}
	(insol.)	**GI (SI)**		**0.1**	**2×10^{-5}**	**0.03**	**6×10^{-6}**
		Lung			4×10^{-5}		10^{-5}
$_{39}Y^{91}$	(sol.)	**GI (LLI)**		**8×10^{-4}**	2×10^{-7}	**3×10^{-4}**	6×10^{-8}
β^-, γ		**Bone**	5	0.8	**4×10^{-8}**	0.3	**10^{-8}**
		Total body	30	5	2×10^{-7}	2	8×10^{-8}
	(insol.)	**Lung**			**3×10^{-8}**		**10^{-8}**
		GI (LLI)		**8×10^{-4}**	10^{-7}	**3×10^{-4}**	5×10^{-8}
$_{39}Y^{92}$	(sol.)	**GI (ULI)**		**2×10^{-3}**	**4×10^{-7}**	**6×10^{-4}**	**10^{-7}**
β^-, γ		Bone	2	100	6×10^{-6}	40	2×10^{-6}
		Total body	10	800	3×10^{-5}	300	10^{-5}
	(insol.)	**GI (ULI)**		**2×10^{-3}**	**3×10^{-7}**	**6×10^{-4}**	**10^{-7}**
		Lung			3×10^{-6}		10^{-6}
$_{39}Y^{93}$	(sol.)	**GI (LLI)**		**8×10^{-4}**	**2×10^{-7}**	**3×10^{-4}**	**6×10^{-8}**
β^-, γ, e^-		Bone	2	50	2×10^{-6}	20	7×10^{-7}
		Total body	10	250	10^{-5}	90	4×10^{-6}
	(insol.)	**GI (LLI)**		**8×10^{-4}**	**10^{-7}**	**3×10^{-4}**	**5×10^{-8}**
		Lung			10^{-6}		4×10^{-7}
$_{40}Zr^{93}$	(sol.)	**GI (LLI)**		**0.02**	5×10^{-6}	**8×10^{-3}**	2×10^{-6}
β^-, γ, e^-		**Bone**	100	3	**10^{-7}**	0.9	**4×10^{-8}**
		Kidney	300	6	3×10^{-7}	2	9×10^{-8}
		Spleen	500	10	4×10^{-7}	3	10^{-7}
		Total body	900	20	8×10^{-7}	6	3×10^{-7}
		Liver	10^3	30	10^{-6}	9	4×10^{-7}
	(insol.)	**Lung**			**3×10^{-7}**		**10^{-7}**
		GI (LLI)		**0.02**	4×10^{-6}	**8×10^{-3}**	10^{-6}
$_{40}Zr^{95}$	(sol.)	**GI (LLI)**		**2×10^{-3}**	4×10^{-7}	**6×10^{-4}**	10^{-7}
β^-, γ, e^-		**Total body**	20	3	**10^{-7}**	1	**4×10^{-8}**
		Bone	30	4	2×10^{-7}	2	6×10^{-8}
		Kidney	30	4	2×10^{-7}	2	6×10^{-8}
		Liver	40	6	3×10^{-7}	2	9×10^{-8}
		Spleen	40	7	3×10^{-7}	2	10^{-7}
	(insol.)	**Lung**			**3×10^{-8}**		**10^{-8}**
		GI (LLI)		**2×10^{-3}**	3×10^{-7}	**6×10^{-4}**	10^{-7}

Radionuclide and type of decay		Organ of reference (critical organ **bold face**)	Maximum permissible burden in total body $q(\mu c)$	Maximum permissible concentrations: For 40 hr week $(MPC)_w$ $(\mu c/cm^3)$	For 40 hr week $(MPC)_a$ $(\mu c/cm^3)$	For 168 hr week $(MPC)_w$ $(\mu c/cm^3)$	For 168 hr week $(MPC)_a$ $(\mu c/cm^3)$
$_{40}Zr^{97}$ β^-, γ	(sol.)	**GI (LLI)**		**5×10^{-4}**	**10^{-7}**	**2×10^{-4}**	**4×10^{-8}**
		Bone	5	60	3×10^{-6}	20	10^{-6}
		Kidney	8	100	5×10^{-6}	40	2×10^{-6}
		Total body	9	100	5×10^{-6}	40	2×10^{-6}
		Liver	10	200	7×10^{-6}	60	3×10^{-6}
		Spleen	10	200	8×10^{-6}	60	3×10^{-6}
	(insol.)	**GI (LLI)**		**5×10^{-4}**	**9×10^{-8}**	**2×10^{-4}**	**3×10^{-8}**
		Lung			6×10^{-7}		2×10^{-7}
$_{41}Nb^{93m}$ γ, e^-	(sol.)	**GI (LLI)**		**0.01**	3×10^{-6}	**4×10^{-3}**	9×10^{-7}
		Bone	200	3	**10^{-7}**	1	**4×10^{-8}**
		Kidney	300	5	2×10^{-7}	2	7×10^{-8}
		Spleen	400	5	2×10^{-7}	2	8×10^{-8}
		Liver	400	6	3×10^{-7}	2	9×10^{-8}
		Total body	500	8	3×10^{-7}	3	10^{-7}
	(insol.)	**Lung**			**2×10^{-7}**		**5×10^{-8}**
		GI (LLI)		**0.01**	2×10^{-6}	**4×10^{-3}**	7×10^{-7}
$_{41}Nb^{95}$ β^-, γ	(sol.)	**GI (LLI)**		**3×10^{-3}**	6×10^{-7}	**10^{-3}**	**2×10^{-7}**
		Total body	40	10	**5×10^{-7}**	4	**2×10^{-7}**
		Liver	60	20	7×10^{-7}	6	3×10^{-7}
		Kidney	60	20	8×10^{-7}	6	3×10^{-7}
		Bone	80	20	9×10^{-7}	7	3×10^{-7}
		Spleen	80	20	10^{-6}	7	3×10^{-7}
	(insol.)	**Lung**			**10^{-7}**		**3×10^{-8}**
		GI (LLI)		**3×10^{-3}**	5×10^{-7}	**10^{-3}**	**2×10^{-7}**
$_{41}Nb^{97}$ β^-, γ	(sol.)	**GI (ULI)**		**0.03**	**6×10^{-6}**	**9×10^{-3}**	**2×10^{-6}**
		Bone	10	2×10^{3}	9×10^{-5}	700	3×10^{-5}
		Kidney	20	4×10^{3}	2×10^{-4}	10^{3}	6×10^{-5}
		Total body	20	4×10^{3}	2×10^{-4}	10^{3}	6×10^{-5}
		Liver	30	4×10^{3}	2×10^{-4}	2×10^{3}	7×10^{-5}
		Spleen	30	5×10^{3}	2×10^{-4}	2×10^{3}	7×10^{-5}
	(insol.)	**GI (ULI)**		**0.03**	**5×10^{-6}**	**9×10^{-3}**	**2×10^{-6}**
		Lung			2×10^{-5}		7×10^{-6}
$_{42}Mo^{99}$ β^-, γ	(sol.)	**Kidney**	8	**5×10^{-3}**	**7×10^{-7}**	**2×10^{-3}**	**3×10^{-7}**
		GI (LLI)		7×10^{-3}	2×10^{-6}	**2×10^{-3}**	5×10^{-7}
		Liver	20	0.01	2×10^{-6}	5×10^{-3}	6×10^{-7}
		Total body	40	0.02	3×10^{-6}	8×10^{-3}	10^{-6}
	(insol.)	**GI (LLI)**		**10^{-3}**	**2×10^{-7}**	**4×10^{-4}**	**7×10^{-8}**
		Lung			5×10^{-7}		2×10^{-7}

Radionuclide and type of decay		Organ of reference (critical organ **bold face**)	Maximum permissible burden in total body $q(\mu c)$	Maximum permissible concentrations: For 40 hr week $(MPC)_w$ $(\mu c/cm^3)$	For 40 hr week $(MPC)_a$ $(\mu c/cm^3)$	For 168 hr week $(MPC)_w$ $(\mu c/cm^3)$	For 168 hr week $(MPC)_a$ $(\mu c/cm^3)$
$_{43}Tc^{96m}$	(sol.)	**GI (LLI)**		**0.4**	**8×10^{-5}**	**0.1**	**3×10^{-5}**
ϵ, γ, e^-		Kidney	60	3	4×10^{-4}	1	10^{-4}
		Total body	70	4	4×10^{-4}	1	10^{-4}
		Liver	800	40	4×10^{-3}	14	10^{-3}
		Lung	2×10^3	130	0.01	40	5×10^{-3}
		Bone	10^4	700	0.08	200	0.03
		Skin	2×10^4	800	0.09	300	0.03
	(insol.)	**Lung**			**3×10^{-5}**		**10^{-5}**
		GI (LLI)		**0.3**	5×10^{-5}	**0.1**	2×10^{-5}
$_{43}Tc^{96}$	(sol.)	**GI (LLI)**		**3×10^{-3}**	**6×10^{-7}**	**10^{-3}**	**2×10^{-7}**
ϵ, γ		Kidney	10	0.03	3×10^{-6}	0.01	10^{-6}
		Total body	10	0.03	4×10^{-6}	0.01	10^{-6}
		Liver	200	0.4	4×10^{-5}	0.1	10^{-5}
		Lung	500	1	10^{-4}	0.4	4×10^{-5}
		Bone	2×10^3	4	5×10^{-4}	1	2×10^{-4}
		Skin	10^4	20	3×10^{-3}	9	9×10^{-4}
	(insol.)	**GI (LLI)**		**10^{-3}**	**2×10^{-7}**	**5×10^{-4}**	**8×10^{-8}**
		Lung			3×10^{-7}		9×10^{-8}
$_{43}Tc^{97m}$	(sol.)	**GI (LLI)**		**0.01**	**2×10^{-6}**	**4×10^{-3}**	**8×10^{-7}**
ϵ, γ, e^-		Kidney	20	0.03	4×10^{-6}	0.01	10^{-6}
		Total body	200	0.4	4×10^{-5}	0.1	2×10^{-5}
		Liver	200	0.4	5×10^{-5}	0.1	2×10^{-5}
		Skin	500	1	10^{-4}	0.3	4×10^{-5}
		Bone	700	1	10^{-4}	0.5	5×10^{-5}
		Lung	2×10^3	4	4×10^{-4}	1	2×10^{-4}
	(insol.)	**Lung**	9.3		**2×10^{-7}**		**5×10^{-8}**
		GI (LLI)	7.1	**5×10^{-3}**	9×10^{-7}	**2×10^{-3}**	3×10^{-7}
$_{43}Tc^{97}$	(sol.)	**GI (LLI)**		**0.05**	**10^{-5}**	**0.02**	**4×10^{-6}**
ϵ		**Kidney**	60	0.1	**10^{-5}**	**0.04**	**4×10^{-6}**
		Liver	800	2	2×10^{-4}	0.5	6×10^{-5}
		Total body	10^3	2	2×10^{-4}	0.6	7×10^{-5}
		Bone	6×10^3	10	10^{-3}	4	4×10^{-4}
		Lung	9×10^3	20	2×10^{-3}	6	7×10^{-4}
		Skin	3×10^4	60	6×10^{-3}	20	2×10^{-3}
	(insol.)	**Lung**			**3×10^{-7}**		**10^{-7}**
		GI (LLI)		**0.02**	4×10^{-6}	**8×10^{-3}**	10^{-6}
$_{43}Tc^{99m}$	(sol.)	**GI (ULI)**		**0.2**	**4×10^{-5}**	**0.06**	**10^{-5}**
β^-, γ		Total body	200	2	2×10^{-4}	0.8	9×10^{-5}
		Kidney	800	7	8×10^{-4}	3	3×10^{-4}

Radionuclide and type of decay	Organ of reference (critical organ **bold face**)	Maximum permissible burden in total body $q(\mu c)$	Maximum permissible concentrations			
			For 40 hr week		For 168 hr week	
			$(MPC)_w$ $(\mu c/cm^3)$	$(MPC)_a$ $(\mu c/cm^3)$	$(MPC)_w$ $(\mu c/cm^3)$	$(MPC)_a$ $(\mu c/cm^3)$
	Liver	10^4	100	0.01	30	4×10^{-3}
	Lung	2×10^4	200	0.02	70	8×10^{-3}
	Bone	10^5	10^3	0.1	400	0.04
	Skin	10^5	10^3	0.1	400	0.04
(insol.)	**GI (ULI)**		**0.08**	**10^{-5}**	**0.03**	**5×10^{-6}**
	Lung			8×10^{-5}		3×10^{-5}
$_{43}Tc^{99}$ (sol.) β^-	**GI (LLI)**		**0.01**	**2×10^{-6}**	**3×10^{-3}**	**7×10^{-7}**
	Kidney	10	0.02	3×10^{-6}	8×10^{-3}	9×10^{-7}
	Liver	200	0.3	4×10^{-5}	0.1	10^{-5}
	Total body	200	0.4	4×10^{-5}	0.1	10^{-5}
	Skin	400	0.7	7×10^{-5}	0.2	3×10^{-5}
	Bone	500	0.9	9×10^{-5}	0.3	3×10^{-5}
	Lung	2×10^3	4	4×10^{-4}	1	10^{-4}
(insol.)	**Lung**			**6×10^{-8}**		**2×10^{-8}**
	GI (LLI)		**5×10^{-3}**	8×10^{-7}	**2×10^{-3}**	3×10^{-7}
$_{44}Ru^{97}$ (sol.) ϵ, γ, e^-	**GI (LLI)**		**0.01**	**2×10^{-6}**	**4×10^{-3}**	**8×10^{-7}**
	Kidney	30	0.4	5×10^{-6}	0.1	10^{-6}
	Total body	100	2	3×10^{-5}	0.7	9×10^{-6}
	Bone	900	10	2×10^{-4}	5	6×10^{-5}
(insol.)	**GI (LLI)**		**0.01**	**2×10^{-6}**	**3×10^{-3}**	**6×10^{-7}**
	Lung			**2×10^{-6}**		7×10^{-7}
$_{44}Ru^{103}$ (sol.) β^-, γ, e^-	**GI (LLI)**		**2×10^{-3}**	**5×10^{-7}**	**8×10^{-4}**	**2×10^{-7}**
	Kidney	20	0.08	10^{-6}	0.03	3×10^{-7}
	Total body	50	0.2	3×10^{-6}	0.08	9×10^{-7}
	Bone	100	0.6	7×10^{-6}	0.2	2×10^{-6}
(insol.)	**Lung**			**8×10^{-8}**		**3×10^{-8}**
	GI (LLI)		**2×10^{-3}**	4×10^{-7}	**8×10^{-4}**	10^{-7}
$_{44}Ru^{105}$ (sol.) β^-, γ, e^-	**GI (ULI)**		**3×10^{-3}**	**7×10^{-7}**	**10^{-3}**	**2×10^{-7}**
	Kidney	2	0.3	3×10^{-6}	0.09	10^{-6}
	Total body	20	3	4×10^{-5}	0.9	10^{-5}
	Bone	40	6	8×10^{-5}	2	3×10^{-5}
(insol.)	**GI (ULI)**		**3×10^{-3}**	**5×10^{-7}**	**10^{-3}**	**2×10^{-7}**
	Lung			4×10^{-6}		10^{-6}
$_{44}Ru^{106}$ (sol.) β^-, γ	**GI (LLI)**		**4×10^{-4}**	**8×10^{-8}**	**10^{-4}**	**3×10^{-8}**
	Kidney	3	0.01	10^{-7}	4×10^{-3}	5×10^{-8}
	Bone	10	0.04	5×10^{-7}	0.01	2×10^{-7}
	Total body	10	0.06	7×10^{-7}	0.02	3×10^{-7}

Radionuclide and type of decay	Organ of reference (critical organ **bold face**)	Maximum permissible burden in total body $q(\mu c)$	Maximum permissible concentrations			
			For 40 hr week		For 168 hr week	
			$(MPC)_w$ $(\mu c/cm^3)$	$(MPC)_a$ $(\mu c/cm^3)$	$(MPC)_w$ $(\mu c/cm^3)$	$(MPC)_a$ $(\mu c/cm^3)$
(insol.)	**Lung**	0.6		**6×10^{-9}**		**2×10^{-9}**
	GI (LLI)		**3×10^{-4}**	6×10^{-8}	**10^{-4}**	2×10^{-8}
$_{45}Rh^{103m}$ (sol.) γ, e^-	**GI (S)**		**0.4**	**8×10^{-5}**	**0.1**	**3×10^{-5}**
	Kidney	200	20	10^{-3}	7	4×10^{-4}
	Spleen	200	30	2×10^{-3}	10	6×10^{-4}
	Total body	400	40	3×10^{-3}	20	10^{-3}
	Liver	700	80	5×10^{-3}	30	2×10^{-3}
	Bone	10^3	100	9×10^{-3}	50	3×10^{-3}
(insol.)	**GI (S)**		**0.3**	**6×10^{-5}**	**0.1**	**2×10^{-5}**
	Lung			3×10^{-4}		10^{-4}
$_{45}Rh^{105}$ (sol.) β^-, γ	**GI (LLI)**		**4×10^{-3}**	**8×10^{-7}**	**10^{-3}**	**3×10^{-7}**
	Bone	200	0.8	5×10^{-5}	0.3	2×10^{-5}
	Kidney	40	0.1	9×10^{-6}	0.05	3×10^{-6}
	Spleen	60	0.2	10^{-5}	0.07	5×10^{-6}
	Total body	100	0.4	2×10^{-5}	0.1	7×10^{-6}
	Liver	200	0.6	4×10^{-5}	0.2	10^{-5}
(insol.)	**GI (LLI)**		**3×10^{-3}**	**5×10^{-7}**	**10^{-3}**	**2×10^{-7}**
	Lung			2×10^{-6}		8×10^{-7}
$_{46}Pd^{103}$ (sol.) ϵ, γ, e^-	**GI (LLI)**		**0.01**	2×10^{-6}	**3×10^{-3}**	8×10^{-7}
	Kidney	20	0.02	**10^{-6}**	7×10^{-3}	**5×10^{-7}**
	Spleen	100	0.1	8×10^{-6}	0.04	3×10^{-6}
	Liver	100	0.1	8×10^{-6}	0.04	3×10^{-6}
	Total body	300	0.4	2×10^{-5}	0.1	8×10^{-6}
(insol.)	**Lung**			**7×10^{-7}**		**3×10^{-7}**
	GI (LLI)		**8×10^{-3}**	10^{-6}	**3×10^{-3}**	5×10^{-7}
$_{46}Pd^{109}$ (sol.) β^-, γ, e^-	**GI (LLI)**		**3×10^{-3}**	**6×10^{-7}**	**9×10^{-4}**	**2×10^{-7}**
	Kidney	7	0.06	4×10^{-6}	0.02	10^{-6}
	Spleen	30	0.3	2×10^{-5}	0.09	5×10^{-6}
	Liver	40	0.3	2×10^{-5}	0.1	7×10^{-6}
	Total body	50	0.4	3×10^{-5}	0.1	9×10^{-6}
(insol.)	**GI (LLI)**		**2×10^{-3}**	**4×10^{-7}**	**7×10^{-4}**	**10^{-7}**
	Lung			3×10^{-6}		10^{-6}
$_{47}Ag^{105}$ (sol.) ϵ, γ	**GI (LLI)**		**3×10^{-3}**	**6×10^{-7}**	**10^{-3}**	**2×10^{-7}**
	Total body	30	0.6	3×10^{-6}	0.2	10^{-6}
	Kidney	30	0.7	3×10^{-6}	0.2	10^{-6}
	Liver	70	1	6×10^{-6}	0.5	2×10^{-6}
	Bone	200	4	2×10^{-5}	1	6×10^{-6}

Radionuclide and type of decay	Organ of reference (critical organ **bold face**)	Maximum permissible burden in total body $q(\mu c)$	Maximum permissible concentrations: For 40 hr week $(MPC)_w$ $(\mu c/cm^3)$	For 40 hr week $(MPC)_a$ $(\mu c/cm^3)$	For 168 hr week $(MPC)_w$ $(\mu c/cm^3)$	For 168 hr week $(MPC)_a$ $(\mu c/cm^3)$
(insol.)	**Lung**			8×10^{-8}		3×10^{-8}
	GI (LLI)		3×10^{-3}	5×10^{-7}	10^{-3}	2×10^{-7}
$_{47}Ag^{110m}$ (sol.) β^-, γ	**GI (LLI)**		9×10^{-4}	2×10^{-7}	3×10^{-4}	7×10^{-8}
	Kidney	10	0.2	8×10^{-7}	0.06	3×10^{-7}
	Total body	10	0.2	9×10^{-7}	0.07	3×10^{-7}
	Liver	20	0.4	2×10^{-6}	0.1	5×10^{-7}
	Bone	40	0.7	3×10^{-6}	0.2	10^{-6}
(insol.)	**Lung**			10^{-8}		3×10^{-9}
	GI (LLI)		9×10^{-4}	2×10^{-7}	3×10^{-4}	5×10^{-8}
$_{47}Ag^{111}$ (sol.) β^-, γ	**GI (LLI)**		10^{-3}	3×10^{-7}	4×10^{-4}	10^{-7}
	Kidney	20	0.7	3×10^{-6}	0.2	10^{-6}
	Total body	50	1	6×10^{-6}	0.5	2×10^{-6}
	Bone	60	2	8×10^{-6}	0.6	3×10^{-6}
	Liver	80	2	10^{-5}	0.8	3×10^{-6}
(insol.)	**GI (LLI)**		10^{-3}	2×10^{-7}	4×10^{-4}	8×10^{-8}
	Lung			3×10^{-7}		9×10^{-8}
$_{48}Cd^{109}$ (sol.) ϵ, γ, e^-	**GI (LLI)**		5×10^{-3}	10^{-6}	2×10^{-3}	4×10^{-7}
	Liver	20	0.05	5×10^{-8}	0.02	2×10^{-8}
	Kidney	20	0.05	6×10^{-8}	0.02	2×10^{-8}
	Total body	200	0.5	5×10^{-7}	0.2	2×10^{-7}
(insol.)	**Lung**			7×10^{-8}		3×10^{-8}
	GI (LLI)		5×10^{-3}	9×10^{-7}	2×10^{-3}	3×10^{-7}
$_{48}Cd^{115m}$ (sol.) β^-, γ, e^-	**GI (LLI)**		7×10^{-4}	2×10^{-7}	3×10^{-4}	6×10^{-8}
	Liver	3	0.03	4×10^{-8}	0.01	10^{-8}
	Kidney	4	0.04	4×10^{-8}	0.01	2×10^{-8}
	Total body	30	0.4	4×10^{-7}	0.1	10^{-7}
(insol.)	**Lung**			4×10^{-8}		10^{-8}
	GI (LLI)		7×10^{-4}	10^{-7}	3×10^{-4}	4×10^{-8}
$_{48}Cd^{115}$ (sol.) β^-, γ, e^-	**GI (LLI)**		10^{-3}	2×10^{-7}	3×10^{-4}	8×10^{-8}
	Liver	3	0.6	6×10^{-7}	0.2	2×10^{-7}
	Kidney	5	0.8	8×10^{-7}	0.3	3×10^{-7}
	Total body	30	5	5×10^{-6}	2	2×10^{-6}
(insol.)	**GI (LLI)**		10^{-3}	2×10^{-7}	4×10^{-4}	6×10^{-8}
	Lung			6×10^{-7}		2×10^{-7}
$_{49}In^{113m}$ (sol.) γ, e^-	**GI (ULI)**		0.04	8×10^{-6}	0.01	3×10^{-6}
	Kidney	30	200	2×10^{-4}	70	6×10^{-5}

Radionuclide and type of decay	Organ of reference (critical organ **bold face**)	Maximum permissible burden in total body $q(\mu c)$	Maximum permissible concentrations			
			For 40 hr week		For 168 hr week	
			$(MPC)_w$ $(\mu c/cm^3)$	$(MPC)_a$ $(\mu c/cm^3)$	$(MPC)_w$ $(\mu c/cm^3)$	$(MPC)_a$ $(\mu c/cm^3)$
	Spleen	30	200	2×10^{-4}	70	6×10^{-5}
	Liver	50	300	3×10^{-4}	100	9×10^{-5}
	Total body	70	400	4×10^{-4}	200	10^{-4}
	Bone	90	600	5×10^{-4}	200	2×10^{-4}
	Skin	100	900	8×10^{-4}	300	3×10^{-4}
	Thyroid	500	3×10^3	3×10^{-3}	10^3	10^{-3}
(insol.)	**GI (ULI)**		**0.04**	**7×10^{-6}**	**0.01**	**2×10^{-6}**
	Lung			5×10^{-5}		2×10^{-5}
$_{49}In^{114m}$ (sol.) $\beta^-, \epsilon, \gamma, e^-$	**GI (LLI)**		**5×10^{-4}**	**10^{-7}**	**2×10^{-4}**	**4×10^{-8}**
	Kidney	6	0.1	**10^{-7}**	0.04	**4×10^{-8}**
	Spleen	7	0.1	**10^{-7}**	0.04	**4×10^{-8}**
	Liver	10	0.2	2×10^{-7}	0.07	6×10^{-8}
	Bone	10	0.3	2×10^{-7}	0.09	8×10^{-8}
	Skin	20	0.4	3×10^{-7}	0.1	10^{-7}
	Total body	20	0.4	4×10^{-7}	0.1	10^{-7}
	Thyroid	50	0.9	8×10^{-7}	0.3	3×10^{-7}
(insol.)	**Lung**	0.89		**2×10^{-8}**		**7×10^{-9}**
	GI (LLI)	0.71	**5×10^{-4}**	8×10^{-8}	**2×10^{-4}**	3×10^{-8}
$_{49}In^{115m}$ (sol.) β^-, γ, e^-	**GI (ULI)**		**0.01**	**2×10^{-6}**	**4×10^{-3}**	**8×10^{-7}**
	Kidney	30	80	7×10^{-5}	30	2×10^{-5}
	Spleen	30	80	7×10^{-5}	30	2×10^{-5}
	Liver	50	100	10^{-4}	40	4×10^{-5}
	Total body	80	200	2×10^{-4}	60	6×10^{-5}
	Thyroid	80	200	2×10^{-4}	70	6×10^{-5}
	Bone	90	200	2×10^{-4}	70	6×10^{-5}
	Skin	100	300	3×10^{-4}	100	10^{-4}
(insol.)	**GI (ULI)**	14.2	**0.01**	**2×10^{-6}**	**4×10^{-3}**	**6×10^{-7}**
	Lung	4.2		2×10^{-5}		6×10^{-6}
$_{49}In^{115}$ (sol.) β^-	**GI (LLI)**		**3×10^{-3}**	6×10^{-7}	**9×10^{-4}**	2×10^{-7}
	Kidney	30	0.3	**2×10^{-7}**	0.1	**9×10^{-8}**
	Spleen	40	0.4	3×10^{-7}	0.1	10^{-7}
	Liver	50	0.5	4×10^{-7}	0.1	10^{-7}
	Bone	60	0.6	5×10^{-7}	0.2	2×10^{-7}
	Skin	80	0.8	7×10^{-7}	0.3	2×10^{-7}
	Total body	100	1	10^{-6}	0.4	3×10^{-7}
	Thyroid	3×10^3	30	2×10^{-5}	9	8×10^{-6}
(insol.)	**Lung**			**3×10^{-8}**		**10^{-8}**
	GI (LLI)		**3×10^{-3}**	5×10^{-7}	**9×10^{-4}**	2×10^{-7}
$_{50}Sn^{113}$ (sol.)	**GI (LLI)**		**2×10^{-3}**	5×10^{-7}	**9×10^{-4}**	2×10^{-7}

Radionuclide and type of decay		Organ of reference (critical organ **bold face**)	Maximum permissible burden in total body $q(\mu c)$	Maximum permissible concentrations			
				For 40 hr week		For 168 hr week	
				$(MPC)_w$ ($\mu c/cm^3$)	$(MPC)_a$ ($\mu c/cm^3$)	$(MPC)_w$ ($\mu c/cm^3$)	$(MPC)_a$ ($\mu c/cm^3$)
ϵ, γ, e^-		**Bone**	30	0.02	4×10^{-7}	6×10^{-3}	10^{-7}
		Total body	60	0.04	8×10^{-7}	0.01	3×10^{-7}
		Prostate	70	0.04	9×10^{-7}	0.02	3×10^{-7}
		Liver	400	0.3	5×10^{-6}	0.09	2×10^{-6}
		Thyroid	10^3	0.9	2×10^{-5}	0.3	6×10^{-6}
	(insol.)	**Lung**			5×10^{-8}		2×10^{-8}
		GI (LLI)		2×10^{-3}	4×10^{-7}	8×10^{-4}	10^{-7}
$_{50}Sn^{125}$ β^-, γ, e^-	(sol.)	**GI (LLI)**		5×10^{-4}	10^{-7}	2×10^{-4}	4×10^{-8}
		Bone	7	0.02	3×10^{-7}	6×10^{-3}	10^{-7}
		Prostate	10	0.03	6×10^{-7}	9×10^{-3}	2×10^{-7}
		Total body	20	0.05	10^{-6}	0.02	4×10^{-7}
		Liver	100	0.3	7×10^{-6}	0.1	2×10^{-6}
		Thyroid	300	0.8	2×10^{-5}	0.3	5×10^{-6}
	(insol.)	**Lung**	0.87		8×10^{-8}		3×10^{-8}
		GI (LLI)	0.71	5×10^{-4}	9×10^{-8}	2×10^{-4}	3×10^{-8}
$_{51}Sb^{122}$ β^-, γ	(sol.)	**GI (LLI)**		8×10^{-4}	2×10^{-7}	3×10^{-4}	6×10^{-8}
		Total body	20	0.3	4×10^{-6}	0.1	10^{-6}
		Lung	40	0.5	6×10^{-6}	0.2	2×10^{-6}
		Bone	40	0.5	6×10^{-6}	0.2	2×10^{-6}
		Liver	10^3	10	2×10^{-4}	4	5×10^{-5}
		Thyroid	3×10^3	40	4×10^{-4}	10	2×10^{-4}
	(insol.)	**GI (LLI)**		8×10^{-4}	10^{-7}	3×10^{-4}	5×10^{-8}
		Lung			4×10^{-7}		10^{-7}
$_{51}Sb^{124}$ β^-, γ	(sol.)	**GI (LLI)**		7×10^{-4}	2×10^{-7}	2×10^{-4}	5×10^{-8}
		Total body	10	0.02	2×10^{-7}	6×10^{-3}	7×10^{-8}
		Lung	20	0.02	3×10^{-7}	8×10^{-3}	10^{-7}
		Bone	30	0.04	5×10^{-7}	0.01	2×10^{-7}
		Liver	800	1	10^{-5}	0.4	4×10^{-6}
		Thyroid	10^4	20	2×10^{-4}	6	7×10^{-5}
	(insol.)	**Lung**			2×10^{-8}		7×10^{-9}
		GI (LLI)		7×10^{-4}	10^{-7}	2×10^{-4}	4×10^{-8}
$_{51}Sb^{125}$ β^-, γ, e^-	(sol.)	**GI (LLI)**		3×10^{-3}	6×10^{-7}	10^{-3}	2×10^{-7}
		Lung	40	0.04	5×10^{-7}	0.01	2×10^{-7}
		Total body	60	0.05	6×10^{-7}	0.02	2×10^{-7}
		Bone	70	0.06	8×10^{-7}	0.02	2×10^{-7}
		Liver	3×10^3	3	3×10^{-5}	0.9	10^{-5}
		Thyroid	7×10^4	60	7×10^{-4}	20	2×10^{-4}
	(insol.)	**Lung**			3×10^{-8}		9×10^{-9}
		GI (LLI)		3×10^{-3}	5×10^{-7}	10^{-3}	2×10^{-7}

Radionuclide and type of decay	Organ of reference (critical organ **bold face**)	Maximum permissible burden in total body $q(\mu c)$	Maximum permissible concentrations: For 40 hr week $(MPC)_w$ $(\mu c/cm^3)$	For 40 hr week $(MPC)_a$ $(\mu c/cm^3)$	For 168 hr week $(MPC)_w$ $(\mu c/cm^3)$	For 168 hr week $(MPC)_a$ $(\mu c/cm^3)$
$_{52}Te^{125m}$ (sol.) γ, e^-	**Kidney**	20	$\mathbf{5 \times 10^{-3}}$	$\mathbf{4 \times 10^{-7}}$	$\mathbf{2 \times 10^{-3}}$	$\mathbf{10^{-7}}$
	GI (LLI)		$\mathbf{5 \times 10^{-3}}$	10^{-6}	$\mathbf{2 \times 10^{-3}}$	4×10^{-7}
	Testis	20	6×10^{-3}	5×10^{-7}	$\mathbf{2 \times 10^{-3}}$	2×10^{-7}
	Spleen	50	0.02	10^{-6}	6×10^{-3}	4×10^{-7}
	Liver	100	0.04	3×10^{-6}	0.01	9×10^{-7}
	Total body	100	0.04	3×10^{-6}	0.01	10^{-6}
	Bone	100	0.04	3×10^{-6}	0.02	10^{-6}
	Thyroid	500	0.2	10^{-5}	0.05	4×10^{-6}
(insol.)	**Lung**			$\mathbf{10^{-7}}$		$\mathbf{4 \times 10^{-8}}$
	GI (LLI)		$\mathbf{3 \times 10^{-3}}$	6×10^{-7}	$\mathbf{10^{-3}}$	2×10^{-7}
$_{52}Te^{127m}$ (sol.) β^-, γ, e^-	**Kidney**	7	$\mathbf{2 \times 10^{-3}}$	$\mathbf{10^{-7}}$	$\mathbf{6 \times 10^{-4}}$	$\mathbf{5 \times 10^{-8}}$
	Testis	7	$\mathbf{2 \times 10^{-3}}$	$\mathbf{10^{-7}}$	7×10^{-4}	$\mathbf{5 \times 10^{-8}}$
	GI (LLI)		$\mathbf{2 \times 10^{-3}}$	5×10^{-7}	8×10^{-4}	2×10^{-7}
	Spleen	20	6×10^{-3}	5×10^{-7}	2×10^{-3}	2×10^{-7}
	Bone	50	0.01	9×10^{-7}	4×10^{-3}	3×10^{-7}
	Liver	50	0.01	10^{-6}	5×10^{-3}	4×10^{-7}
	Total body	60	0.02	10^{-6}	6×10^{-3}	4×10^{-7}
	Thyroid	200	0.05	4×10^{-6}	0.02	10^{-6}
(insol.)	**Lung**			$\mathbf{4 \times 10^{-8}}$		$\mathbf{10^{-8}}$
	GI (LLI)		$\mathbf{2 \times 10^{-3}}$	3×10^{-7}	$\mathbf{5 \times 10^{-4}}$	9×10^{-8}
$_{52}Te^{127}$ (sol.) β^-	**GI (LLI)**		$\mathbf{8 \times 10^{-3}}$	$\mathbf{2 \times 10^{-6}}$	$\mathbf{3 \times 10^{-3}}$	$\mathbf{6 \times 10^{-7}}$
	Kidney	20	0.1	10^{-5}	0.05	4×10^{-6}
	Testis	20	0.2	10^{-5}	0.05	4×10^{-6}
	Spleen	50	0.5	4×10^{-5}	0.2	10^{-5}
	Total body	80	0.8	6×10^{-5}	0.3	2×10^{-5}
	Bone	100	1	7×10^{-5}	0.3	2×10^{-5}
	Liver	100	1	9×10^{-5}	0.4	3×10^{-5}
	Thyroid	100	1	10^{-4}	0.5	4×10^{-5}
(insol.)	**GI (LLI)**	7.1	$\mathbf{5 \times 10^{-3}}$	$\mathbf{9 \times 10^{-7}}$	$\mathbf{2 \times 10^{-3}}$	$\mathbf{3 \times 10^{-7}}$
	Lung	3.5		8×10^{-6}		3×10^{-6}
$_{52}Te^{129m}$ (sol.) β^-, γ, e^-	**GI (LLI)**		$\mathbf{10^{-3}}$	2×10^{-7}	$\mathbf{3 \times 10^{-4}}$	7×10^{-8}
	Kidney	3	$\mathbf{10^{-3}}$	$\mathbf{8 \times 10^{-8}}$	4×10^{-4}	$\mathbf{3 \times 10^{-8}}$
	Testis	3	$\mathbf{10^{-3}}$	9×10^{-8}	4×10^{-4}	$\mathbf{3 \times 10^{-8}}$
	Spleen	10	4×10^{-3}	3×10^{-7}	10^{-3}	9×10^{-8}
	Total body	20	6×10^{-3}	5×10^{-7}	2×10^{-3}	2×10^{-7}
	Liver	20	8×10^{-3}	6×10^{-7}	3×10^{-3}	2×10^{-7}
	Bone	20	9×10^{-3}	6×10^{-7}	3×10^{-3}	2×10^{-7}
	Thyroid	70	0.03	2×10^{-6}	8×10^{-3}	6×10^{-7}
(insol.)	**Lung**			$\mathbf{3 \times 10^{-8}}$		$\mathbf{10^{-8}}$
	GI (LLI)		$\mathbf{6 \times 10^{-4}}$	10^{-7}	$\mathbf{2 \times 10^{-4}}$	4×10^{-8}

Radionuclide and type of decay	Organ of reference (critical organ **bold face**)	Maximum permissible burden in total body $q(\mu c)$	Maximum permissible concentrations: For 40 hr week $(MPC)_w$ $(\mu c/cm^3)$	For 40 hr week $(MPC)_a$ $(\mu c/cm^3)$	For 168 hr week $(MPC)_w$ $(\mu c/cm^3)$	For 168 hr week $(MPC)_a$ $(\mu c/cm^3)$
$_{52}Te^{129}$ (sol.) β^-, γ, e^-	**GI (S)**		**0.02**	**5×10^{-6}**	**8×10^{-3}**	**2×10^{-6}**
	Kidney	5	0.4	3×10^{-5}	0.1	10^{-5}
	Testis	6	0.4	3×10^{-5}	0.2	10^{-5}
	Spleen	20	1	10^{-4}	0.5	3×10^{-5}
	Total body	20	2	10^{-4}	0.5	4×10^{-5}
	Liver	40	3	2×10^{-4}	1	7×10^{-5}
	Bone	40	3	2×10^{-4}	1	8×10^{-5}
	Thyroid	60	4	3×10^{-4}	1	10^{-4}
(insol.)	**GI (ULI)**		**0.02**	**4×10^{-6}**	**8×10^{-3}**	**10^{-6}**
	Lung			2×10^{-5}		7×10^{-6}
$_{52}Te^{131m}$ (sol.) β^-, γ, e^-	**GI (LLI)**		**2×10^{-3}**	**4×10^{-7}**	**6×10^{-4}**	**10^{-7}**
	Kidney	4	0.01	10^{-6}	5×10^{-3}	3×10^{-7}
	Total body	10	0.04	3×10^{-6}	0.01	10^{-6}
	Spleen	20	0.05	4×10^{-6}	0.02	10^{-6}
	Liver	30	0.09	7×10^{-6}	0.03	2×10^{-6}
	Bone	50	0.1	10^{-5}	0.05	4×10^{-6}
	Thyroid	50	0.2	10^{-5}	0.06	4×10^{-6}
(insol.)	**GI (LLI)**	1.42	**10^{-3}**	**2×10^{-7}**	**4×10^{-4}**	**6×10^{-8}**
	Lung	0.84		6×10^{-7}		2×10^{-7}
$_{52}Te^{132}$ (sol.) β^-, γ, e^-	**GI (LLI)**		**9×10^{-4}**	**2×10^{-7}**	**3×10^{-4}**	**7×10^{-8}**
	Kidney	3	5×10^{-3}	4×10^{-7}	2×10^{-3}	10^{-7}
	Testis	5	7×10^{-3}	5×10^{-7}	2×10^{-3}	2×10^{-7}
	Total body	10	0.02	10^{-6}	5×10^{-3}	4×10^{-7}
	Spleen	10	0.02	10^{-6}	6×10^{-3}	4×10^{-7}
	Liver	20	0.03	2×10^{-6}	0.01	8×10^{-7}
	Bone	30	0.05	4×10^{-6}	0.02	10^{-6}
	Thyroid	50	0.07	5×10^{-6}	0.02	10^{-6}
(insol.)	**GI (LLI)**		**6×10^{-4}**	**10^{-7}**	**2×10^{-4}**	**4×10^{-8}**
	Lung			2×10^{-7}		7×10^{-8}
$_{53}I^{126}$ (sol.) $\beta^-, \epsilon, \gamma$	**Thyroid**	1	**5×10^{-5}**	**8×10^{-9}**	**2×10^{-5}**	**3×10^{-9}**
	Total body	90	6×10^{-3}	9×10^{-7}	2×10^{-3}	3×10^{-7}
	GI (LLI)		0.05	10^{-5}	0.02	4×10^{-6}
(insol.)	**Lung**			**3×10^{-7}**		**10^{-7}**
	GI (LLI)		**3×10^{-3}**	5×10^{-7}	**9×10^{-4}**	2×10^{-7}
$_{53}I^{129}$ (sol.) β^-, γ, e^-	**Thyroid**	3	**10^{-5}**	**2×10^{-9}**	**4×10^{-6}**	**6×10^{-10}**
	Total body	200	2×10^{-3}	2×10^{-7}	5×10^{-4}	7×10^{-8}
	GI (LLI)		0.1	3×10^{-5}	0.04	9×10^{-6}
(insol.)	**Lung**	10.2		**7×10^{-8}**		**2×10^{-8}**

Radionuclide and type of decay	Organ of reference (critical organ **bold face**)	Maximum permissible burden in total body $q(\mu c)$	Maximum permissible concentrations			
			For 40 hr week		For 168 hr week	
			$(MPC)_w$ $(\mu c/cm^3)$	$(MPC)_a$ $(\mu c/cm^3)$	$(MPC)_w$ $(\mu c/cm^3)$	$(MPC)_a$ $(\mu c/cm^3)$
	GI (LLI)		6×10^{-3}	10^{-6}	2×10^{-3}	4×10^{-7}
$_{53}I^{131}$ (sol.) β^-, γ, e^-	**Thyroid**	0.7	6×10^{-5}	9×10^{-9}	2×10^{-5}	3×10^{-9}
	Total body	50	5×10^{-3}	8×10^{-7}	2×10^{-3}	3×10^{-7}
	GI (LLI)		0.03	7×10^{-6}	0.01	2×10^{-6}
(insol.)	**GI (LLI)**		2×10^{-3}	3×10^{-7}	6×10^{-4}	10^{-7}
	Lung			3×10^{-7}		10^{-7}
$_{53}I^{132}$ (sol.) β^-, γ, e^-	**Thyroid**	0.3	2×10^{-3}	2×10^{-7}	6×10^{-4}	8×10^{-8}
	GI (SI)		0.01	3×10^{-6}	4×10^{-3}	9×10^{-7}
	Total body	10	0.1	2×10^{-5}	0.04	6×10^{-6}
(insol.)	**GI (ULI)**		5×10^{-3}	9×10^{-7}	2×10^{-3}	3×10^{-7}
	Lung			7×10^{-6}		2×10^{-6}
$_{53}I^{133}$ (sol.) β^-, γ, e^-	**Thyroid**	0.3	2×10^{-4}	3×10^{-8}	7×10^{-5}	10^{-8}
	GI (SI)		0.02	4×10^{-6}	6×10^{-3}	10^{-6}
	Total body	20	0.02	4×10^{-6}	9×10^{-3}	10^{-6}
(insol.)	**GI (LLI)**		10^{-3}	2×10^{-7}	4×10^{-4}	7×10^{-8}
	Lung			10^{-6}		4×10^{-7}
$_{53}I^{134}$ (sol.) β^-, γ	**Thyroid**	0.2	4×10^{-3}	5×10^{-7}	10^{-3}	2×10^{-7}
	GI (S)		0.02	4×10^{-6}	6×10^{-3}	10^{-6}
	Total body	10	0.3	5×10^{-5}	0.1	2×10^{-5}
(insol.)	**GI (S)**		0.02	3×10^{-6}	6×10^{-3}	10^{-6}
	Lung			2×10^{-5}		7×10^{-6}
$_{53}I^{135}$ (sol.) β^-, γ, e^-	**Thyroid**	0.3	7×10^{-4}	10^{-7}	2×10^{-4}	4×10^{-8}
	GI (SI)		0.01	3×10^{-6}	5×10^{-3}	10^{-6}
	Total body	20	0.05	7×10^{-6}	0.02	3×10^{-6}
(insol.)	**GI (LLI)**		2×10^{-3}	4×10^{-7}	7×10^{-4}	10^{-7}
	Lung			3×10^{-6}		10^{-6}
$_{54}Xe^{131m}$ (submersion) γ, e^-	**Total body**			2×10^{-5}		4×10^{-6}
$_{54}Xe^{133}$ (submersion) γ, e^-	**Total body**			10^{-5}		3×10^{-6}
$_{54}Xe^{135}$ (submersion) β^-, γ	**Total body**			4×10^{-6}		10^{-6}
$_{55}Cs^{131}$ (sol.)	**Total body**	700	0.07	10^{-5}	0.02	4×10^{-6}

Radionuclide and type of decay	Organ of reference (critical organ **bold face**)	Maximum permissible burden in total body $q(\mu c)$	Maximum permissible concentrations: For 40 hr week $(MPC)_w$ $(\mu c/cm^3)$	For 40 hr week $(MPC)_a$ $(\mu c/cm^3)$	For 168 hr week $(MPC)_w$ $(\mu c/cm^3)$	For 168 hr week $(MPC)_a$ $(\mu c/cm^3)$
ϵ	**Liver**	800	**0.09**	$\mathbf{10^{-5}}$	**0.03**	$\mathbf{4 \times 10^{-6}}$
	Spleen	10^3	0.1	2×10^{-5}	0.04	6×10^{-6}
	Kidney	10^3	0.1	2×10^{-5}	0.05	7×10^{-6}
	Muscle	2×10^3	0.2	3×10^{-5}	0.07	10^{-5}
	GI (SI)		0.5	10^{-4}	0.2	4×10^{-5}
	Bone	8×10^3	0.9	10^{-4}	0.3	4×10^{-5}
	Lung	10^4	1	2×10^{-4}	0.4	5×10^{-5}
(insol.)	**Lung**			$\mathbf{3 \times 10^{-6}}$		$\mathbf{10^{-6}}$
	GI (LLI)		**0.03**	5×10^{-6}	$\mathbf{9 \times 10^{-3}}$	2×10^{-6}
$_{55}Cs^{134m}$ (sol.) β^-, γ, e^-	**GI (S)**		**0.2**	$\mathbf{4 \times 10^{-5}}$	**0.06**	$\mathbf{10^{-5}}$
	Total body	100	0.7	10^{-4}	0.3	4×10^{-5}
	Liver	100	1	10^{-4}	0.3	5×10^{-5}
	Spleen	200	1	2×10^{-4}	0.5	7×10^{-5}
	Kidney	200	2	2×10^{-4}	0.6	8×10^{-5}
	Muscle	200	2	2×10^{-4}	0.6	9×10^{-5}
	Bone	600	4	6×10^{-4}	1	2×10^{-4}
	Lung	2×10^3	10	2×10^{-3}	4	6×10^{-4}
(insol.)	**GI (ULI)**	4.26	**0.03**	$\mathbf{6 \times 10^{-6}}$	**0.01**	$\mathbf{2 \times 10^{-6}}$
	Lung	4.94		3×10^{-5}		10^{-5}
$_{55}Cs^{134}$ (sol.) β^-, γ	**Total body**	20	$\mathbf{3 \times 10^{-4}}$	$\mathbf{4 \times 10^{-8}}$	$\mathbf{9 \times 10^{-5}}$	$\mathbf{10^{-8}}$
	Liver	30	4×10^{-4}	6×10^{-8}	10^{-4}	2×10^{-8}
	Muscle	30	4×10^{-4}	6×10^{-8}	2×10^{-4}	2×10^{-8}
	Spleen	40	6×10^{-4}	9×10^{-8}	2×10^{-4}	3×10^{-8}
	Kidney	90	10^{-3}	2×10^{-7}	4×10^{-4}	6×10^{-8}
	Bone	200	2×10^{-3}	3×10^{-7}	7×10^{-4}	10^{-7}
	Lung	300	4×10^{-3}	5×10^{-7}	10^{-3}	2×10^{-7}
	GI (SI)		0.01	3×10^{-6}	5×10^{-3}	10^{-6}
(insol.)	**Lung**			$\mathbf{10^{-8}}$		$\mathbf{4 \times 10^{-9}}$
	GI (LLI)		$\mathbf{10^{-3}}$	2×10^{-7}	$\mathbf{4 \times 10^{-4}}$	7×10^{-8}
$_{55}Cs^{135}$ (sol.) β^-	**Liver**	200	$\mathbf{3 \times 10^{-3}}$	$\mathbf{5 \times 10^{-7}}$	$\mathbf{10^{-3}}$	$\mathbf{2 \times 10^{-7}}$
	Spleen	300	4×10^{-3}	$\mathbf{5 \times 10^{-7}}$	$\mathbf{10^{-3}}$	$\mathbf{2 \times 10^{-7}}$
	Total body	300	4×10^{-3}	6×10^{-7}	$\mathbf{10^{-3}}$	$\mathbf{2 \times 10^{-7}}$
	Bone	400	6×10^{-3}	8×10^{-7}	2×10^{-3}	3×10^{-7}
	Muscle	500	6×10^{-3}	9×10^{-7}	2×10^{-3}	3×10^{-7}
	Kidney	600	9×10^{-3}	10^{-6}	3×10^{-3}	4×10^{-7}
	Lung	2×10^3	0.03	4×10^{-6}	0.01	10^{-6}
	GI (LLI)		0.1	3×10^{-5}	0.05	10^{-5}
(insol.)	**GI (LLI)**		$\mathbf{7 \times 10^{-3}}$	10^{-6}	$\mathbf{2 \times 10^{-3}}$	4×10^{-7}
	Lung			$\mathbf{9 \times 10^{-8}}$		$\mathbf{3 \times 10^{-8}}$

Radionuclide and type of decay		Organ of reference (critical organ **bold face**)	Maximum permissible burden in total body $q(\mu c)$	Maximum permissible concentrations			
				For 40 hr week		For 168 hr week	
				$(MPC)_w$ ($\mu c/cm^3$)	$(MPC)_a$ ($\mu c/cm^3$)	$(MPC)_w$ ($\mu c/cm^3$)	$(MPC)_a$ ($\mu c/cm^3$)
$_{55}Cs^{136}$ β^-, γ	(sol.)	**Total body**	30	2×10^{-3}	4×10^{-7}	9×10^{-4}	10^{-7}
		Liver	60	5×10^{-3}	7×10^{-7}	2×10^{-3}	2×10^{-7}
		Spleen	80	7×10^{-3}	10^{-6}	2×10^{-3}	4×10^{-7}
		Muscle	90	8×10^{-3}	10^{-6}	3×10^{-3}	4×10^{-7}
		Kidney	100	8×10^{-3}	10^{-6}	3×10^{-3}	4×10^{-7}
		GI (SI)		0.02	5×10^{-6}	8×10^{-3}	2×10^{-6}
		Bone	400	0.03	4×10^{-6}	0.01	2×10^{-6}
		Lung	800	0.06	9×10^{-6}	0.02	3×10^{-6}
	(insol.)	**Lung**			2×10^{-7}		6×10^{-8}
		GI (LLI)		2×10^{-3}	3×10^{-7}	6×10^{-4}	10^{-7}
$_{55}Cs^{137}$ β^-, γ, e^-	(sol.)	**Total body**	30	4×10^{-4}	6×10^{-8}	2×10^{-4}	2×10^{-8}
		Liver	40	5×10^{-4}	8×10^{-8}	2×10^{-4}	3×10^{-8}
		Spleen	50	6×10^{-4}	9×10^{-8}	2×10^{-4}	3×10^{-8}
		Muscle	50	7×10^{-4}	10^{-7}	2×10^{-4}	4×10^{-8}
		Bone	100	10^{-3}	2×10^{-7}	5×10^{-4}	7×10^{-8}
		Kidney	100	10^{-3}	2×10^{-7}	5×10^{-4}	8×10^{-8}
		Lung	300	5×10^{-3}	6×10^{-7}	2×10^{-3}	2×10^{-7}
		GI (SI)		0.02	5×10^{-6}	8×10^{-3}	2×10^{-6}
	(insol.)	**Lung**	2.7		10^{-8}		5×10^{-9}
		GI (LLI)		10^{-3}	2×10^{-7}	4×10^{-4}	8×10^{-8}
$_{56}Ba^{131}$ ϵ, γ	(sol.)	**GI (LLI)**		5×10^{-3}	10^{-6}	2×10^{-3}	4×10^{-7}
		Total body	50	0.1	2×10^{-6}	0.03	7×10^{-7}
		Bone	80	0.1	3×10^{-6}	0.05	10^{-6}
		Liver	10^4	20	4×10^{-4}	7	10^{-4}
		Muscle	2×10^4	40	7×10^{-4}	10	2×10^{-4}
		Lung	2×10^4	40	7×10^{-4}	10	2×10^{-4}
		Spleen	3×10^4	60	10^{-3}	20	4×10^{-4}
		Kidney	4×10^4	70	10^{-3}	20	5×10^{-4}
	(insol.)	**Lung**			4×10^{-7}		10^{-7}
		GI (LLI)		5×10^{-3}	9×10^{-7}	2×10^{-3}	3×10^{-7}
$_{56}Ba^{140}$ β^-, γ	(sol.)	**GI (LLI)**		8×10^{-4}	2×10^{-7}	3×10^{-4}	6×10^{-8}
		Bone	4	6×10^{-3}	10^{-7}	2×10^{-3}	4×10^{-8}
		Total body	9	0.01	3×10^{-7}	5×10^{-3}	10^{-7}
		Liver	10^3	2	5×10^{-5}	0.9	2×10^{-5}
		Lung	3×10^3	4	9×10^{-5}	2	3×10^{-5}
		Muscle	3×10^3	5	10^{-4}	2	4×10^{-5}
		Spleen	4×10^3	6	10^{-4}	2	4×10^{-5}
		Kidney	4×10^3	8	2×10^{-4}	3	5×10^{-5}
	(insol.)	**Lung**			4×10^{-8}		10^{-8}
		GI (LLI)		7×10^{-4}	10^{-7}	2×10^{-4}	4×10^{-8}

Radionuclide and type of decay		Organ of reference (critical organ **bold face**)	Maximum permissible burden in total body $q(\mu c)$	Maximum permissible concentrations: For 40 hr week $(MPC)_w$ $(\mu c/cm^3)$	For 40 hr week $(MPC)_a$ $(\mu c/cm^3)$	For 168 hr week $(MPC)_w$ $(\mu c/cm^3)$	For 168 hr week $(MPC)_a$ $(\mu c/cm^3)$
$_{57}La^{140}$ β^-, γ	(sol.)	**GI (LLI)**		7×10^{-4}	2×10^{-7}	2×10^{-4}	5×10^{-8}
		Liver	9	50	2×10^{-6}	20	7×10^{-7}
		Bone	10	60	2×10^{-6}	20	8×10^{-7}
		Total body	10	60	2×10^{-6}	20	9×10^{-7}
	(insol.)	**GI (LLI)**		7×10^{-4}	10^{-7}	2×10^{-4}	4×10^{-8}
		Lung			4×10^{-7}		10^{-7}
$_{58}Ce^{141}$ β^-, γ	(sol.)	**GI (LLI)**		3×10^{-3}	6×10^{-7}	9×10^{-4}	2×10^{-7}
		Liver	30	10	4×10^{-7}	3	2×10^{-7}
		Bone	40	10	6×10^{-7}	5	2×10^{-7}
		Kidney	70	20	9×10^{-7}	7	3×10^{-7}
		Total body	90	30	10^{-6}	10	4×10^{-7}
	(insol.)	**Lung**			2×10^{-7}		5×10^{-8}
		GI (LLI)		3×10^{-3}	5×10^{-7}	9×10^{-4}	2×10^{-7}
$_{58}Ce^{143}$ β^-, γ	(sol.)	**GI (LLI)**		10^{-3}	3×10^{-7}	4×10^{-4}	9×10^{-8}
		Liver	7	50	2×10^{-6}	20	7×10^{-7}
		Bone	10	70	3×10^{-6}	20	10^{-6}
		Kidney	20	100	5×10^{-6}	40	2×10^{-6}
		Total body	20	100	6×10^{-6}	50	2×10^{-6}
	(insol.)	**GI (LLI)**		10^{-3}	2×10^{-7}	4×10^{-4}	7×10^{-8}
		Lung			6×10^{-7}		2×10^{-7}
$_{58}Ce^{144}$ α, β^-, γ	(sol.)	**GI (LLI)**		3×10^{-4}	8×10^{-8}	10^{-4}	3×10^{-8}
		Bone	5	0.2	10^{-8}	0.08	3×10^{-9}
		Liver	6	0.3	10^{-8}	0.1	4×10^{-9}
		Kidney	10	0.5	2×10^{-8}	0.2	7×10^{-9}
		Total body	20	0.7	3×10^{-8}	0.3	10^{-8}
	(insol.)	**Lung**			6×10^{-9}		2×10^{-9}
		GI (LLI)		3×10^{-4}	6×10^{-8}	10^{-4}	2×10^{-8}
$_{59}Pr^{142}$ β^-, γ	(sol.)	**GI (LLI)**		9×10^{-4}	2×10^{-7}	3×10^{-4}	7×10^{-8}
		Bone	7	80	4×10^{-6}	30	10^{-6}
		Liver	9	100	4×10^{-6}	40	2×10^{-6}
		Kidney	20	200	8×10^{-6}	60	3×10^{-6}
		Total body	20	300	10^{-5}	90	4×10^{-6}
	(insol.)	**GI (LLI)**		9×10^{-4}	2×10^{-7}	3×10^{-4}	5×10^{-8}
		Lung			10^{-6}		4×10^{-7}
$_{59}Pr^{143}$ β^-	(sol.)	**GI (LLI)**		10^{-3}	3×10^{-7}	5×10^{-4}	10^{-7}
		Bone	20	10	5×10^{-7}	4	2×10^{-7}
		Liver	20	20	7×10^{-7}	5	2×10^{-7}

Radionuclide and type of decay	Organ of reference (critical organ **bold face**)	Maximum permissible burden in total body $q(\mu c)$	Maximum permissible concentrations: For 40 hr week $(MPC)_w$ $(\mu c/cm^3)$	For 40 hr week $(MPC)_a$ $(\mu c/cm^3)$	For 168 hr week $(MPC)_w$ $(\mu c/cm^3)$	For 168 hr week $(MPC)_a$ $(\mu c/cm^3)$
	Kidney	40	30	10^{-6}	9	4×10^{-7}
	Total body	60	40	2×10^{-6}	10	6×10^{-7}
(insol.)	**Lung**			**2×10^{-7}**		**6×10^{-8}**
	GI (LLI)		**10^{-3}**	3×10^{-7}	**5×10^{-4}**	9×10^{-8}
$_{60}Nd^{144}$ (sol.) α	**Bone**	0.1	**2×10^{-3}**	**8×10^{-11}**	**7×10^{-4}**	**3×10^{-11}**
	GI (LLI)		**2×10^{-3}**	5×10^{-7}	8×10^{-4}	2×10^{-7}
	Kidney	0.3	4×10^{-3}	2×10^{-10}	10^{-3}	5×10^{-11}
	Liver	0.7	0.01	4×10^{-10}	3×10^{-3}	2×10^{-10}
	Total body	1	0.01	6×10^{-10}	5×10^{-3}	2×10^{-10}
(insol.)	**Lung**			**3×10^{-10}**		**10^{-10}**
	GI (LLI)		**2×10^{-3}**	4×10^{-7}	**8×10^{-4}**	10^{-7}
$_{60}Nd^{147}$ (sol.) α, β^-, γ	**GI (LLI)**		**2×10^{-3}**	**4×10^{-7}**	**6×10^{-4}**	**10^{-7}**
	Liver	10	8	**4×10^{-7}**	3	**10^{-7}**
	Kidney	20	10	6×10^{-7}	5	2×10^{-7}
	Bone	20	20	8×10^{-7}	6	3×10^{-7}
	Total body	50	40	2×10^{-6}	10	6×10^{-7}
(insol.)	**Lung**			**2×10^{-7}**		**8×10^{-8}**
	GI (LLI)		**2×10^{-3}**	3×10^{-7}	**6×10^{-4}**	10^{-7}
$_{60}Nd^{149}$ (sol.) β^-, γ	**GI (LLI)**		**8×10^{-3}**	**2×10^{-6}**	**3×10^{-3}**	**6×10^{-7}**
	Liver	3	300	10^{-5}	100	5×10^{-6}
	Kidney	5	600	3×10^{-5}	200	9×10^{-6}
	Bone	7	700	3×10^{-5}	300	10^{-5}
	Total body	20	2×10^{3}	9×10^{-5}	700	3×10^{-5}
(insol.)	**GI (ULI)**		**8×10^{-3}**	**10^{-6}**	**3×10^{-3}**	**5×10^{-7}**
	Lung			9×10^{-6}		3×10^{-6}
$_{61}Pm^{147}$ (sol.) α, β^-	**GI (LLI)**		**6×10^{-3}**	10^{-6}	**2×10^{-3}**	5×10^{-7}
	Bone	60	1	**6×10^{-8}**	0.5	**2×10^{-8}**
	Kidney	200	4	2×10^{-7}	2	7×10^{-8}
	Total body	300	7	3×10^{-7}	2	10^{-7}
	Liver	300	8	4×10^{-7}	3	10^{-7}
(insol.)	**Lung**	12.0		**10^{-7}**		**3×10^{-8}**
	GI (LLI)	8.5	**6×10^{-3}**	10^{-6}	**2×10^{-3}**	4×10^{-7}
$_{61}Pm^{149}$ (sol.) β^-, γ	**GI (LLI)**		**10^{-3}**	**3×10^{-7}**	**4×10^{-4}**	**10^{-7}**
	Bone	20	70	3×10^{-6}	20	10^{-6}
	Kidney	30	100	6×10^{-6}	40	2×10^{-6}
	Total body	40	200	7×10^{-6}	50	2×10^{-6}
	Liver	50	200	10^{-5}	80	3×10^{-6}

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Radionuclide and type of decay	Organ of reference (critical organ **bold face**)	Maximum permissible burden in total body $q(\mu c)$	Maximum permissible concentrations			
			For 40 hr week		For 168 hr week	
			$(MPC)_w$ $(\mu c/cm^3)$	$(MPC)_a$ $(\mu c/cm^3)$	$(MPC)_w$ $(\mu c/cm^3)$	$(MPC)_a$ $(\mu c/cm^3)$
(insol.)	**GI (LLI)**		$\mathbf{10^{-3}}$	$\mathbf{2 \times 10^{-7}}$	$\mathbf{4 \times 10^{-4}}$	$\mathbf{8 \times 10^{-8}}$
	Lung			7×10^{-7}		3×10^{-7}
$_{62}Sm^{147}$ (sol.) α	**Bone**	0.1	$\mathbf{2 \times 10^{-3}}$	$\mathbf{7 \times 10^{-11}}$	$\mathbf{6 \times 10^{-4}}$	$\mathbf{2 \times 10^{-11}}$
	GI (LLI)		$\mathbf{2 \times 10^{-3}}$	4×10^{-7}	$\mathbf{7 \times 10^{-4}}$	2×10^{-7}
	Kidney	0.6	8×10^{-3}	4×10^{-10}	3×10^{-3}	10^{-10}
	Liver	0.6	9×10^{-3}	4×10^{-10}	3×10^{-3}	10^{-10}
	Total body	0.9	0.01	5×10^{-10}	4×10^{-3}	2×10^{-10}
(insol.)	**Lung**			$\mathbf{3 \times 10^{-10}}$		$\mathbf{9 \times 10^{-11}}$
	GI (LLI)		2×10^{-3}	4×10^{-7}	7×10^{-4}	10^{-7}
$_{62}Sm^{151}$ (sol.) β^-, γ	**GI (LLI)**		**0.01**	2×10^{-6}	$\mathbf{4 \times 10^{-3}}$	8×10^{-7}
	Bone	100	2	$\mathbf{6 \times 10^{-8}}$	0.5	$\mathbf{2 \times 10^{-8}}$
	Kidney	300	4	2×10^{-7}	2	6×10^{-8}
	Liver	300	5	2×10^{-7}	2	7×10^{-8}
	Total body	500	7	3×10^{-7}	2	10^{-7}
(insol.)	**Lung**			$\mathbf{10^{-7}}$		$\mathbf{5 \times 10^{-8}}$
	GI (LLI)		**0.01**	2×10^{-6}	$\mathbf{4 \times 10^{-3}}$	7×10^{-7}
$_{62}Sm^{153}$ (sol.) β^-, γ	**GI (LLI)**		$\mathbf{2 \times 10^{-3}}$	$\mathbf{5 \times 10^{-7}}$	$\mathbf{8 \times 10^{-4}}$	$\mathbf{2 \times 10^{-7}}$
	Liver	20	70	3×10^{-6}	30	10^{-6}
	Bone	30	100	6×10^{-6}	50	2×10^{-6}
	Kidney	50	200	10^{-5}	80	4×10^{-6}
	Total body	70	300	10^{-5}	100	5×10^{-6}
(insol.)	**GI (LLI)**	2.84	$\mathbf{2 \times 10^{-3}}$	$\mathbf{4 \times 10^{-7}}$	$\mathbf{8 \times 10^{-4}}$	$\mathbf{10^{-7}}$
	Lung	3.23		10^{-6}		5×10^{-7}
$_{63}Eu^{152m}$ (9.2 hr) (sol.) $\beta^-, \epsilon, \gamma$	**GI (LLI)**		$\mathbf{2 \times 10^{-3}}$	$\mathbf{4 \times 10^{-7}}$	$\mathbf{6 \times 10^{-4}}$	$\mathbf{10^{-7}}$
	Liver	8	200	9×10^{-6}	70	3×10^{-6}
	Bone	10	300	10^{-5}	90	4×10^{-6}
	Kidney	10	300	10^{-5}	100	5×10^{-6}
	Total body	20	500	2×10^{-5}	200	8×10^{-6}
(insol.)	**GI (LLI)**	2.84	$\mathbf{2 \times 10^{-3}}$	$\mathbf{3 \times 10^{-7}}$	$\mathbf{6 \times 10^{-4}}$	$\mathbf{10^{-7}}$
	Lung	1.18		3×10^{-6}		9×10^{-7}
$_{63}Eu^{152}$ (13 years) (sol.) $\beta^-, \epsilon, \gamma$	**GI (LLI)**		$\mathbf{2 \times 10^{-3}}$	5×10^{-7}	$\mathbf{8 \times 10^{-4}}$	2×10^{-7}
	Kidney	20	0.3	$\mathbf{10^{-8}}$	0.09	$\mathbf{4 \times 10^{-9}}$
	Total body	30	0.5	2×10^{-8}	0.2	7×10^{-9}
	Bone	30	0.6	3×10^{-8}	0.2	8×10^{-9}
	Liver	80	1.0	6×10^{-8}	0.4	2×10^{-8}
(insol.)	**Lung**	2.55		$\mathbf{2 \times 10^{-8}}$		$\mathbf{6 \times 10^{-9}}$
	GI (LLI)	2.84	2×10^{-3}	4×10^{-7}	8×10^{-4}	10^{-7}

Radionuclide and type of decay	Organ of reference (critical organ **bold face**)	Maximum permissible burden in total body $q(\mu c)$	Maximum permissible concentrations			
			For 40 hr week		For 168 hr week	
			$(MPC)_w$ $(\mu c/cm^3)$	$(MPC)_a$ $(\mu c/cm^3)$	$(MPC)_w$ $(\mu c/cm^3)$	$(MPC)_a$ $(\mu c/cm^3)$
$_{63}Eu^{154}$ (sol.)	**GI (LLI)**		**6×10^{-4}**	10^{-7}	**2×10^{-4}**	5×10^{-8}
$\beta^-, \epsilon, \gamma$	**Kidney**	5	0.09	**4×10^{-9}**	0.03	**10^{-9}**
	Bone	5	0.09	**4×10^{-9}**	0.03	**10^{-9}**
	Total body	20	0.2	10^{-8}	0.08	4×10^{-9}
	Liver	30	0.5	2×10^{-8}	0.2	7×10^{-9}
(insol.)	**Lung**			**7×10^{-9}**		**2×10^{-9}**
	GI (LLI)		**6×10^{-4}**	10^{-7}	**2×10^{-4}**	4×10^{-8}
$_{63}Eu^{155}$ (sol.)	**GI (LLI)**		**6×10^{-3}**	10^{-6}	**2×10^{-3}**	4×10^{-7}
β^-, γ	**Kidney**	70	2	**9×10^{-8}**	0.7	**3×10^{-8}**
	Bone	80	2	10^{-7}	0.8	**3×10^{-8}**
	Total body	100	4	2×10^{-7}	1	5×10^{-8}
	Liver	200	5	2×10^{-7}	2	8×10^{-8}
(insol.)	**Lung**	8.8		**7×10^{-8}**		**3×10^{-8}**
	GI (LLI)		6×10^{-3}	10^{-6}	**2×10^{-3}**	4×10^{-7}
$_{64}Gd^{153}$ (sol.)	**GI (LLI)**		**6×10^{-3}**	10^{-6}	**2×10^{-3}**	5×10^{-7}
ϵ, γ, e^-	**Bone**	90	5	**2×10^{-7}**	2	**8×10^{-8}**
	Total body	100	7	3×10^{-7}	2	10^{-7}
	Liver	100	7	3×10^{-7}	2	10^{-7}
(insol.)	**Lung**			**9×10^{-8}**		**3×10^{-8}**
	GI (LLI)		**6×10^{-3}**	10^{-6}	**2×10^{-3}**	4×10^{-7}
$_{64}Gd^{159}$ (sol.)	**GI (LLI)**		**2×10^{-3}**	**5×10^{-7}**	**8×10^{-4}**	**2×10^{-7}**
β^-, γ	Bone	20	200	9×10^{-6}	70	3×10^{-6}
	Liver	40	400	2×10^{-5}	200	7×10^{-6}
	Total body	50	700	3×10^{-5}	200	10^{-5}
(insol.)	**GI (LLI)**		**2×10^{-3}**	**4×10^{-7}**	**8×10^{-4}**	**10^{-7}**
	Lung			3×10^{-6}		10^{-6}
$_{65}Tb^{160}$ (sol.)	**GI (LLI)**		**10^{-3}**	3×10^{-7}	**4×10^{-4}**	10^{-7}
β^-, γ	**Bone**	20	2	**10^{-7}**	0.8	**3×10^{-8}**
	Kidney	20	3	**10^{-7}**	1	4×10^{-8}
	Total body	20	3	**10^{-7}**	1	5×10^{-8}
(insol.)	**Lung**			**3×10^{-8}**		**10^{-8}**
	GI (LLI)		**10^{-3}**	2×10^{-7}	**4×10^{-4}**	8×10^{-8}
$_{66}Dy^{165}$ (sol.)	**GI (ULI)**		**0.01**	**3×10^{-6}**	**4×10^{-3}**	**9×10^{-7}**
β^-, γ	Bone	10	10^3	5×10^{-5}	400	2×10^{-5}
	Total body	40	4×10^3	2×10^{-4}	10^3	6×10^{-5}
	Liver	60	6×10^3	3×10^{-4}	2×10^3	9×10^{-5}

Radionuclide and type of decay		Organ of reference (critical organ **bold face**)	Maximum permissible burden in total body $q(\mu c)$	Maximum permissible concentrations: For 40 hr week $(MPC)_w$ $(\mu c/cm^3)$	For 40 hr week $(MPC)_a$ $(\mu c/cm^3)$	For 168 hr week $(MPC)_w$ $(\mu c/cm^3)$	For 168 hr week $(MPC)_a$ $(\mu c/cm^3)$
	(insol.)	**GI (ULI)**		**0.01**	**2×10^{-6}**	**4×10^{-3}**	**7×10^{-7}**
		Lung			2×10^{-5}		6×10^{-6}
$_{66}Dy^{166}$ β^-, γ, e^-	(sol.)	**GI (LLI)**		**10^{-3}**	**2×10^{-7}**	**4×10^{-4}**	**8×10^{-8}**
		Bone	5	10	6×10^{-7}	4	2×10^{-7}
		Total body	30	70	3×10^{-6}	20	10^{-6}
		Liver	30	80	4×10^{-6}	30	10^{-6}
	(insol.)	**GI (LLI)**		**10^{-3}**	**2×10^{-7}**	**4×10^{-4}**	**7×10^{-8}**
		Lung			3×10^{-7}		10^{-7}
$_{67}Ho^{166}$ β^-, γ, e^-	(sol.)	**GI (LLI)**		**9×10^{-4}**	**2×10^{-7}**	**3×10^{-4}**	**7×10^{-8}**
		Bone	5	40	2×10^{-6}	10	6×10^{-7}
		Kidney	20	200	7×10^{-6}	50	2×10^{-6}
		Total body	30	200	10^{-6}	80	4×10^{-7}
		Liver	40	300	10^{-5}	100	4×10^{-6}
	(insol.)	**GI (LLI)**		**9×10^{-4}**	**2×10^{-7}**	**3×10^{-4}**	**6×10^{-8}**
		Lung			10^{-6}		3×10^{-7}
$_{68}Er^{169}$ β^-, γ	(sol.)	**GI (LLI)**		**3×10^{-3}**	**6×10^{-7}**	**9×10^{-4}**	**2×10^{-7}**
		Bone	30	30	10^{-6}	10	5×10^{-7}
		Total body	50	50	2×10^{-6}	20	8×10^{-7}
		Kidney	70	60	3×10^{-6}	20	10^{-6}
		Liver	200	200	9×10^{-6}	70	3×10^{-6}
	(insol.)	**Lung**			**4×10^{-7}**		**10^{-7}**
		GI (LLI)		**3×10^{-3}**	6×10^{-7}	**9×10^{-4}**	2×10^{-7}
$_{68}Er^{171}$ β^-, γ, e^-	(sol.)	**GI (ULI)**		**3×10^{-3}**	**7×10^{-7}**	**10^{-3}**	**2×10^{-7}**
		Bone	9	300	10^{-5}	90	4×10^{-6}
		Kidney	30	800	4×10^{-5}	300	10^{-5}
		Total body	30	900	4×10^{-5}	300	10^{-5}
	(insol.)	**GI (ULI)**		**3×10^{-3}**	**6×10^{-7}**	**10^{-3}**	**2×10^{-7}**
		Lung			5×10^{-6}		2×10^{-6}
$_{69}Tm^{170}$ $\beta^-, \epsilon, \gamma, e^-$	(sol.)	**GI (LLI)**		**10^{-3}**	3×10^{-7}	**5×10^{-4}**	10^{-7}
		Bone	9	**0.8**	**4×10^{-8}**	**0.3**	**10^{-8}**
		Kidney	30	4	2×10^{-7}	1	6×10^{-8}
		Total body	60	5	2×10^{-7}	2	7×10^{-8}
	(insol.)	**Lung**			**3×10^{-8}**		**10^{-8}**
		GI (LLI)		**10^{-3}**	2×10^{-7}	**5×10^{-4}**	8×10^{-8}
$_{69}Tm^{171}$ β^-	(sol.)	**GI (LLI)**		**0.01**	3×10^{-6}	**5×10^{-3}**	10^{-6}
		Bone	90	3	**10^{-7}**	0.9	**4×10^{-8}**

Radionuclide and type of decay	Organ of reference (critical organ **bold face**)	Maximum permissible burden in total body $q(\mu c)$	Maximum permissible concentrations: For 40 hr week $(MPC)_w$ $(\mu c/cm^3)$	For 40 hr week $(MPC)_a$ $(\mu c/cm^3)$	For 168 hr week $(MPC)_w$ $(\mu c/cm^3)$	For 168 hr week $(MPC)_a$ $(\mu c/cm^3)$
	Kidney	700	20	8×10^{-7}	6	3×10^{-7}
	Total body	700	20	8×10^{-7}	6	3×10^{-7}
(insol.)	**Lung**			**2×10^{-7}**		**8×10^{-8}**
	GI (LLI)		**0.01**	3×10^{-6}	**5×10^{-3}**	9×10^{-7}
$_{70}Yb^{175}$ (sol.) β^-, γ	**GI (LLI)**		**3×10^{-3}**	**7×10^{-7}**	**10^{-3}**	**2×10^{-7}**
	Bone	30	60	3×10^{-6}	20	9×10^{-7}
	Kidney	30	80	3×10^{-6}	30	10^{-6}
	Total body	100	300	10^{-5}	100	4×10^{-6}
(insol.)	**GI (LLI)**		**3×10^{-3}**	**6×10^{-7}**	**10^{-3}**	**2×10^{-7}**
	Lung			10^{-6}		4×10^{-7}
$_{71}Lu^{177}$ (sol.) β^-, γ	**GI (LLI)**		**3×10^{-3}**	**6×10^{-7}**	**10^{-3}**	**2×10^{-7}**
	Bone	20	30	10^{-6}	10	4×10^{-7}
	Total body	100	200	7×10^{-6}	60	2×10^{-6}
	Kidney	200	200	10^{-5}	80	3×10^{-6}
(insol.)	**GI (LLI)**		3×10^{-3}	5×10^{-7}	**10^{-3}**	**2×10^{-7}**
	Lung			7×10^{-7}		**2×10^{-7}**
$_{72}Hf^{181}$ (sol.) β^-, γ	**GI (LLI)**		**2×10^{-3}**	4×10^{-7}	**7×10^{-4}**	2×10^{-7}
	Spleen	4	0.9	**4×10^{-8}**	0.3	**10^{-8}**
	Liver	10	2	10^{-7}	0.8	4×10^{-8}
	Total body	40	9	4×10^{-7}	3	10^{-7}
	Kidney	50	10	5×10^{-7}	4	2×10^{-7}
	Bone	100	20	9×10^{-7}	7	3×10^{-7}
(insol.)	**Lung**			**7×10^{-8}**		**3×10^{-8}**
	GI (LLI)		**2×10^{-3}**	4×10^{-7}	**7×10^{-4}**	10^{-7}
$_{73}Ta^{182}$ (sol.) β^-, γ	**GI (LLI)**		**10^{-3}**	3×10^{-7}	**4×10^{-4}**	9×10^{-8}
	Liver	7	0.9	**4×10^{-8}**	0.3	**10^{-8}**
	Kidney	20	2	8×10^{-8}	0.7	3×10^{-8}
	Total body	20	2	9×10^{-8}	0.7	3×10^{-8}
	Spleen	30	4	10^{-7}	1	5×10^{-8}
	Bone	50	6	3×10^{-7}	2	9×10^{-8}
(insol.)	**Lung**			**2×10^{-8}**		**7×10^{-9}**
	GI (LLI)		**10^{-3}**	2×10^{-7}	**4×10^{-4}**	7×10^{-8}
$_{74}W^{181}$ (sol.) ϵ, γ	**GI (LLI))**		**0.01**	**2×10^{-6}**	**4×10^{-3}**	**8×10^{-7}**
	Liver	70	0.6	2×10^{-5}	0.2	8×10^{-6}
	Total body	100	0.9	3×10^{-5}	0.3	10^{-5}
	Bone	200	2	7×10^{-5}	0.7	2×10^{-5}

Radionuclide and type of decay	Organ of reference (critical organ **bold face**)	Maximum permissible burden in total body $q(\mu c)$	Maximum permissible concentrations: For 40 hr week $(MPC)_w$ $(\mu c/cm^3)$	For 40 hr week $(MPC)_a$ $(\mu c/cm^3)$	For 168 hr week $(MPC)_w$ $(\mu c/cm^3)$	For 168 hr week $(MPC)_a$ $(\mu c/cm^3)$
(insol.)	**Lung**			**10^{-7}**		**4×10^{-8}**
	GI (LLI)		**0.01**	2×10^{-6}	**3×10^{-3}**	6×10^{-7}
$_{74}W^{185}$ (sol.) β^-	**GI (LLI)**		**4×10^{-3}**	**8×10^{-7}**	**10^{-3}**	**3×10^{-7}**
	Bone	30	0.3	10^{-5}	0.09	3×10^{-6}
	Liver	40	0.4	2×10^{-5}	0.1	5×10^{-6}
	Total body	100	1	5×10^{-5}	0.5	2×10^{-5}
(insol.)	**Lung**	6,00		**10^{-7}**		**4×10^{-8}**
	GI (LLI)	4.26	**3×10^{-3}**	6×10^{-7}	**10^{-3}**	2×10^{-7}
$_{74}W^{187}$ (sol.) β^-, γ	**GI (LLI)**		**2×10^{-3}**	**4×10^{-7}**	**7×10^{-4}**	**2×10^{-7}**
	Total body	30	0.5	2×10^{-5}	0.2	7×10^{-6}
	Liver	30	0.6	2×10^{-5}	0.2	8×10^{-6}
	Bone	60	1	4×10^{-5}	0.4	10^{-5}
(insol.)	**GI (LLI)**		**2×10^{-3}**	**3×10^{-7}**	**6×10^{-4}**	**10^{-7}**
	Lung			2×10^{-6}		6×10^{-7}
$_{75}Re^{183}$ (sol.) ϵ, γ	**GI (LLI)**		**0.02**	4×10^{-6}	**6×10^{-3}**	10^{-6}
	Total body	80	**0.02**	**3×10^{-6}**	8×10^{-3}	**9×10^{-7}**
	Thyroid	300	0.09	10^{-5}	0.03	3×10^{-6}
	Liver	800	0.2	3×10^{-5}	0.08	8×10^{-6}
	Skin	4×10^3	1	10^{-4}	0.4	4×10^{-5}
	Bone	2×10^4	6	6×10^{-4}	2	2×10^{-4}
(insol.)	**Lung**			**2×10^{-7}**		**5×10^{-8}**
	GI (LLI)		**8×10^{-3}**	10^{-6}	**3×10^{-3}**	5×10^{-7}
$_{75}Re^{186}$ (sol.) β^-, γ	**GI (LLI)**		**3×10^{-3}**	**6×10^{-7}**	**9×10^{-4}**	**2×10^{-7}**
	Thyroid	20	0.01	2×10^{-6}	5×10^{-3}	5×10^{-7}
	Skin	30	0.02	2×10^{-6}	7×10^{-3}	8×10^{-7}
	Total body	50	0.04	4×10^{-6}	0.01	10^{-6}
	Liver	300	0.2	3×10^{-5}	0.08	9×10^{-6}
	Bone	800	0.6	7×10^{-5}	0.2	2×10^{-5}
(insol.)	**GI (LLI)**		**10^{-3}**	**2×10^{-7}**	**5×10^{-4}**	**8×10^{-8}**
	Lung			5×10^{-7}		2×10^{-7}
$_{75}Re^{187}$ (sol.) β^-	**GI (LLI)**		**0.07**	2×10^{-5}	**0.03**	6×10^{-6}
	Skin	300	**0.08**	**9×10^{-6}**	**0.03**	**3×10^{-6}**
	Thyroid	900	0.2	3×10^{-5}	0.08	9×10^{-6}
	Total body	2×10^3	0.4	5×10^{-5}	0.2	2×10^{-5}
	Liver	6×10^3	2	2×10^{-4}	0.5	6×10^{-5}
	Bone	4×10^4	9	10^{-3}	3	4×10^{-4}
(insol.)	**Lung**			**5×10^{-7}**		**2×10^{-7}**

Radionuclide and type of decay	Organ of reference (critical organ **bold face**)	Maximum permissible burden in total body $q(\mu c)$	Maximum permissible concentrations: For 40 hr week $(MPC)_w$ ($\mu c/cm^3$)	For 40 hr week $(MPC)_a$ ($\mu c/cm^3$)	For 168 hr week $(MPC)_w$ ($\mu c/cm^3$)	For 168 hr week $(MPC)_a$ ($\mu c/cm^3$)
	GI (LLI)		**0.04**	7×10^{-6}	**0.02**	2×10^{-6}
$_{75}Re^{188}$ (sol.) β^-, γ	**GI (LLI)**		$\mathbf{2 \times 10^{-3}}$	$\mathbf{4 \times 10^{-7}}$	$\mathbf{6 \times 10^{-4}}$	$\mathbf{10^{-7}}$
	Thyroid	7	0.02	2×10^{-6}	7×10^{-3}	7×10^{-7}
	Skin	20	0.05	5×10^{-6}	0.02	2×10^{-6}
	Total body	20	0.06	7×10^{-6}	0.02	2×10^{-6}
	Liver	200	0.5	5×10^{-5}	0.2	2×10^{-5}
	Bone	300	0.9	10^{-4}	0.3	3×10^{-5}
(insol.)	**GI (LLI)**		$\mathbf{9 \times 10^{-4}}$	$\mathbf{2 \times 10^{-7}}$	$\mathbf{3 \times 10^{-4}}$	$\mathbf{6 \times 10^{-8}}$
	Lung			10^{-6}		4×10^{-7}
$_{76}Os^{185}$ (sol.) ϵ, γ, e^-	**GI (LLI)**		$\mathbf{2 \times 10^{-3}}$	$\mathbf{5 \times 10^{-7}}$	$\mathbf{7 \times 10^{-4}}$	$\mathbf{2 \times 10^{-7}}$
	Kidney	8	0.04	10^{-6}	0.01	5×10^{-7}
	Total body	40	0.2	6×10^{-6}	0.06	2×10^{-6}
	Liver	50	0.2	8×10^{-6}	0.08	3×10^{-6}
(insol.)	**Lung**			$\mathbf{5 \times 10^{-8}}$		$\mathbf{2 \times 10^{-8}}$
	GI (LLI)		$\mathbf{2 \times 10^{-3}}$	3×10^{-7}	$\mathbf{7 \times 10^{-4}}$	10^{-7}
$_{76}Os^{191m}$ (sol.) β^-, γ, e^-	**GI (LLI)**		**0.07**	$\mathbf{2 \times 10^{-5}}$	**0.03**	$\mathbf{6 \times 10^{-6}}$
	Kidney	100	2	8×10^{-5}	0.8	3×10^{-5}
	Total body	300	7	2×10^{-4}	2	8×10^{-5}
	Liver	600	10	5×10^{-4}	4	2×10^{-4}
(insol.)	**Lung**			$\mathbf{9 \times 10^{-6}}$		$\mathbf{3 \times 10^{-6}}$
	GI (LLI)		**0.07**	10^{-5}	**0.02**	4×10^{-6}
$_{76}Os^{191}$ (sol.) β^-, γ, e^-	**GI (LLI)**		$\mathbf{5 \times 10^{-3}}$	$\mathbf{10^{-6}}$	$\mathbf{2 \times 10^{-3}}$	$\mathbf{4 \times 10^{-7}}$
	Kidney	20	0.1	4×10^{-6}	0.04	10^{-6}
	Total body	100	0.6	4×10^{-5}	0.2	8×10^{-6}
	Liver	100	0.7	3×10^{-5}	0.2	9×10^{-6}
(insol.)	**Lung**	7.0		$\mathbf{4 \times 10^{-7}}$		$\mathbf{10^{-7}}$
	GI (LLI)	7.1	$\mathbf{5 \times 10^{-3}}$	8×10^{-7}	$\mathbf{2 \times 10^{-3}}$	3×10^{-7}
$_{76}Os^{193}$ (sol.) β^-	**GI (LLI)**		$\mathbf{2 \times 10^{-3}}$	$\mathbf{4 \times 10^{-7}}$	$\mathbf{6 \times 10^{-4}}$	$\mathbf{10^{-7}}$
	Kidney	10	0.1	4×10^{-6}	0.04	2×10^{-6}
	Total body	30	0.6	2×10^{-5}	0.2	7×10^{-6}
	Liver	70	0.9	3×10^{-5}	0.3	10^{-5}
(insol.)	**GI (LLI)**		$\mathbf{2 \times 10^{-3}}$	$\mathbf{3 \times 10^{-7}}$	$\mathbf{5 \times 10^{-4}}$	$\mathbf{9 \times 10^{-8}}$
	Lung			10^{-6}		5×10^{-7}
$_{77}Ir^{190}$ (sol.) ϵ, γ	**GI (LLI)**		$\mathbf{6 \times 10^{-3}}$	$\mathbf{10^{-6}}$	$\mathbf{2 \times 10^{-3}}$	$\mathbf{4 \times 10^{-7}}$
	Liver	40	0.04	2×10^{-6}	0.02	5×10^{-7}
	Kidney	40	0.04	2×10^{-6}	0.02	6×10^{-7}

Radionuclide and type of decay		Organ of reference (critical organ **bold face**)	Maximum permissible burden in total body $q(\mu c)$	Maximum permissible concentrations			
				For 40 hr week		For 168 hr week	
				$(MPC)_w$ ($\mu c/cm^3$)	$(MPC)_a$ ($\mu c/cm^3$)	$(MPC)_w$ ($\mu c/cm^3$)	$(MPC)_a$ ($\mu c/cm^3$)
		Spleen	40	0.05	2×10^{-6}	0.02	6×10^{-7}
		Total body	50	0.06	2×10^{-6}	0.02	8×10^{-7}
	(insol.)	**Lung**			**4×10^{-7}**		**10^{-7}**
		GI (LLI)		**5×10^{-3}**	9×10^{-7}	**2×10^{-3}**	3×10^{-7}
$_{77}Ir^{192}$ β^-, γ	(sol.)	**GI (LLI)**		**10^{-3}**	3×10^{-7}	**4×10^{-4}**	9×10^{-8}
		Kidney	6	4×10^{-3}	**10^{-7}**	10^{-3}	**4×10^{-8}**
		Spleen	7	4×10^{-3}	**10^{-7}**	10^{-3}	5×10^{-8}
		Liver	8	5×10^{-3}	2×10^{-7}	2×10^{-3}	6×10^{-8}
		Total body	20	0.01	4×10^{-7}	4×10^{-3}	10^{-7}
	(insol.)	**Lung**			**3×10^{-8}**		**9×10^{-9}**
		GI (LLI)		**10^{-3}**	2×10^{-7}	**4×10^{-4}**	6×10^{-8}
$_{77}Ir^{194}$ β^-	(sol.)	**GI (LLI)**		**10^{-3}**	**2×10^{-7}**	**3×10^{-4}**	**8×10^{-8}**
		Kidney	7	0.08	3×10^{-6}	0.03	10^{-6}
		Liver	8	0.09	3×10^{-6}	0.03	10^{-6}
		Spleen	8	0.09	4×10^{-6}	0.03	10^{-6}
		Total body	20	0.3	10^{-5}	0.1	4×10^{-6}
	(insol.)	**GI (LLI)**		**9×10^{-4}**	**2×10^{-7}**	**3×10^{-4}**	**5×10^{-8}**
		Lung			10^{-6}		4×10^{-7}
$_{78}Pt^{191}$ ϵ, γ	(sol.)	**GI (LLI)**		**4×10^{-3}**	**8×10^{-7}**	**10^{-3}**	**3×10^{-7}**
		Kidney	10	0.04	10^{-6}	0.01	5×10^{-7}
		Total body	30	0.1	4×10^{-6}	0.03	10^{-6}
		Liver	30	0.1	4×10^{-6}	0.04	2×10^{-6}
		Spleen	70	0.2	8×10^{-6}	0.08	3×10^{-6}
	(insol.)	**GI (LLI)**		**3×10^{-8}**	**6×10^{-7}**	**10^{-3}**	**2×10^{-7}**
		Lung			8×10^{-7}		3×10^{-7}
$_{78}Pt^{193m}$ ϵ, γ	(sol.)	**GI (LLI)**		**0.03**	**7×10^{-6}**	**0.01**	**2×10^{-6}**
		Kidney	100	0.3	10^{-5}	0.1	4×10^{-6}
		Total body	300	0.8	3×10^{-5}	0.3	10^{-5}
		Liver	300	1	4×10^{-5}	0.3	10^{-5}
		Spleen	600	2	7×10^{-5}	0.7	2×10^{-5}
	(insol.)	**GI (LLI)**		**0.03**	**5×10^{-6}**	**0.01**	**2×10^{-6}**
		Lung			7×10^{-6}		**2×10^{-6}**
$_{78}Pt^{193}$ ϵ	(sol.)	**Kidney**	70	**0.03**	**10^{-6}**	**9×10^{-3}**	**4×10^{-7}**
		GI (LLI)		0.05	10^{-5}	0.02	4×10^{-6}
		Spleen	500	0.2	6×10^{-6}	0.06	2×10^{-6}
		Total body	500	0.2	6×10^{-6}	0.06	2×10^{-6}
		Liver	600	0.2	9×10^{-6}	0.09	3×10^{-6}

Radionuclide and type of decay	Organ of reference (critical organ **bold face**)	Maximum permissible burden in total body $q(\mu c)$	Maximum permissible concentrations			
			For 40 hr week		For 168 hr week	
			$(MPC)_w$ $(\mu c/cm^3)$	$(MPC)_a$ $(\mu c/cm^3)$	$(MPC)_w$ $(\mu c/cm^3)$	$(MPC)_a$ $(\mu c/cm^3)$
(insol.)	**Lung**			**3×10^{-7}**		**10^{-7}**
	GI (LLI)		**0.05**	8×10^{-6}	**0.02**	3×10^{-6}
$_{78}Pt^{197m}$ (sol.)	**GI (ULI)**		**0.03**	**6×10^{-6}**	**0.01**	**2×10^{-6}**
β^-, γ, e^-	Kidney	5	0.8	3×10^{-5}	0.3	10^{-5}
	Liver	20	3	10^{-4}	1	4×10^{-5}
	Spleen	30	5	2×10^{-4}	2	7×10^{-5}
	Total body	40	6	2×10^{-4}	2	7×10^{-5}
(insol.)	**GI (ULI)**		**0.03**	**5×10^{-6}**	**9×10^{-3}**	**2×10^{-6}**
	Lung			2×10^{-5}		8×10^{-6}
$_{78}Pt^{197}$ (sol.)	**GI (LLI)**		**4×10^{-3}**	**8×10^{-7}**	**10^{-3}**	**3×10^{-7}**
β^-, γ	Kidney	10	0.1	5×10^{-6}	0.05	2×10^{-6}
	Liver	40	0.6	2×10^{-5}	0.2	7×10^{-6}
	Spleen	70	0.8	3×10^{-5}	0.3	10^{-5}
	Total body	80	1	4×10^{-5}	0.3	10^{-5}
(insol.)	**GI (LLI)**		**3×10^{-3}**	**6×10^{-7}**	**10^{-3}**	**2×10^{-7}**
	Lung			4×10^{-6}		10^{-6}
$_{79}Au^{196}$ (sol.)	**GI (LLI)**		**5×10^{-3}**	**10^{-6}**	**2×10^{-3}**	**4×10^{-7}**
β^-, γ, e^-	Total body	40	0.07	3×10^{-6}	0.03	9×10^{-7}
	Kidney	50	0.09	4×10^{-6}	0.03	10^{-6}
	Spleen	200	0.3	10^{-5}	0.1	4×10^{-6}
	Liver	200	0.3	10^{-5}	0.1	4×10^{-6}
(insol.)	**Lung**			**6×10^{-7}**		**2×10^{-7}**
	GI (LLI)		**4×10^{-3}**	8×10^{-7}	**10^{-3}**	3×10^{-7}
$_{79}Au^{198}$ (sol.)	**GI (LLI)**		**2×10^{-3}**	**3×10^{-7}**	**5×10^{-4}**	**10^{-7}**
β^-, γ	Kidney	20	0.07	3×10^{-6}	0.02	9×10^{-7}
	Total body	30	0.1	4×10^{-6}	0.04	2×10^{-6}
	Spleen	60	0.2	8×10^{-6}	0.07	3×10^{-6}
	Liver	80	0.3	10^{-5}	0.1	4×10^{-6}
(insol.)	**GI (LLI)**		**10^{-3}**	**2×10^{-7}**	**5×10^{-4}**	**8×10^{-8}**
	Lung			6×10^{-7}		2×10^{-7}
$_{79}Au^{199}$ (sol.)	**GI (LLI)**		**5×10^{-3}**	**10^{-6}**	**2×10^{-3}**	**4×10^{-7}**
β^-, γ	Kidney	70	0.2	8×10^{-6}	0.07	3×10^{-6}
	Total body	100	0.3	10^{-5}	0.1	4×10^{-6}
	Spleen	200	0.6	2×10^{-5}	0.2	8×10^{-6}
	Liver	300	0.8	3×10^{-5}	0.3	10^{-5}
(insol.)	**GI (LLI)**		**4×10^{-3}**	**8×10^{-7}**	**2×10^{-3}**	**3×10^{-7}**
	Lung			2×10^{-6}		6×10^{-7}

Radionuclide and type of decay	Organ of reference (critical organ **bold face**)	Maximum permissible burden in total body $q(\mu c)$	Maximum permissible concentrations			
			For 40 hr week		For 168 hr week	
			$(MPC)_w$ $(\mu c/cm^3)$	$(MPC)_a$ $(\mu c/cm^3)$	$(MPC)_w$ $(\mu c/cm^3)$	$(MPC)_a$ $(\mu c/cm^3)$
$_{80}Hg^{197m}$ (sol.) ϵ, γ, e^-	**Kidney**	4	$\mathbf{6 \times 10^{-3}}$	$\mathbf{7 \times 10^{-7}}$	$\mathbf{2 \times 10^{-3}}$	$\mathbf{3 \times 10^{-7}}$
	GI (LLI)		0.02	4×10^{-6}	7×10^{-3}	10^{-6}
	Spleen	40	0.05	7×10^{-6}	0.02	2×10^{-6}
	Liver	50	0.07	9×10^{-6}	0.02	3×10^{-6}
	Total body	70	0.09	10^{-5}	0.03	4×10^{-6}
(insol.)	**GI (LLI)**	7.1	$\mathbf{5 \times 10^{-3}}$	$\mathbf{8 \times 10^{-7}}$	$\mathbf{2 \times 10^{-3}}$	$\mathbf{3 \times 10^{-7}}$
	Lung			4×10^{-6}		10^{-6}
$_{80}Hg^{197}$ (sol.) ϵ, γ, e^-	**Kidney**	20	$\mathbf{9 \times 10^{-3}}$	$\mathbf{10^{-6}}$	$\mathbf{3 \times 10^{-3}}$	$\mathbf{4 \times 10^{-7}}$
	GI (LLI)		0.06	10^{-5}	0.02	4×10^{-6}
	Spleen	200	0.08	10^{-5}	0.03	4×10^{-6}
	Liver	200	0.1	10^{-5}	0.03	4×10^{-6}
	Total body	200	0.1	2×10^{-5}	0.04	5×10^{-6}
(insol.)	**GI (LLI)**		**0.01**	$\mathbf{3 \times 10^{-6}}$	$\mathbf{5 \times 10^{-3}}$	$\mathbf{9 \times 10^{-7}}$
	Lung			5×10^{-6}		2×10^{-6}
$_{80}Hg^{203}$ (sol.) β^-, γ, e^-	**Kidney**	4	$\mathbf{5 \times 10^{-4}}$	$\mathbf{7 \times 10^{-8}}$	$\mathbf{2 \times 10^{-4}}$	$\mathbf{2 \times 10^{-8}}$
	Spleen	40	6×10^{-3}	8×10^{-7}	2×10^{-3}	3×10^{-7}
	Liver	40	7×10^{-3}	9×10^{-7}	2×10^{-3}	3×10^{-7}
	Total body	80	0.01	2×10^{-6}	4×10^{-3}	5×10^{-7}
	GI (LLI)		0.01	3×10^{-6}	4×10^{-3}	10^{-6}
(insol.)	**Lung**			$\mathbf{10^{-7}}$		$\mathbf{4 \times 10^{-8}}$
	GI (LLI)		$\mathbf{3 \times 10^{-3}}$	6×10^{-7}	$\mathbf{10^{-3}}$	2×10^{-7}
$_{81}Tl^{200}$ (sol.) ϵ, γ	**GI (LLI)**		**0.01**	$\mathbf{3 \times 10^{-6}}$	$\mathbf{4 \times 10^{-3}}$	$\mathbf{9 \times 10^{-7}}$
	Kidney	40	0.08	8×10^{-6}	0.03	3×10^{-6}
	Total body	50	0.1	10^{-5}	0.04	4×10^{-6}
	Muscle	100	0.3	3×10^{-5}	0.09	9×10^{-6}
	Liver	200	0.4	5×10^{-5}	0.2	2×10^{-5}
	Lung	800	2	2×10^{-4}	0.6	6×10^{-5}
	Bone	10^3	2	2×10^{-4}	0.8	9×10^{-5}
(insol.)	**GI (LLI)**		$\mathbf{7 \times 10^{-3}}$	$\mathbf{10^{-6}}$	$\mathbf{2 \times 10^{-3}}$	$\mathbf{4 \times 10^{-7}}$
	Lung			4×10^{-6}		10^{-6}
$_{81}Tl^{201}$ (sol.) ϵ, γ, e^-	**GI (LLI)**		$\mathbf{9 \times 10^{-3}}$	$\mathbf{2 \times 10^{-6}}$	$\mathbf{3 \times 10^{-3}}$	$\mathbf{7 \times 10^{-7}}$
	Kidney	40	0.04	5×10^{-6}	0.02	2×10^{-6}
	Total body	100	0.1	10^{-5}	0.04	4×10^{-6}
	Muscle	300	0.3	3×10^{-5}	0.1	10^{-5}
	Liver	300	0.3	3×10^{-5}	0.1	10^{-5}
	Bone	400	0.4	5×10^{-5}	0.2	2×10^{-5}
	Lung	10^3	1	10^{-4}	0.4	4×10^{-5}
(insol.)	**GI (LLI)**		$\mathbf{5 \times 10^{-3}}$	$\mathbf{9 \times 10^{-7}}$	$\mathbf{2 \times 10^{-3}}$	$\mathbf{3 \times 10^{-7}}$

Radionuclide and type of decay	Organ of reference (critical organ **bold face**)	Maximum permissible burden in total body $q(\mu c)$	Maximum permissible concentrations: For 40 hr week $(MPC)_w$ $(\mu c/cm^3)$	For 40 hr week $(MPC)_a$ $(\mu c/cm^3)$	For 168 hr week $(MPC)_w$ $(\mu c/cm^3)$	For 168 hr week $(MPC)_a$ $(\mu c/cm^3)$
	Lung			2×10^{-6}		7×10^{-7}
$_{81}Tl^{202}$ (sol.) ϵ, γ, e^-	**GI (LLI)**		**4×10^{-3}**	**8×10^{-7}**	**10^{-3}**	**3×10^{-7}**
	Kidney	20	0.01	10^{-6}	3×10^{-3}	4×10^{-7}
	Total body	50	0.03	3×10^{-6}	0.01	10^{-6}
	Muscle	100	0.07	7×10^{-6}	0.02	2×10^{-6}
	Liver	100	0.08	8×10^{-6}	0.03	3×10^{-6}
	Bone	200	0.1	10^{-5}	0.03	4×10^{-6}
	Lung	400	0.3	3×10^{-5}	0.09	9×10^{-6}
(insol.)	**Lung**			**2×10^{-7}**		**8×10^{-8}**
	GI (LLI)		**2×10^{-3}**	4×10^{-7}	**7×10^{-4}**	10^{-7}
$_{81}Tl^{204}$ (sol.) β^-	GI (LLI)		**3×10^{-3}**	7×10^{-7}	**10^{-3}**	**2×10^{-7}**
	Kidney	10	6×10^{-3}	**6×10^{-7}**	2×10^{-3}	**2×10^{-7}**
	Total body	80	0.03	3×10^{-6}	0.01	10^{-6}
	Bone	100	0.04	5×10^{-6}	0.02	2×10^{-6}
	Liver	100	0.06	6×10^{-6}	0.02	2×10^{-6}
	Muscle	200	0.07	7×10^{-6}	0.02	3×10^{-6}
	Lung	500	0.2	2×10^{-5}	0.07	7×10^{-6}
(insol.)	**Lung**			**3×10^{-8}**		**9×10^{-9}**
	GI (LLI)		**2×10^{-3}**	3×10^{-7}	**6×10^{-4}**	10^{-7}
$_{82}Pb^{203}$ (sol.) ϵ, γ	**GI (LLI)**		**0.01**	**3×10^{-6}**	**4×10^{-3}**	**9×10^{-7}**
	Kidney	30	0.1	4×10^{-6}	0.05	10^{-6}
	Total body	90	0.5	10^{-5}	0.2	5×10^{-6}
	Liver	200	1	3×10^{-5}	0.3	10^{-5}
	Bone	400	2	7×10^{-5}	0.8	2×10^{-5}
(insol.)	**GI (LLI)**		**0.01**	**2×10^{-6}**	**4×10^{-3}**	**6×10^{-7}**
	Lung			4×10^{-6}		10^{-6}
$_{82}Pb^{210}$ (sol.) α, β^-, γ	**Kidney**	0.4	**4×10^{-6}**	10^{-10}	**10^{-6}**	**4×10^{-11}**
	Total body	4	**4×10^{-6}**	10^{-9}	**10^{-6}**	**4×10^{-10}**
	Bone	0.7	6×10^{-6}	2×10^{-10}	2×10^{-6}	7×10^{-11}
	Liver	1	10^{-5}	4×10^{-10}	5×10^{-6}	10^{-10}
	GI (LLI)		6×10^{-3}	10^{-6}	2×10^{-3}	4×10^{-7}
(insol.)	**Lung**			**2×10^{-10}**		**8×10^{-11}**
	GI (LLI)		**5×10^{-3}**	9×10^{-7}	**2×10^{-3}**	3×10^{-7}
$_{82}Pb^{212}$ (sol.) $\alpha, \beta^-, \gamma, e^-$	**Kidney**	0.02	**6×10^{-4}**	**2×10^{-8}**	**2×10^{-4}**	**6×10^{-9}**
	GI (LLI)		**6×10^{-4}**	10^{-7}	**2×10^{-4}**	4×10^{-8}
	Bone	0.1	2×10^{-3}	7×10^{-8}	8×10^{-4}	3×10^{-8}
	Liver	0.2	6×10^{-3}	2×10^{-7}	2×10^{-3}	6×10^{-8}
	Total body	0.2	6×10^{-3}	2×10^{-7}	2×10^{-3}	6×10^{-8}

Radionuclide and type of decay	Organ of reference (critical organ **bold face**)	Maximum permissible burden in total body $q(\mu c)$	Maximum permissible concentrations			
			For 40 hr week		For 168 hr week	
			$(MPC)_w$ ($\mu c/cm^3$)	$(MPC)_a$ ($\mu c/cm^3$)	$(MPC)_w$ ($\mu c/cm^3$)	$(MPC)_a$ ($\mu c/cm^3$)
(insol.)	**Lung**			2×10^{-8}		7×10^{-9}
	GI (LLI)		5×10^{-4}	9×10^{-8}	2×10^{-4}	3×10^{-8}
$_{83}Bi^{206}$ (sol.) ϵ, γ	**GI (LLI)**		10^{-3}	2×10^{-7}	4×10^{-4}	8×10^{-8}
	Kidney	1	0.04	2×10^{-7}	0.02	6×10^{-8}
	Liver	7	0.2	10^{-6}	0.08	4×10^{-7}
	Total body	10	0.4	2×10^{-6}	0.1	5×10^{-7}
	Spleen	20	0.5	2×10^{-6}	0.2	8×10^{-7}
	Bone	300	10	4×10^{-5}	3	10^{-5}
(insol.)	**Lung**			10^{-7}		5×10^{-8}
	GI (LLI)		10^{-3}	2×10^{-7}	4×10^{-4}	7×10^{-8}
$_{83}Bi^{207}$ (sol.) ϵ, γ	**GI (LLI)**		2×10^{-3}	4×10^{-7}	6×10^{-4}	10^{-7}
	Kidney	2	0.04	2×10^{-7}	0.02	6×10^{-8}
	Liver	7	0.1	6×10^{-7}	0.05	2×10^{-7}
	Spleen	20	0.4	2×10^{-6}	0.1	5×10^{-7}
	Total body	20	0.4	2×10^{-6}	0.1	5×10^{-7}
	Bone	300	6	2×10^{-5}	2	8×10^{-6}
(insol.)	**Lung**			10^{-8}		5×10^{-9}
	GI (LLI)		2×10^{-3}	3×10^{-7}	6×10^{-4}	10^{-7}
$_{83}Bi^{210}$ (sol.) α, β^-	**GI (LLI)**		10^{-3}	3×10^{-7}	4×10^{-4}	9×10^{-8}
	Kidney	0.04	2×10^{-3}	6×10^{-9}	5×10^{-4}	2×10^{-9}
	Liver	0.5	0.02	8×10^{-8}	6×10^{-3}	3×10^{-8}
	Spleen	0.6	0.02	10^{-7}	8×10^{-3}	3×10^{-8}
	Total body	20	0.07	3×10^{-7}	0.03	10^{-7}
	Bone	6	0.2	10^{-6}	0.08	3×10^{-7}
(insol.)	**Lung**			6×10^{-9}		2×10^{-9}
	GI (LLI)		10^{-3}	2×10^{-7}	4×10^{-4}	7×10^{-8}
$_{83}Bi^{212}$ (sol.) α, β^-, γ	**GI (S)**		0.01	2×10^{-6}	4×10^{-3}	8×10^{-7}
	Kidney	0.01	0.02	10^{-7}	8×10^{-3}	3×10^{-8}
	Liver	0.1	0.3	10^{-6}	0.09	4×10^{-7}
	Spleen	0.2	0.4	10^{-6}	0.1	5×10^{-7}
	Total body	0.2	0.5	2×10^{-6}	0.2	8×10^{-7}
	Bone	0.9	2	8×10^{-6}	0.7	3×10^{-6}
(insol.)	**Lung**	0.01		2×10^{-7}		7×10^{-8}
	GI (S)	14.2	0.01	2×10^{-6}	4×10^{-3}	6×10^{-7}
$_{84}Po^{210}$ (sol.) α	**Spleen**	0.03	2×10^{-5}	5×10^{-10}	7×10^{-6}	2×10^{-10}
	Kidney	0.04	2×10^{-5}	5×10^{-10}	8×10^{-6}	2×10^{-10}
	Liver	0.1	7×10^{-5}	2×10^{-9}	3×10^{-5}	6×10^{-10}
	Total body	0.4	2×10^{-4}	5×10^{-9}	8×10^{-5}	2×10^{-9}

Radionuclide and type of decay	Organ of reference (critical organ **bold face**)	Maximum permissible burden in total body $q(\mu c)$	Maximum permissible concentrations: For 40 hr week $(MPC)_w$ $(\mu c/cm^3)$	For 40 hr week $(MPC)_a$ $(\mu c/cm^3)$	For 168 hr week $(MPC)_w$ $(\mu c/cm^3)$	For 168 hr week $(MPC)_a$ $(\mu c/cm^3)$
	Bone	0.5	3×10^{-4}	7×10^{-9}	10^{-4}	2×10^{-9}
	GI (LLI)		9×10^{-4}	2×10^{-7}	3×10^{-4}	7×10^{-8}
(insol.)	**Lung**	0.015		**2×10^{-10}**		**7×10^{-11}**
	GI (LLI)	1.14	**8×10^{-4}**	2×10^{-7}	**3×10^{-4}**	5×10^{-8}
$_{85}At^{211}$ (sol.) α, ϵ, γ	**Thyroid**	0.02	**5×10^{-5}**	**7×10^{-9}**	**2×10^{-5}**	**2×10^{-9}**
	Ovary	0.02	**5×10^{-5}**	**7×10^{-9}**	**2×10^{-5}**	3×10^{-9}
	Spleen	0.06	2×10^{-4}	3×10^{-8}	6×10^{-5}	9×10^{-9}
	Total body	0.3	8×10^{-4}	10^{-7}	3×10^{-4}	4×10^{-8}
	GI (S)		0.02	4×10^{-6}	7×10^{-3}	2×10^{-6}
(insol.)	**Lung**			**3×10^{-8}**		**10^{-8}**
	GI (ULI)		**2×10^{-3}**	4×10^{-7}	**7×10^{-4}**	10^{-7}
$_{86}Rn^{220}$ * $\alpha, \beta^-, \gamma, e^-$	**Lung**			**3×10^{-7}***		**10^{-7}** *
$_{86}Rn^{222}$ * α, β^-, γ	**Lung**			**3×10^{-8}***		**10^{-8}** *
$_{88}Ra^{223}$ (sol.) α, β^-, γ	**Bone**	0.05	**2×10^{-5}**	**2×10^{-9}**	**7×10^{-6}**	**6×10^{-10}**
	Total body	0.07	4×10^{-5}	3×10^{-9}	10^{-5}	10^{-9}
	GI (LLI)		2×10^{-4}	4×10^{-8}	6×10^{-5}	10^{-8}
(insol.)	**Lung**			**2×10^{-10}**		**8×10^{-11}**
	GI (LLI)		**10^{-4}**	2×10^{-8}	**4×10^{-5}**	7×10^{-9}
$_{88}Ra^{224}$ (sol.) $\alpha, \beta^-, \gamma, e^-$	**Bone**	0.06	**7×10^{-5}**	**5×10^{-9}**	**2×10^{-5}**	**2×10^{-9}**
	Total body	0.07	9×10^{-5}	8×10^{-9}	3×10^{-5}	3×10^{-9}
	GI (LLI)		2×10^{-4}	5×10^{-8}	7×10^{-5}	2×10^{-8}
(insol.)	**Lung**			**7×10^{-10}**		**2×10^{-10}**
	GI (LLI)		**2×10^{-4}**	3×10^{-8}	**5×10^{-5}**	9×10^{-9}
$_{88}Ra^{226}$ (sol.) α, β^-, γ	**Bone**	0.1	**4×10^{-7}**	**3×10^{-11}**	**10^{-7}**	**10^{-11}**
	Total body	0.2	6×10^{-7}	5×10^{-11}	2×10^{-7}	2×10^{-11}
	GI (LLI)		10^{-3}	3×10^{-7}	5×10^{-4}	10^{-7}
(insol.)	**GI (LLI)**		**9×10^{-4}**	**2×10^{-7}**	**3×10^{-4}**	**6×10^{-8}**
$_{88}Ra^{228}$ (sol.) $\alpha, \beta^-, \gamma, e^-$	**Bone**	0.06	**8×10^{-7}**	**7×10^{-11}**	**3×10^{-7}**	**2×10^{-11}**
	Total body	0.09	10^{-6}	9×10^{-11}	4×10^{-7}	3×10^{-11}
	GI (LLI)		10^{-3}	2×10^{-7}	4×10^{-4}	8×10^{-8}

* The daughter elements of Rn^{220} and Rn^{222} are assumed present to the extent they occur in unfiltered air. For all other isotopes the daughter elements are not considered as part of the intake and if present they must be considered on the basis of the rules for mixtures. (See Section IV.6, p. 23.)

Radionuclide and type of decay	Organ of reference (critical organ **bold face**)	Maximum permissible burden in total body $q(\mu c)$	Maximum permissible concentrations: For 40 hr week $(MPC)_w$ $(\mu c/cm^3)$	For 40 hr week $(MPC)_a$ $(\mu c/cm^3)$	For 168 hr week $(MPC)_w$ $(\mu c/cm^3)$	For 168 hr week $(MPC)_a$ $(\mu c/cm^3)$
(insol.)	**Lung**			**4×10^{-11}**		**10^{-11}**
	GI (LLI)		**7×10^{-4}**	10^{-7}	**3×10^{-4}**	4×10^{-8}
$_{89}Ac^{227}$ (sol.) α, β^-, γ	**Bone**	**0.03**	**6×10^{-5}**	**2×10^{-12}**	**2×10^{-5}**	**8×10^{-13}**
	Total body	0.1	2×10^{-4}	7×10^{-12}	6×10^{-5}	3×10^{-12}
	Liver	0.2	2×10^{-4}	10^{-11}	8×10^{-5}	3×10^{-12}
	Kidney	0.4	7×10^{-4}	3×10^{-11}	2×10^{-4}	9×10^{-12}
	GI (LLI)		9×10^{-3}	2×10^{-6}	3×10^{-3}	7×10^{-7}
(insol.)	**Lung**			**3×10^{-11}**		**9×10^{-12}**
	GI (LLI)		**9×10^{-3}**	2×10^{-6}	**3×10^{-3}**	5×10^{-7}
$_{89}Ac^{228}$ (sol.) $\alpha, \beta^-, \gamma, e^-$	**GI (ULI)**		**3×10^{-3}**	6×10^{-7}	**9×10^{-4}**	2×10^{-7}
	Bone	**0.04**	2	9×10^{-8}	0.5	**3×10^{-8}**
	Liver	**0.05**	2	**8×10^{-8}**	0.6	**3×10^{-8}**
	Total body	0.09	3	10^{-7}	1	5×10^{-8}
	Kidney	0.5	20	6×10^{-7}	6	2×10^{-7}
(insol.)	**Lung**			**2×10^{-8}**		**6×10^{-9}**
	GI (ULI)		**3×10^{-3}**	4×10^{-7}	**9×10^{-4}**	2×10^{-7}
$_{90}Th^{227}$ (sol.) α, β^-, γ	**GI (LLI)**		**5×10^{-4}**	10^{-7}	**2×10^{-4}**	4×10^{-8}
	Bone	**0.02**	8×10^{-3}	**3×10^{-10}**	3×10^{-3}	**10^{-10}**
	Kidney	0.08	0.04	2×10^{-9}	0.01	6×10^{-10}
	Total body	0.1	0.05	2×10^{-9}	0.02	7×10^{-10}
	Liver	0.5	0.2	10^{-8}	0.08	4×10^{-9}
(insol.)	**Lung**			**2×10^{-10}**		**6×10^{-11}**
	GI (LLI)		**5×10^{-4}**	9×10^{-8}	**2×10^{-4}**	3×10^{-8}
$_{90}Th^{228}$ (sol.) $\alpha, \beta^-, \gamma, e^-$	**Bone**	**0.02**	**2×10^{-4}**	**9×10^{-12}**	**7×10^{-5}**	**3×10^{-12}**
	GI (LLI)		4×10^{-4}	8×10^{-8}	10^{-4}	3×10^{-8}
	Kidney	0.09	10^{-3}	5×10^{-11}	4×10^{-4}	2×10^{-11}
	Total body	0.09	10^{-3}	5×10^{-11}	4×10^{-4}	2×10^{-11}
	Liver	0.5	7×10^{-3}	3×10^{-10}	2×10^{-3}	10^{-10}
(insol.)	**Lung**	0.0035		**6×10^{-12}**		**2×10^{-12}**
	GI (LLI)	0.57	**4×10^{-4}**	7×10^{-8}	**10^{-4}**	2×10^{-8}
$_{90}Th^{230}$ (sol.) α, γ	**Bone**	**0.05**	**5×10^{-5}**	**2×10^{-12}**	**2×10^{-5}**	**8×10^{-13}**
	Kidney	0.3	10^{-4}	4×10^{-12}	3×10^{-5}	2×10^{-12}
	Total body	0.4	3×10^{-4}	2×10^{-11}	10^{-4}	5×10^{-12}
	Liver	0.6	5×10^{-4}	2×10^{-11}	2×10^{-4}	7×10^{-12}
	GI (LLI)		9×10^{-4}	2×10^{-7}	3×10^{-4}	7×10^{-8}
(insol.)	**Lung**	0.018		**10^{-11}**		**3×10^{-12}**
	GI (LLI)	1.28	**9×10^{-4}**	2×10^{-7}	**3×10^{-4}**	6×10^{-8}

Radionuclide and type of decay	Organ of reference (critical organ **bold face**)	Maximum permissible burden in total body $q(\mu c)$	Maximum permissible concentrations: For 40 hr week, $(MPC)_w$ $(\mu c/cm^3)$	For 40 hr week, $(MPC)_a$ $(\mu c/cm^3)$	For 168 hr week, $(MPC)_w$ $(\mu c/cm^3)$	For 168 hr week, $(MPC)_a$ $(\mu c/cm^3)$
$_{90}Th^{231}$ (sol.) α, β^-, γ	**GI (LLI)**		7×10^{-3}	10^{-6}	2×10^{-3}	5×10^{-7}
	Bone	30	200	10^{-5}	80	4×10^{-6}
	Kidney	40	300	10^{-5}	100	5×10^{-6}
	Total body	100	900	4×10^{-5}	300	10^{-5}
	Liver	300	2×10^{3}	10^{-4}	800	3×10^{-5}
(insol.)	**GI (LLI)**	9.9	7×10^{-3}	10^{-6}	2×10^{-3}	4×10^{-7}
	Lung	7.64		6×10^{-6}		2×10^{-6}
$_{90}Th^{232}$ * (sol.) $\alpha, \beta^-, \gamma, e^-$	**Bone**	0.04	5×10^{-5}	2×10^{-12}*	2×10^{-5}	7×10^{-13}*
	Kidney	0.3	10^{-4}	5×10^{-12}	4×10^{-5}	2×10^{-12}
	Total body	0.3	3×10^{-4}	10^{-11}	9×10^{-5}	4×10^{-12}
	Liver	0.7	6×10^{-4}	3×10^{-11}	2×10^{-4}	9×10^{-12}
	GI (LLI)		10^{-3}	2×10^{-7}	4×10^{-4}	8×10^{-8}
(insol.)	**Lung**			10^{-11}		4×10^{-12}
	GI (LLI)		10^{-3}	2×10^{-7}	4×10^{-4}	7×10^{-8}
$_{90}Th^{234}$ (sol.) β^-, γ	**GI (LLI)**		5×10^{-4}	10^{-7}	2×10^{-4}	4×10^{-8}
	Bone	4	1	6×10^{-8}	0.5	2×10^{-8}
	Kidney	6	2	9×10^{-8}	0.7	3×10^{-8}
	Total body	20	8	4×10^{-7}	3	10^{-7}
	Liver	30	10	5×10^{-7}	4	2×10^{-7}
(insol.)	**Lung**			3×10^{-8}		10^{-8}
	GI (LLI)		5×10^{-4}	9×10^{-8}	2×10^{-4}	3×10^{-8}
$_{90}$Th-Nat * (sol.) $\alpha, \beta^-, \gamma, e^-$	**Bone**	0.01	3×10^{-5}	2×10^{-12}*	10^{-5}	6×10^{-13}*
	Kidney	0.07	10^{-4}	4×10^{-12}	4×10^{-5}	2×10^{-12}
	Total body	0.07	2×10^{-4}	9×10^{-12}	7×10^{-5}	3×10^{-12}
	GI (LLI)		3×10^{-4}	6×10^{-8}	10^{-4}	2×10^{-8}
	Liver	0.3	5×10^{-4}	2×10^{-11}	2×10^{-4}	8×10^{-12}
(insol.)	**Lung**			4×10^{-12}		10^{-12}
	GI (LLI)		3×10^{-4}	5×10^{-8}	10^{-4}	2×10^{-8}
$_{91}Pa^{230}$ (sol.) $\alpha, \beta^-, \epsilon, \gamma$	**GI (LLI)**		7×10^{-3}	2×10^{-6}	2×10^{-3}	5×10^{-7}
	Bone	0.07	0.04	2×10^{-9}	0.01	6×10^{-10}
	Kidney	0.2	0.1	5×10^{-9}	0.04	2×10^{-9}
	Total body	0.3	0.2	8×10^{-9}	0.06	3×10^{-9}

* *Provisional values for* Th^{232} *and* Th-nat. Although calculations and animal experiments suggest that Th-nat, if injected intravenously, is perhaps as hazardous as Pu and indicate the values listed above, experience to date has suggested that in industrial circumstances the hazard of Th-nat is not much greater than that of U-nat. Therefore, pending further investigation the values $(MPC)_a = 3 \times 10^{-11}$ $\mu c/cm^3$ for the 40-hour week and $(MPC)_a = 10^{-11}$ $\mu c/cm^3$ for continuous occupational exposure (168 hr/wk) are recommended as provisional levels, permissible for exposure to inhaled Th-nat or Th^{232}. However, the values given in *Table 1* are listed to indicate the possibility that further evidence may require lower values and to urge especially that exposure levels for these radionuclides be kept as low as is operationally possible. It may be possible to show that similar considerations apply to other inhaled long-lived thorium isotopes under conditions in which the physical characteristics of the airborne particulates are much the same as in the case of Th-nat, and where there is a large amount of airborne material serving as an effective carrier for the thorium.

Radionuclide and type of decay	Organ of reference (critical organ **bold face**)	Maximum permissible burden in total body $q(\mu c)$	Maximum permissible concentrations: For 40 hr week $(MPC)_w$ ($\mu c/cm^3$)	For 40 hr week $(MPC)_a$ ($\mu c/cm^3$)	For 168 hr week $(MPC)_w$ ($\mu c/cm^3$)	For 168 hr week $(MPC)_a$ ($\mu c/cm^3$)
(insol.)	**Lung**			8×10^{-10}		3×10^{-10}
	GI (LLI)		7×10^{-3}	10^{-6}	2×10^{-3}	4×10^{-7}
$_{91}Pa^{231}$ (sol.) α, β^-, γ	**Bone**	0.02	3×10^{-5}	10^{-12}	9×10^{-6}	4×10^{-13}
	Kidney	0.06	7×10^{-5}	3×10^{-12}	2×10^{-5}	10^{-12}
	Total body	0.1	10^{-4}	5×10^{-12}	4×10^{-5}	2×10^{-12}
	Liver	0.3	4×10^{-4}	2×10^{-11}	10^{-4}	5×10^{-12}
	GI (LLI)		8×10^{-4}	2×10^{-7}	3×10^{-4}	6×10^{-8}
(insol.)	**Lung**			10^{-10}		4×10^{-11}
	GI (LLI)		8×10^{-4}	10^{-7}	3×10^{-4}	5×10^{-8}
$_{91}Pa^{233}$ (sol.) β^-, γ	**GI (LLI)**		4×10^{-3}	8×10^{-7}	10^{-3}	3×10^{-7}
	Kidney	40	10	6×10^{-7}	5	2×10^{-7}
	Bone	60	20	9×10^{-7}	7	3×10^{-7}
	Total body	60	20	9×10^{-7}	7	3×10^{-7}
	Liver	200	50	2×10^{-6}	20	8×10^{-7}
(insol.)	**Lung**			2×10^{-7}		6×10^{-8}
	GI (LLI)		3×10^{-3}	6×10^{-7}	10^{-3}	2×10^{-7}
$_{92}U^{230}$ (sol.) α, β^-, γ	**GI (LLI)**		10^{-4}	3×10^{-8}	5×10^{-5}	10^{-8}
	Kidney	0.01	7×10^{-3}	3×10^{-10}	2×10^{-3}	10^{-10}
	Total body	0.06	0.03	10^{-9}	0.01	5×10^{-10}
	Bone	7×10^{-3}	0.04	2×10^{-9}	0.02	6×10^{-10}
(insol.)	**Lung**	0.0024		10^{-10}		4×10^{-11}
	GI (LLI)	0.142	10^{-4}	2×10^{-8}	5×10^{-5}	8×10^{-9}
$_{92}U^{232}$ (sol.) $\alpha, \beta^-, \gamma, e^-$	**GI (LLI)**		8×10^{-4}	2×10^{-7}	3×10^{-4}	6×10^{-8}
	Bone	0.01	2×10^{-3}	10^{-10}	8×10^{-4}	3×10^{-11}
	Total body	0.07	6×10^{-3}	3×10^{-10}	2×10^{-3}	10^{-10}
	Kidney	0.04	0.01	6×10^{-10}	4×10^{-3}	2×10^{-10}
(insol.)	**Lung**	0.004		3×10^{-11}		9×10^{-12}
	GI (LLI)	1.14	8×10^{-4}	10^{-7}	3×10^{-4}	5×10^{-8}
$_{92}U^{233}$ (sol.) α, γ	**GI (LLI)**		9×10^{-4}	2×10^{-7}	3×10^{-4}	7×10^{-8}
	Bone	0.05	0.01	5×10^{-10}	4×10^{-3}	2×10^{-10}
	Kidney	0.08	0.03	10^{-9}	0.01	4×10^{-10}
	Total body	0.4	0.04	2×10^{-9}	0.01	5×10^{-10}
(insol.)	**Lung**	0.017		10^{-10}		4×10^{-11}
	GI (LLI)	1.28	9×10^{-4}	2×10^{-7}	3×10^{-4}	6×10^{-8}
$_{92}U^{234}$ (sol.) α, γ	**GI (LLI)**		9×10^{-4}	2×10^{-7}	3×10^{-4}	7×10^{-8}
	Bone	0.05	0.01	6×10^{-10}	4×10^{-3}	2×10^{-10}
	Kidney	0.08	0.03	10^{-9}	0.01	4×10^{-10}
	Total body	0.4	0.04	2×10^{-9}	0.01	6×10^{-10}

Radionuclide and type of decay	Organ of reference (critical organ **bold face**)	Maximum permissible burden in total body $q(\mu c)$	Maximum permissible concentrations			
			For 40 hr week		For 168 hr week	
			$(MPC)_w$ $(\mu c/cm^3)$	$(MPC)_a$ $(\mu c/cm^3)$	$(MPC)_w$ $(\mu c/cm^3)$	$(MPC)_a$ $(\mu c/cm^3)$
(insol.)	**Lung** GI (LLI)		 9×10^{-4}	10^{-10} 2×10^{-7}	 3×10^{-4}	4×10^{-11} 6×10^{-8}
$_{92}U^{235}$ (sol.) α, β^-, γ	GI (LLI) **Kidney** **Bone** Total body	 0.03 0.06 0.4	8×10^{-4} 0.01 0.01 0.04	2×10^{-7} 5×10^{-10} 6×10^{-10} 2×10^{-9}	3×10^{-4} 4×10^{-3} 5×10^{-3} 0.01	6×10^{-8} 2×10^{-10} 2×10^{-10} 6×10^{-10}
(insol.)	**Lung** GI (LLI)		 8×10^{-4}	10^{-10} 10^{-7}	 3×10^{-4}	4×10^{-11} 5×10^{-8}
$_{92}U^{236}$ (sol.) α, γ	GI (LLI) **Bone** Kidney Total body	 0.06 0.08 0.4	10^{-3} 0.01 0.03 0.04	2×10^{-7} 6×10^{-10} 10^{-9} 2×10^{-9}	3×10^{-4} 5×10^{-3} 0.01 0.01	7×10^{-8} 2×10^{-10} 4×10^{-10} 6×10^{-10}
(insol.)	**Lung** GI (LLI)		 10^{-3}	10^{-10} 2×10^{-7}	 3×10^{-4}	4×10^{-11} 6×10^{-8}
$_{92}U^{238}$ (sol.) α, γ, e^-	GI (LLI) **Kidney** Bone Total body	 5×10^{-3} 0.06 0.5	10^{-3} 2×10^{-3} 0.01 0.04	2×10^{-7} 7×10^{-11} 6×10^{-10} 2×10^{-9}	4×10^{-4} 6×10^{-4} 5×10^{-3} 0.01	8×10^{-8} 3×10^{-11} 2×10^{-10} 6×10^{-10}
(insol.)	**Lung** GI (LLI)		 10^{-3}	10^{-10} 2×10^{-7}	 4×10^{-4}	5×10^{-11} 6×10^{-8}
$_{92}$U–Natural (sol.) $\alpha, \beta^-, \gamma, e^-$	GI (LLI) **Kidney** Bone Total body	 5×10^{-3} 0.03 0.2	5×10^{-4} 2×10^{-3} 6×10^{-3} 0.02	10^{-7} 7×10^{-11} 3×10^{-10} 8×10^{-10}	2×10^{-4} 6×10^{-4} 2×10^{-3} 7×10^{-3}	4×10^{-8} 3×10^{-11} 10^{-10} 3×10^{-10}
(insol.)	**Lung** GI (LLI)		 5×10^{-4}	6×10^{-11} 8×10^{-8}	 2×10^{-4}	2×10^{-11} 3×10^{-8}
$_{93}Np^{237}$ (sol.) α, β^-, γ	**Bone** Kidney Total body Liver GI (LLI)	0.06 0.1 0.5 0.5	9×10^{-5} 2×10^{-4} 4×10^{-4} 6×10^{-4} 9×10^{-4}	4×10^{-12} 7×10^{-12} 2×10^{-11} 2×10^{-11} 2×10^{-7}	3×10^{-5} 6×10^{-5} 10^{-4} 2×10^{-4} 3×10^{-4}	10^{-12} 2×10^{-12} 6×10^{-12} 8×10^{-12} 7×10^{-8}
(insol.)	**Lung** GI (LLI)		 9×10^{-4}	10^{-10} 2×10^{-7}	 3×10^{-4}	4×10^{-11} 5×10^{-8}
$_{93}Np^{239}$ (sol.) α, β^-, γ	**GI (LLI)** Bone Kidney	 30 40	4×10^{-3} 100 200	8×10^{-7} 4×10^{-6} 7×10^{-6}	10^{-3} 30 50	3×10^{-7} 2×10^{-6} 2×10^{-6}

Radionuclide and type of decay		Organ of reference (critical organ **bold face**)	Maximum permissible burden in total body $q(\mu c)$	Maximum permissible concentrations: For 40 hr week $(MPC)_w$ $(\mu c/cm^3)$	For 40 hr week $(MPC)_a$ $(\mu c/cm^3)$	For 168 hr week $(MPC)_w$ $(\mu c/cm^3)$	For 168 hr week $(MPC)_a$ $(\mu c/cm^3)$
		Total body	70	300	10^{-5}	90	4×10^{-6}
		Liver	100	500	2×10^{-5}	200	8×10^{-6}
	(insol.)	**GI (LLI)**		**4×10^{-3}**	**7×10^{-7}**	**10^{-3}**	**2×10^{-7}**
		Lung	5.25		2×10^{-6}		7×10^{-7}
$_{94}Pu^{238}$ α, γ	(sol.)	**Bone**	0.04	**10^{-4}**	**2×10^{-12}**	**5×10^{-5}**	**7×10^{-13}**
		Liver	0.2	6×10^{-4}	8×10^{-12}	2×10^{-4}	3×10^{-12}
		Kidney	0.3	8×10^{-4}	10^{-11}	3×10^{-4}	4×10^{-12}
		GI (LLI)		8×10^{-4}	2×10^{-7}	3×10^{-4}	6×10^{-8}
		Total body	0.3	10^{-3}	10^{-11}	4×10^{-4}	5×10^{-12}
	(insol.)	**Lung**	0.015		**3×10^{-11}**		**10^{-11}**
		GI (LLI)		**8×10^{-4}**	10^{-7}	**3×10^{-4}**	5×10^{-8}
$_{94}Pu^{239}$ α, γ	(sol.)	**Bone**	0.04	**10^{-4}**	**2×10^{-12}**	**5×10^{-5}**	**6×10^{-13}**
		Liver	0.4	5×10^{-4}	7×10^{-12}	2×10^{-4}	2×10^{-12}
		Kidney	0.5	7×10^{-4}	9×10^{-12}	2×10^{-4}	3×10^{-12}
		GI (LLI)		8×10^{-4}	2×10^{-7}	3×10^{-4}	6×10^{-8}
		Total body	0.4	10^{-3}	10^{-11}	3×10^{-4}	5×10^{-12}
	(insol.)	**Lung**	0.016		**4×10^{-11}**		**10^{-11}**
		GI (LLI)		**8×10^{-4}**	2×10^{-7}	**3×10^{-4}**	5×10^{-8}
$_{94}Pu^{240}$ α, γ	(sol.)	**Bone**	0.04	**10^{-4}**	**2×10^{-12}**	**5×10^{-5}**	**6×10^{-13}**
		Liver	0.4	5×10^{-4}	7×10^{-12}	2×10^{-4}	2×10^{-12}
		Kidney	0.5	7×10^{-4}	9×10^{-12}	2×10^{-4}	3×10^{-12}
		GI (LLI)		8×10^{-4}	2×10^{-7}	3×10^{-4}	6×10^{-8}
		Total body	0.4	10^{-3}	10^{-11}	3×10^{-4}	5×10^{-12}
	(insol.)	**Lung**	0.016		**4×10^{-11}**		**10^{-11}**
		GI (LLI)		**8×10^{-4}**	2×10^{-7}	**3×10^{-4}**	5×10^{-8}
$_{94}Pu^{241}$ α, β^-, γ	(sol.)	**Bone**	0.9	**7×10^{-3}**	**9×10^{-11}**	**2×10^{-3}**	**3×10^{-11}**
		Kidney	5	0.04	5×10^{-10}	0.01	2×10^{-10}
		GI (LLI)		0.04	8×10^{-6}	0.01	3×10^{-6}
		Total body	9	0.06	8×10^{-10}	0.02	3×10^{-10}
		Liver	10	0.07	10^{-9}	0.03	3×10^{-10}
	(insol.)	**Lung**	.16		**4×10^{-8}**		**10^{-8}**
		GI (LLI)		**0.04**	7×10^{-6}	**0.01**	2×10^{-6}
$_{94}Pu^{242}$ α	(sol.)	**Bone**	0.05	**10^{-4}**	**2×10^{-12}**	**5×10^{-5}**	**6×10^{-13}**
		Liver	0.4	6×10^{-4}	7×10^{-12}	2×10^{-4}	3×10^{-12}
		Kidney	0.5	7×10^{-4}	10^{-11}	3×10^{-4}	3×10^{-12}
		GI (LLI)		9×10^{-4}	2×10^{-7}	3×10^{-4}	7×10^{-8}
		Total body	0.4	10^{-3}	10^{-11}	4×10^{-4}	5×10^{-12}

Radionuclide and type of decay	Organ of reference (critical organ **bold face**)	Maximum permissible burden in total body $q(\mu c)$	Maximum permissible concentrations: For 40 hr week $(MPC)_w$ $(\mu c/cm^3)$	For 40 hr week $(MPC)_a$ $(\mu c/cm^3)$	For 168 hr week $(MPC)_w$ $(\mu c/cm^3)$	For 168 hr week $(MPC)_a$ $(\mu c/cm^3)$
(insol.)	**Lung**	.016		4×10^{-11}		10^{-11}
	GI (LLI)		9×10^{-4}	2×10^{-7}	3×10^{-4}	5×10^{-8}
$_{95}Am^{241}$ (sol.) α, γ	**Kidney**	0.1	10^{-4}	6×10^{-12}	4×10^{-5}	2×10^{-12}
	Bone	0.05	10^{-4}	6×10^{-12}	5×10^{-5}	2×10^{-12}
	Liver	0.4	2×10^{-4}	9×10^{-12}	7×10^{-5}	3×10^{-12}
	Total body	0.3	4×10^{-4}	2×10^{-11}	10^{-4}	5×10^{-12}
	GI (LLI)		8×10^{-4}	2×10^{-7}	3×10^{-4}	6×10^{-8}
(insol.)	**Lung**	.0147		10^{-10}		4×10^{-11}
	GI (LLI)		8×10^{-4}	10^{-7}	3×10^{-4}	5×10^{-8}
$_{95}Am^{243}$ (sol.) α, β^-, γ	**Bone**	0.05	10^{-4}	6×10^{-12}	4×10^{-5}	2×10^{-12}
	Kidney	0.1	10^{-4}	6×10^{-12}	5×10^{-5}	2×10^{-12}
	Liver	0.4	2×10^{-4}	9×10^{-12}	7×10^{-5}	3×10^{-12}
	Total body	0.4	4×10^{-4}	2×10^{-11}	10^{-4}	5×10^{-12}
	GI (LLI)		8×10^{-4}	2×10^{-7}	3×10^{-4}	6×10^{-8}
(insol.)	**Lung**			10^{-10}		4×10^{-11}
	GI (LLI)		8×10^{-4}	10^{-7}	3×10^{-4}	5×10^{-8}
$_{96}Cm^{242}$ (sol.) α, γ	**GI (LLI)**		7×10^{-4}	2×10^{-7}	2×10^{-4}	5×10^{-8}
	Liver	0.05	3×10^{-3}	10^{-10}	9×10^{-4}	4×10^{-11}
	Bone	0.09	5×10^{-3}	2×10^{-10}	2×10^{-3}	8×10^{-11}
	Kidney	0.2	9×10^{-3}	4×10^{-10}	3×10^{-3}	10^{-10}
	Total body	0.2	0.01	6×10^{-10}	5×10^{-3}	2×10^{-10}
(insol.)	**Lung**	0.013		2×10^{-10}		6×10^{-11}
	GI (LLI)	0.99	7×10^{-4}	10^{-7}	2×10^{-4}	4×10^{-8}
$_{96}Cm^{243}$ (sol.) α, γ	**Bone**	0.09	10^{-4}	6×10^{-12}	5×10^{-5}	2×10^{-12}
	Liver	0.2	2×10^{-4}	10^{-11}	8×10^{-5}	3×10^{-12}
	Kidney	0.2	3×10^{-4}	10^{-11}	10^{-4}	4×10^{-12}
	Total body	0.3	5×10^{-4}	2×10^{-11}	2×10^{-4}	7×10^{-12}
	GI (LLI)		7×10^{-4}	2×10^{-7}	2×10^{-4}	5×10^{-8}
(insol.)	**Lung**			10^{-10}		3×10^{-11}
	GI (LLI)		7×10^{-4}	10^{-7}	2×10^{-4}	4×10^{-8}
$_{96}Cm^{244}$ (sol.) α, γ	**Bone**	0.1	2×10^{-4}	9×10^{-12}	7×10^{-5}	3×10^{-12}
	Liver	0.2	3×10^{-4}	10^{-11}	9×10^{-5}	4×10^{-12}
	Kidney	0.2	4×10^{-4}	2×10^{-11}	10^{-4}	6×10^{-12}
	Total body	0.3	6×10^{-4}	3×10^{-11}	2×10^{-4}	9×10^{-12}
	GI (LLI)		8×10^{-4}	2×10^{-7}	3×10^{-4}	6×10^{-8}
(insol.)	**Lung**	0.014		10^{-10}		3×10^{-11}
	GI (LLI)	1.14	8×10^{-4}	10^{-7}	3×10^{-4}	5×10^{-8}

Radionuclide and type of decay		Organ of reference (critical organ **bold face**)	Maximum permissible burden in total body $q(\mu c)$	Maximum permissible concentrations			
				For 40 hr week		For 168 hr week	
				$(MPC)_w$ ($\mu c/cm^3$)	$(MPC)_a$ ($\mu c/cm^3$)	$(MPC)_w$ ($\mu c/cm^3$)	$(MPC)_a$ ($\mu c/cm^3$)
$_{96}Cm^{245}$	(sol.)	**Bone**	0.04	$\mathbf{10^{-4}}$	$\mathbf{5 \times 10^{-12}}$	$\mathbf{4 \times 10^{-5}}$	$\mathbf{2 \times 10^{-12}}$
α, β^-, γ		Liver	0.5	2×10^{-4}	8×10^{-12}	7×10^{-5}	3×10^{-12}
		Kidney	0.2	2×10^{-4}	9×10^{-12}	7×10^{-5}	3×10^{-12}
		Total body	0.4	3×10^{-4}	10^{-11}	10^{-4}	5×10^{-12}
		GI (LLI)		8×10^{-4}	2×10^{-7}	3×10^{-4}	6×10^{-8}
	(insol.)	**Lung**			$\mathbf{10^{-10}}$		$\mathbf{4 \times 10^{-11}}$
		GI (LLI)		$\mathbf{8 \times 10^{-4}}$	10^{-7}	$\mathbf{3 \times 10^{-4}}$	5×10^{-8}
$_{96}Cm^{246}$	(sol.)	**Bone**	0.05	$\mathbf{10^{-4}}$	$\mathbf{5 \times 10^{-12}}$	$\mathbf{4 \times 10^{-5}}$	$\mathbf{2 \times 10^{-12}}$
α		Liver	0.5	2×10^{-4}	8×10^{-12}	7×10^{-5}	3×10^{-12}
		Kidney	0.2	2×10^{-4}	9×10^{-12}	7×10^{-5}	3×10^{-12}
		Total body	0.4	3×10^{-4}	10^{-11}	10^{-4}	5×10^{-12}
		GI (LLI)		8×10^{-4}	2×10^{-7}	3×10^{-4}	6×10^{-8}
	(insol.)	**Lung**			$\mathbf{10^{-10}}$		$\mathbf{4 \times 10^{-11}}$
		GI (LLI)		$\mathbf{8 \times 10^{-4}}$	10^{-7}	$\mathbf{3 \times 10^{-4}}$	5×10^{-8}
$_{97}Bk^{249}$	(sol.)	**GI (LLI)**		**0.02**	4×10^{-6}	$\mathbf{6 \times 10^{-3}}$	10^{-6}
α, β^-, γ		**Bone**	0.7	0.07	$\mathbf{9 \times 10^{-10}}$	0.02	$\mathbf{3 \times 10^{-10}}$
		Total body	5	0.5	7×10^{-9}	0.2	2×10^{-9}
	(insol.)	**Lung**			$\mathbf{10^{-7}}$		$\mathbf{4 \times 10^{-8}}$
		GI (LLI)		**0.02**	3×10^{-6}	$\mathbf{6 \times 10^{-3}}$	10^{-6}
$_{98}Cf^{249}$	(sol.)	**Bone**	0.04	$\mathbf{10^{-4}}$	$\mathbf{2 \times 10^{-12}}$	$\mathbf{4 \times 10^{-5}}$	$\mathbf{5 \times 10^{-13}}$
α, γ		GI (LLI)		7×10^{-4}	2×10^{-7}	2×10^{-4}	5×10^{-8}
		Total body	0.3	9×10^{-4}	10^{-11}	3×10^{-4}	4×10^{-12}
	(insol.)	**Lung**			$\mathbf{10^{-10}}$		$\mathbf{3 \times 10^{-11}}$
		GI (LLI)		$\mathbf{7 \times 10^{-4}}$	10^{-7}	$\mathbf{2 \times 10^{-4}}$	4×10^{-8}
$_{98}Cf^{250}$	(sol.)	**Bone**	0.04	$\mathbf{4 \times 10^{-4}}$	$\mathbf{5 \times 10^{-12}}$	$\mathbf{10^{-4}}$	$\mathbf{2 \times 10^{-12}}$
α		GI (LLI)		7×10^{-4}	2×10^{-7}	3×10^{-4}	6×10^{-8}
		Total body	0.3	3×10^{-3}	4×10^{-11}	10^{-3}	10^{-11}
	(insol.)	**Lung**	0.014		$\mathbf{10^{-10}}$		$\mathbf{3 \times 10^{-11}}$
		GI (LLI)	0.99	$\mathbf{7 \times 10^{-4}}$	10^{-7}	$\mathbf{3 \times 10^{-4}}$	4×10^{-8}
$_{98}Cf^{252}$	(sol.)	**GI (LLI)**		$\mathbf{2 \times 10^{-4}}$	4×10^{-8}	$\mathbf{7 \times 10^{-5}}$	2×10^{-8}
α, γ		**Bone**	0.01	5×10^{-4}	$\mathbf{6 \times 10^{-12}}$	2×10^{-4}	$\mathbf{2 \times 10^{-12}}$
Spontaneous Fission		Total body	0.09	4×10^{-3}	5×10^{-11}	10^{-3}	2×10^{-11}
	(insol.)	**Lung**	0.004		$\mathbf{3 \times 10^{-11}}$		$\mathbf{10^{-11}}$
		GI (LLI)		$\mathbf{2 \times 10^{-4}}$	4×10^{-8}	$\mathbf{7 \times 10^{-5}}$	10^{-8}
$_{98}Cf^{254}$ Spontaneous Fission only							

Table 2. Radionuclides which do not reach equilibrium in the body within 50 years

Z	Radionuclide	T_r (years)	T_b (years)	T (years)	Percentage equil. reached in 50 years
38	Sr^{90}	28	50	18	86
88	Ra^{226}	1622	45	44	56
89	Ac^{227}	21.8	200	20	83
90	Th^{230}	8.0×10^4	200	200	16
90	Th^{232}	1.38×10^{10}	200	200	16
91	Pa^{231}	3.43×10^4	200	200	16
93	Np^{237}	2.20×10^6	200	200	16
94	Pu^{238}	89.6	200	62	43
94	Pu^{239}	2.44×10^4	200	200	16
94	Pu^{240}	6.6×10^3	200	190	16
94	Pu^{241}	13.2	200	12	94
94	Pu^{242}	3.8×10^5	200	200	16
95	Am^{241}	462	200	140	22
95	Am^{243}	8×10^3	200	200	16
96	Cm^{243}	35	200	30	69
96	Cm^{244}	18.4	200	17	87
96	Cm^{245}	2×10^4	200	200	16
96	Cm^{246}	6.6×10^3	200	190	16
98	Cf^{249}	4.7×10^2	200	140	22
98	Cf^{250}	10	200	10	97

Table 3. Maximum permissible concentration of unidentified radionuclides in water, $(MPCU)_w$ values, for continuous occupational exposure*

Limitations	μc/cm³ of water†	
If no one of the radionuclides Sr^{90}, I^{126}, I^{129}, I^{131}, Pb^{210}, Po^{210}, At^{211}, Ra^{223}, Ra^{224}, Ra^{226}, Ra^{228}, Ac^{227}, Th^{230}, Pa^{231}, Th^{232}, and Th-nat is present, then the $(MPCU)_w$ is	3×10^{-5}	66
If no one of the radionuclides Sr^{90}, I^{129}, Pb^{210}, Po^{210}, Ra^{223}, Ra^{226}, Ra^{228}, Pa^{231}, and Th-nat is present, then the $(MPCU)_w$ is	2×10^{-5}	44
If no one of the radionuclides Sr^{90}, I^{129}, Pb^{210}, Ra^{226}, and Ra^{228} is present, then the $(MPCU)_w$ is	7×10^{-6}	15.4
If neither Ra^{226} nor Ra^{228} is present, then the $(MPCU)_w$ is	10^{-6}	2.2
If no analysis of the water is made, then the $(MPCU)_w$ is	10^{-7}	0.22

* Each $(MPCU)_w$ value is the smallest value of $(MPC)_w$ in Table 1 for radionuclides other than those listed opposite the value. Thus these $(MPCU)_w$ values are permissible levels for continuous occupational exposure (168 hr/wk) for any radionuclide or mixture of radionuclides where the indicated isotopes are not present (i.e., where the concentration of the radionuclide in water is small compared with the $(MPC)_w$ value for this radionuclide). The $(MPCU)_w$ may be much smaller than the more exact maximum permissible concentration of the material, but the determination of this $(MPC)_w$ requires identification of the radionuclides present and the concentration of each.

† Use one-tenth of these values for interim application in the neighborhood of an atomic energy plant.

Table 4. Maximum permissible concentration of unidentified radionuclides in air, $(MPCU)_a$ values, for continuous occupational exposure*

Limitations	μc/cm³ of air†	pc/
If there are no α-emitting radionuclides and if no one of the β-emitting radionuclides Sr^{90}, I^{129}, Pb^{210}, Ac^{227}, Ra^{228}, Pa^{230}, Pu^{241}, and Bk^{249} is present, then the $(MPCU)_a$ is	10^{-9} (418,000)	28,000
If there are no α-emitting radionuclides and if no one of the β-emitting radionuclides Pb^{210}, Ac^{227}, Ra^{228}, and Pu^{241} is present, then the $(MPCU)_a$ is	10^{-10} (41,800)	2800
If there are no α-emitting radionuclides and if the β-emitting radionuclide Ac^{227} is not present, then the $(MPCU)_a$ is	10^{-11} (4,180)	280
If no one of the radionuclides Ac^{227}, Th^{230}, Pa^{231}, Th^{232}, Th-nat, Pu^{238}, Pu^{239}, Pu^{240}, Pu^{242}, and Cf^{249} is present, then the $(MPCU)_a$ is	10^{-12} (418)	28.0
If no one of the radionuclides Pa^{231}, Th-nat, Pu^{239}, Pu^{240}, Pu^{242}, and Cf^{249} is present, then the $(MPCU)_a$ is	7×10^{-13} (292)	19.6
If no analysis of the air is made, then the $(MPCU)_a$ is	4×10^{-13} (167)	11.2

* Each $(MPCU)_a$ value is the smallest value of $(MPC)_a$ in Table 1 for radionuclides other than those listed opposite the value. Thus these $(MPCU)_a$ values are permissible levels for continuous occupational exposure (168 hr/wk) for any radionuclide or mixture of radionuclides where the indicated isotopes are not present (i.e., where the concentration of the radionuclide in air is small compared with the $(MPC)_a$ value for this radionuclide). The $(MPCU)_a$ value may be much smaller than the more exact maximum permissible concentration of the material, but the determination of this $(MPC)_a$ requires identification of the radionuclides present and the concentration of each.

† Use one-tenth of these values for interim application in the neighborhood of an atomic energy plant.

(for 40 hour/wk occupan)

dpm/100 cm² surface

if 1 particle inhaled per hour for every 500/sq ft. of surface

Uranium (6×10 for 40 hr)

13,480

Table 5. Ef[illegible]ve energies

Z	Radionuclide (T_r in days)	Organ of reference*	$\Sigma EF(\mathrm{RBE})n$ (E in MeV)
1	H^3(HTO or H_2^3O)	Total body	0.010
	(4.5×10^3)	Submersion	0.010
		Body tissue	0.010
4	Be^7	Total body	0.035
	(53.6)	Lung (insol.)	0.016
		GI (S)	0.016
		GI (SI)	0.035
		GI (LI)	0.0085
		Kidney	0.012
		Liver	0.016
		Bone	0.0085
		Spleen	0.012
6	$C^{14}(CO_2)$	Total body	0.054
	(2.0×10^6)	GI (S)	0.054
		GI (SI)	0.054
		GI (LI)	0.054
		Submersion	0.054
		Fat	0.054
		Bone	0.27
9	F^{18}	Total body	0.89
	(0.078)	Lung (insol.)	0.54
		GI (S)	0.54
		GI (SI)	0.89
		GI (LI)	0.41
		Bone and teeth	1.4
11	Na^{22}	Total body	1.6
	(950)	Lung (insol.)	0.80
		GI (S)	0.80
		GI (SI)	1.6
		GI (LI)	0.53
11	Na^{24}	Total body	2.7
	(0.63)	Lung (insol.)	1.5

Z	Radionuclide (T_r in days)	Organ of reference	$\Sigma EF(\mathrm{RBE})n$ (E in MeV)
		GI (SI)	2.3
		GI (LI)	1.7
18	A^{37}	Submersion	0.0026
	(34.1)		
18	A^{41}	Submersion	1.8
	(0.076)		
19	K^{42}	Total body	1.6
	(0.52)	Lung (insol.)	1.5
		GI (S)	1.5
		GI (SI)	1.6
		GI (LI)	1.5
		Brain	1.5
		Spleen	1.5
		Muscle	1.6
		Liver	1.5
20	Ca^{45}	Total body	0.086
	(164)	Lung (insol.)	0.086
		GI (S)	0.086
		GI (SI)	0.086
		GI (LI)	0.086
		Bone	0.43
20	Ca^{47}	Total body	1.4
	(4.9)	Lung (insol.)	0.81
	Sc^{47}	Bone	2.6
	(3.43)		
21	Sc^{46}	Total body	1.3
	(85)	Lung (insol.)	0.64
		GI (S)	0.64
		GI (SI)	1.3
		GI (LI)	0.40
		Liver	0.64

		GI (S)	1.5
		GI (SI)	2.7
		GI (LI)	1.0
14	Si^{31} (0.11)	Total body	0.59
		Lung (insol.)	0.59
		GI (S)	0.59
		GI (SI)	0.59
		GI (LI)	0.59
		Adrenal	0.59
		Testis	0.59
		Ovary	0.59
		Skin	0.59
		Lung (sol.)	0.59
15	P^{32} (14.3)	Total body	0.69
		Lung (insol.)	0.69
		GI (S)	0.69
		GI (SI)	0.69
		GI (LI)	0.69
		Liver	0.69
		Bone	3.5
		Brain	0.69
16	S^{35} (87.1)	Total body	0.056
		Lung (insol.)	0.056
		GI (S)	0.056
		GI (SI)	0.056
		GI (LI)	0.056
		Testis	0.056
		Bone	0.28
		Skin	0.056
17	Cl^{36} (1.2×10^8)	Total body	0.26
		Lung (insol.)	0.26
		GI (S)	0.26
		GI (SI)	0.26
		GI (LI)	0.26
17	Cl^{38} (0.026)	Total body	2.3
		Lung (insol.)	1.9
		GI (S)	1.9
		Kidney	0.50
		Bone	0.90
21	Sc^{47} (3.43)	Total body	0.26
		Lung (insol.)	0.21
		GI (S)	0.21
		GI (SI)	0.26
		GI (LI)	0.19
		Liver	0.21
		Kidney	0.20
		Bone	0.89
21	Sc^{48} (1.83)	Total body	2.2
		Lung (insol.)	1.1
		GI (S)	1.1
		GI (SI)	2.2
		GI (LI)	0.69
		Kidney	0.85
		Liver	1.1
		Bone	1.6
23	V^{48} (16.1)	Total body	1.9
		Lung (insol.)	0.90
		GI (S)	0.90
		GI (SI)	1.9
		GI (LI)	0.56
		Kidney	0.70
		Spleen	0.70
		Liver	0.90
		Bone	1.2
24	Cr^{51} (27.8)	Total body	0.025
		Lung (insol.)	0.014
		GI (S)	0.014
		GI (SI)	0.025
		GI (LI)	0.010
		Lung (sol.)	0.014
		Prostate	0.0084
		Thyroid	0.0084
		Kidney	0.012

* The abbreviations GI, S, SI and LI refer to gastrointestinal tract, stomach, small intestine, and large intestine (either upper or lower large intestine), respectively.

Z	Radionuclide (T_r in days)	Organ of reference	$\Sigma EF(RBE)n$ (E in MeV)
25	Mn^{52} (5.55)	Total body	2.1
		Lung (insol.)	0.96
		GI (S)	0.96
		GI (SI)	2.1
		GI (LI)	0.56
		Pancreas	0.56
		Liver	0.96
25	Mn^{54} (300)	Total body	0.51
		Lung (insol.)	0.23
		GI (S)	0.23
		GI (SI)	0.51
		GI (LI)	0.13
		Liver	0.23
		Pancreas	0.13
25	Mn^{56} (0.11)	Total body	1.9
		Lung (insol.)	1.3
		GI (S)	1.3
		GI (SI)	1.9
		GI (LI)	1.1
		Pancreas	1.1
		Liver	1.3
26	Fe^{55} (1.1×10^3)	Total body	0.0065
		Lung (insol.)	0.0065
		GI (S)	0.0065
		GI (SI)	0.0065
		GI (LI)	0.0065
		Spleen	0.0065
		Liver	0.0065
		Lung (sol.)	0.0065
		Bone	0.0065
26	Fe^{59} (45.1)	Total body	0.81
		Lung (insol.)	0.42
		GI (S)	0.42
		GI (SI)	0.81
		GI (LI)	0.29
		GI (S)	0.0077
		GI (SI)	0.0077
		GI (LI)	0.0077
		Bone	0.0077
		Liver	0.0077
28	Ni^{63} (2.9×10^4)	Total body	0.021
		Lung (insol.)	0.021
		GI (S)	0.021
		GI (SI)	0.021
		GI (LI)	0.021
		Bone	0.11
		Liver	0.021
28	Ni^{65} (0.11)	Total body	1.4
		Lung (insol.)	1.2
		GI (S)	1.2
		GI (SI)	1.4
		GI (LI)	1.1
		Bone	5.3
		Liver	1.2
29	Cu^{64} (0.53)	Total body	0.25
		Lung (insol.)	0.19
		GI (S)	0.19
		GI (SI)	0.25
		GI (LI)	0.16
		Spleen	0.17
		Kidney	0.17
		Liver	0.19
		Heart	0.17
		Brain	0.21
30	Zn^{65} (245)	Total body	0.32
		Lung (insol.)	0.15
		GI (S)	0.15
		GI (SI)	0.32
		GI (LI)	0.084
		Prostate	0.056

		Spleen	0.34
		Liver	0.42
		Lung (sol.)	0.42
27	Co^{57} (270)	Total body	0.090
		Lung (insol.)	0.053
		GI (S)	0.053
		GI (SI)	0.090
		GI (LI)	0.040
		Pancreas	0.040
		Liver	0.053
		Spleen	0.045
		Kidney	0.045
27	Co^{58m} (0.38) Co^{58} (72)	Total body	0.099
		Lung (insol.)	0.20
		Pancreas	0.039
		Liver	0.059
		Spleen	0.048
		Kidney	0.048
27	Co^{58} (72)	Total body	0.61
		Lung (insol.)	0.29
		GI (S)	0.29
		GI (SI)	0.61
		GI (LI)	0.17
		Pancreas	0.17
		Liver	0.29
		Spleen	0.22
		Kidney	0.22
27	Co^{60} (1.9×10^3)	Total body	1.5
		Lung (insol.)	0.72
		GI (S)	0.72
		GI (SI)	1.5
		GI (LI)	0.44
		Pancreas	0.44
		Liver	0.72
		Spleen	0.56
		Kidney	0.56
28	Ni^{59} (2.9×10^7)	Total body	0.0077
		Lung (insol.)	0.0077
		Liver	0.15
		Kidney	0.11
		Pancreas	0.084
		Muscle	0.32
		Ovary	0.056
		Testis	0.056
		Bone	0.094
30	Zn^{69m} (0.58) Zn^{69} (0.036)	Total body	0.64
		Lung (insol.)	0.50
		Prostate	0.43
		Pancreas	0.45
		Liver	0.50
		Kidney	0.47
		Ovary	0.43
		Testis	0.43
		Bone	2.1
		Muscle	0.64
30	Zn^{69} (0.036)	Total body	0.37
		Lung (insol.)	0.37
		GI (S)	0.37
		GI (SI)	0.37
		GI (LI)	0.37
		Prostate	0.37
		Pancreas	0.37
		Liver	0.37
		Ovary	0.37
		Kidney	0.37
		Testis	0.37
		Bone	1.9
		Muscle	0.37
31	Ga^{72} (0.59)	Total body	1.8
		Lung (insol.)	1.1
		GI (S)	1.1
		GI (SI)	1.8
		GI (LI)	0.78
		Liver	1.1
		Spleen	0.89
		Kidney	0.89
		Bone	2.6

Z	Radionuclide (T_r in days)	Organ of reference	$\Sigma EF(RBE)n$ (E in MeV)
32	Ge^{71} (12)	Total body	0.010
		Lung (insol.)	0.010
		GI (S)	0.010
		GI (SI)	0.010
		GI (LI)	0.010
		Kidney	0.010
		Liver	0.010
33	$As^{73} + Ge^{73m}$ (76)	Total body	0.061
		Lung (insol.)	0.041
		GI (S)	0.041
		GI (SI)	0.061
		GI (LI)	0.033
		Kidney	0.036
		Liver	0.041
33	As^{74} (17.5)	Total body	0.56
		Lung (insol.)	0.38
		GI (S)	0.38
		GI (SI)	0.56
		GI (LI)	0.32
		Kidney	0.34
		Liver	0.38
33	As^{76} (1.11)	Total body	1.3
		Lung (insol.)	1.1
		GI (S)	1.1
		GI (SI)	1.3
		GI (LI)	1.1
		Kidney	1.1
		Liver	1.1
33	As^{77} (1.62)	Total body	0.24
		Lung (insol.)	0.24
		GI (S)	0.24
		GI (SI)	0.24
		GI (LI)	0.24
		Kidney	0.24
		Liver	0.24

Z	Radionuclide (T_r in days)	Organ of reference	$\Sigma EF(RBE)n$ (E in MeV)
38	Sr^{85m} (0.049) Sr^{85} (65) } 86%	Total body	0.47
		Lung (insol.)	0.17
		Bone	0.13
38	Sr^{85m} (0.049) 14%	Total body	0.098
		Lung (insol.)	0.051
		GI (S)	0.051
		GI (SI)	0.098
		GI (LI)	0.034
		Bone	0.034
38	Sr^{85} (65)	Total body	0.33
		Lung (insol.)	0.16
		GI (S)	0.16
		GI (SI)	0.33
		GI (LI)	0.091
		Bone	0.091
38	Sr^{89} (50.5)	Total body	0.55
		Lung (insol.)	0.55
		GI (S)	0.55
		GI (SI)	0.55
		GI (LI)	0.55
		Bone	2.8
38	Sr^{90} (1.0×10^4) Y^{90} (2.68)	Total body	1.1
		Lung (insol.)	1.1
		Bone	5.5
38	Sr^{91} (0.40) + drs. } 59%	Total body	1.9
		Lung (insol.)	1.2
		Bone	5.4
38	Sr^{91} (0.40) Y^{91} (58) } 41%	Total body	2.4
		Lung (insol.)	2.0
		Bone	7.4

34	Se^{75}	Total body	0.20
	(127)	Lung (insol.)	0.094
		GI (S)	0.094
		GI (SI)	0.20
		GI (LI)	0.056
		Kidney	0.072
		Liver	0.094
		Spleen	0.072
35	Br^{82}	Total body	1.8
	(1.5)	Lung (insol.)	0.85
		GI (S)	0.85
		GI (SI)	1.8
		GI (LI)	0.53
36	Kr^{85m} (0.18)	Submersion	0.44
36	Kr^{85} (3.9×10^3)	Submersion	0.24
36	Kr^{87} (0.054)	Submersion	2.8
37	Rb^{86}	Total body	0.70
	(18.6)	Lung (insol.)	0.66
		GI (S)	0.66
		GI (SI)	0.70
		GI (LI)	0.65
		Pancreas	0.65
		Liver	0.66
		Spleen	0.66
		Muscle	0.70
37	Rb^{87}	Total body	0.090
	(1.8×10^{13})	Lung (insol.)	0.090
		GI (S)	0.090
		GI (SI)	0.090
		GI (LI)	0.090
		Pancreas	0.090
		Liver	0.090
		Spleen	0.090
		Muscle	0.090
38	Sr^{92} (0.11)	Total body	2.6
	Y^{92}	Lung (insol.)	2.0
	(0.15)	Bone	8.0
39	Y^{90}	Total body	0.89
	(2.68)	Lung (insol.)	0.89
		GI (S)	0.89
		GI (SI)	0.89
		GI (LI)	0.89
		Bone	4.4
39	Y^{91m}	Total body	0.93
	(0.035)	Lung (insol.)	0.55
	Y^{91}	Bone	3.0
	(58)		
39	Y^{91}	Total body	0.59
	(58)	Lung (insol.)	0.59
		GI (S)	0.59
		GI (SI)	0.59
		GI (LI)	0.59
		Bone	2.9
39	Y^{92}	Total body	1.6
	(0.15)	Lung (insol.)	1.5
		GI (S)	1.5
		GI (SI)	1.6
		GI (LI)	1.4
		Bone	6.9
39	Y^{93} (0.42) + drs. } 50%	Total body	1.7
		Lung (insol.)	1.5
		Bone	6.5
39	Y^{93} (0.42) Zr^{93} (4.0×10^8) } 50%	Total body	1.7
		Lung (insol.)	1.5
		Bone	6.5
40	Zr^{93}	Total body	0.024
	(4.0×10^8)	Lung (insol.)	0.020
	Nb^{93m}	Bone	0.11

Z	Radionuclide (T_r in days)	Organ of reference	$\Sigma EF(RBE)n$ (E in MeV)
	(3.7×10^3)	Kidney	0.024
		Spleen	0.025
		Liver	0.025
40	Zr^{93} 50%	Total body	0.019
	(4.0×10^8)	Lung (insol.)	0.019
		GI (S)	0.019
		GI (SI)	0.019
		GI (LI)	0.019
		Bone	0.095
		Kidney	0.019
		Spleen	0.019
		Liver	0.019
40	Zr^{95}	Total body	1.1
	(63.3)	Lung (insol.)	0.52
	+ drs.	Kidney	0.46
		Spleen	0.46
		Liver	0.57
		Bone	1.1
40	Zr^{97}	Total body	2.1
	(0.71)	Lung (insol.)	1.6
	+ drs.	Bone	6.2
		Kidney	1.5
		Liver	1.6
		Spleen	1.5
41	Nb^{93m}	Total body	0.038
	(3.7×10^3)	Lung (insol.)	0.038
		GI (S)	0.038
		GI (SI)	0.038
		GI (LI)	0.038
		Bone	0.12
		Kidney	0.038
		Spleen	0.038
		Liver	0.038
41	Nb^{95}	Total body	0.51

Z	Radionuclide (T_r in days)	Organ of reference	$\Sigma EF(RBE)n$ (E in MeV)
		Liver	0.64
		Lung (sol.)	0.64
		Bone	0.35
		Skin	0.0083
43	Tc^{97m}	Total body	0.090
	(92)	Lung (insol.)	0.090
	Tc^{97}	Kidney	0.090
	(3.7×10^6)	Liver	0.090
		Skin	0.071
		Bone	0.37
		Lung (sol.)	0.090
43	Tc^{97}	Total body	0.020
	(3.7×10^6)	Lung (insol.)	0.020
		GI (S)	0.020
		GI (SI)	0.020
		GI (LI)	0.019
		Kidney	0.020
		Liver	0.020
		Bone	0.019
		Lung (sol.)	0.020
		Skin	0.0011
43	Tc^{99m}	Total body	0.080
	(0.25)	Lung (insol.)	0.035
	Tc^{99}	Kidney	0.026
	(7.3×10^7)	Lung (sol.)	0.035
		Liver	0.035
		Bone	0.020
		Skin	0.0022
43	Tc^{99}	Total body	0.094
	(7.3×10^7)	Lung (insol.)	0.094
		GI (S)	0.094
		GI (SI)	0.094
		GI (LI)	0.094
		Kidney	0.094
		Liver	0.094

	(35)	Lung (insol.)	0.26
		GI (S)	0.26
		GI (SI)	0.51
		GI (LI)	0.16
		Liver	0.26
		Kidney	0.20
		Bone	0.37
		Spleen	0.20
41	Nb^{97} (0.051)	Total body	0.87
		Lung (insol.)	0.64
		GI (S)	0.64
		GI (SI)	0.87
		GI (LI)	0.56
		Bone	2.4
		Kidney	0.60
		Liver	0.64
		Spleen	0.60
42	Mo^{99} (2.79) + drs. } 87%	Total body	0.51
		Lung (insol.)	0.49
		Kidney	0.48
		Liver	0.48
42	Mo^{99} (2.79) Tc^{99} (7.3×10^7) } 13%	Total body	0.71
		Lung (insol.)	0.40
		Kidney	0.34
		Liver	0.40
43	Tc^{96m} (0.036) Tc^{96} (4.3)	Total body	0.30
		Lung (insol.)	0.66
		Kidney	0.42
		Liver	0.60
		Lung (sol.)	0.38
		Bone	0.39
		Skin	0.021
43	Tc^{96} (4.3)	Total body	1.4
		Lung (insol.)	0.64
		GI (S)	0.64
		GI (SI)	1.4
		GI (LI)	0.35
		Kidney	0.47
		Skin	0.094
		Bone	0.47
		Lung (sol.)	0.094
44	Ru^{97} (2.8) + drs.	Total body	0.15
		Lung (insol.)	0.13
		Kidney	0.077
		Bone	0.13
44	Ru^{103} (41) Rh^{103m} (0.038)	Total body	0.44
		Lung (insol.)	0.27
		Kidney	0.22
		Bone	0.62
44	Ru^{105} (0.19) + drs.	Total body	1.2
		Lung (insol.)	0.91
		Kidney	0.84
		Bone	3.5
44	$Ru^{106} + Rh^{106}$ (365)	Total body	1.4
		Lung (insol.)	1.4
		GI (S)	1.4
		GI (SI)	1.4
		GI (LI)	1.3
		Kidney	1.3
		Bone	6.5
45	Rh^{103m} (0.038)	Total body	0.055
		Lung (insol.)	0.055
		GI (S)	0.055
		GI (SI)	0.055
		GI (LI)	0.053
		Kidney	0.054
		Spleen	0.054
		Liver	0.055
		Bone	0.19
45	Rh^{105} (1.52)	Total body	0.20
		Lung (insol.)	0.19
		GI (S)	0.19
		GI (SI)	0.20
		GI (LI)	0.19
		Kidney	0.19

Z	Radionuclide (T_r in days)	Organ of reference	$\Sigma EF(\text{RBE})n$ (E in MeV)
		Spleen	0.19
		Liver	0.19
		Bone	0.95
46	Pd^{103}	Total body	0.064
	(17)	Lung (insol.)	0.063
	Rh^{103m}	Kidney	0.061
	(0.038)	Spleen	0.061
		Liver	0.063
46	$Pd^{109} + Ag^{109m}$	Total body	0.42
	(0.57)	Lung (insol.)	0.42
		GI (S)	0.42
		GI (SI)	0.42
		GI (LI)	0.42
		Kidney	0.42
		Spleen	0.42
		Liver	0.42
47	Ag^{105}	Total body	0.63
	(40)	Lung (insol.)	0.29
		GI (S)	0.29
		GI (SI)	0.63
		GI (LI)	0.16
		Kidney	0.22
		Liver	0.29
		Bone	0.16
47	$Ag^{110m} + Ag^{110}$	Total body	1.7
	(270)	Lung (insol.)	0.84
		GI (S)	0.84
		GI (SI)	1.7
		GI (LI)	0.51
		Kidney	0.65
		Liver	0.84
		Bone	1.1
47	$Ag^{111} + Cd^{111m}$	Total body	0.40
	(7.5)	Lung (insol.)	0.38

Z	Radionuclide (T_r in days)	Organ of reference	$\Sigma EF(\text{RBE})n$ (E in MeV)
		Kidney	0.93
		Spleen	0.93
		Liver	0.94
		Bone	4.5
		Skin	0.90
		Thyroid	0.92
49	In^{115m}	Total body	0.26
	(0.19)	Lung (insol.)	0.20
	In^{115}	Kidney	0.19
	(2.2×10^{17})	Spleen	0.19
		Liver	0.20
		Thyroid	0.16
		Bone	0.74
		Skin	0.14
49	In^{115}	Total body	0.17
	(2.2×10^{17})	Lung (insol.)	0.17
		GI (S)	0.17
		GI (SI)	0.17
		GI (LI)	0.17
		Kidney	0.17
		Spleen	0.17
		Liver	0.17
		Bone	0.85
		Skin	0.17
		Thyroid	0.17
50	Sn^{113}	Total body	0.32
	(112)	Lung (insol.)	0.23
	In^{113m}	Bone	0.70
	(0.073)	Prostate	0.16
		Liver	0.23
		Thyroid	0.16
50	Sn^{125} } 83%	Total body	0.94
	(9.5)	Lung (insol.)	0.96
	+ drs.	Bone	4.8
		Prostate	0.94

		GI (S)	0.38
		GI (SI)	0.40
		GI (LI)	0.37
		Kidney	0.37
		Bone	1.8
		Liver	0.38
48	Cd^{109} + Ag^{109m} (475)	Total body	0.11
		Lung (insol.)	0.10
		GI (S)	0.10
		GI (SI)	0.11
		GI (LI)	0.092
		Liver	0.10
		Kidney	0.098
48	Cd^{115m} (43) + drs.	Total body	0.61
		Lung (insol.)	0.61
		Liver	0.61
		Kidney	0.61
48	Cd^{115} (2.2) + drs.	Total body	0.71
		Lung (insol.)	0.58
		Liver	0.58
		Kidney	0.56
49	In^{113m} (0.073)	Total body	0.29
		Lung (insol.)	0.21
		GI (S)	0.21
		GI (SI)	0.29
		GI (LI)	0.17
		Kidney	0.19
		Spleen	0.19
		Liver	0.21
		Bone	0.68
		Skin	0.13
		Thyroid	0.16
49	In^{114m} + In^{114} (49)	Total body	0.97
		Lung (insol.)	0.94
		GI (S)	0.94
		GI (SI)	0.97
		GI (LI)	0.93

			Liver	0.94
			Thyroid	0.93
50	Sn^{125} (9.5) Sb^{125} (877)	17%	Total body	0.95
			Lung (insol.)	0.96
			Bone	4.7
			Prostate	0.93
			Liver	0.94
			Thyroid	0.93
51	Sb^{122} (2.8)		Total body	0.82
			Lung (insol.)	0.67
			GI (S)	0.67
			GI (SI)	0.82
			GI (LI)	0.61
			Lung (sol.)	0.67
			Bone	2.7
			Liver	0.67
			Thyroid	0.59
51	Sb^{124} (60)		Total body	1.6
			Lung (insol.)	0.92
			GI (S)	0.92
			GI (SI)	1.6
			GI (LI)	0.68
			Lung (sol.)	0.92
			Bone	2.3
			Liver	0.92
			Thyroid	0.57
51	Sb^{125} (877) Te^{125m} (58)	83%	Total body	0.34
			Lung (insol.)	0.26
			Lung (sol.)	0.23
			Bone	0.69
			Liver	0.23
			Thyroid	0.15
51	Sb^{125} (877)	17%	Total body	0.43
			Lung (insol.)	0.21
			GI (S)	0.21
			GI (SI)	0.43
			GI (LI)	0.13

Z	Radionuclide (T_r in days)	Organ of reference	$\Sigma EF(\mathrm{RBE})n$ (E in MeV)
		Lung (sol.)	0.21
		Bone	0.28
		Liver	0.21
		Thyroid	0.095
52	Te^{125m} (58)	Total body	0.15
		Lung (insol.)	0.14
		GI (S)	0.14
		GI (SI)	0.15
		GI (LI)	0.13
		Kidney	0.14
		Testis	0.11
		Spleen	0.14
		Liver	0.14
		Bone	0.51
		Thyroid	0.11
52	Te^{127m} (105) Te^{127} (0.39)	Total body	0.32
		Lung (insol.)	0.32
		Kidney	0.32
		Testis	0.31
		Spleen	0.32
		Bone	1.5
		Liver	0.32
		Thyroid	0.30
52	Te^{127} (0.39)	Total body	0.24
		Lung (insol.)	0.24
		GI (S)	0.24
		GI (SI)	0.24
		GI (LI)	0.24
		Kidney	0.24
		Testis	0.24
		Spleen	0.24
		Bone	1.2
		Liver	0.24
		Thyroid	0.24
53	I^{129} (6.3×10^9)	Total body	0.089
		Lung (insol.)	0.082
		GI (S)	0.082
		GI (SI)	0.089
		GI (LI)	0.073
		Thyroid	0.068
53	$I^{131} + Xe^{131m}$ (8.05)	Total body	0.44
		Lung (insol.)	0.30
		GI (S)	0.30
		GI (SI)	0.44
		GI (LI)	0.25
		Thyroid	0.23
53	I^{132} (0.097)	Total body	1.7
		Lung (insol.)	1.0
		GI (S)	1.0
		GI (SI)	1.7
		GI (LI)	0.76
		Thyroid	0.65
53	I^{133} (0.87) + drs.	Total body	0.84
		Lung (insol.)	0.64
		Thyroid	0.54
53	I^{134} (0.036)	Total body	1.5
		Lung (insol)	1.1
		GI (S)	1.1
		GI (SI)	1.5
		GI (LI)	0.90
		Thyroid	0.82
53	I^{135} (0.28) + drs.	Total body	1.3
		Lung (insol.)	0.77
		Thyroid	0.52
54	Xe^{131m} (12)	Submersion	0.16

52	Te^{129m} (33) + drs.	Total body	1.1
		Lung (insol.)	0.83
		Kidney	0.78
		Testis	0.69
		Spleen	0.78
		Liver	0.83
		Bone	3.2
		Thyroid	0.68
52	Te^{129} (0.051) I^{129} (6.3 × 10^9)	Total body	0.98
		Lung (insol.)	0.73
		Kidney	0.68
		Testis	0.60
		Spleen	0.68
		Liver	0.73
		Bone	2.8
		Thyroid	0.60
52	Te^{131m} (1.25) + drs.	Total body	1.6
		Lung (insol.)	1.0
		Kidney	0.81
		Spleen	0.80
		Liver	0.97
		Bone	2.6
		Thyroid	0.69
52	Tc^{132} (3.2) I^{132} (0.097)	Total body	1.9
		Lung (insol.)	1.1
		Kidney	0.96
		Spleen	0.96
		Testis	0.73
		Bone	3.1
		Liver	1.1
		Thyroid	0.74
53	I^{126} (13.3)	Total body	0.23
		Lung (insol.)	0.18
		GI (S)	0.18
		GI (SI)	0.23
		GI (LI)	0.17
		Thyroid	0.16
54	Xe^{133} (5.27)	Submersion	0.19
54	Xe^{135} + Cs^{135m} (0.38)	Submersion	0.62
55	Cs^{131} (10)	Total body	0.029
		Lung (insol.)	0.024
		GI (S)	0.024
		GI (SI)	0.029
		GI (LI)	0.017
		Liver	0.024
		Spleen	0.021
		Kidney	0.021
		Muscle	0.029
		Bone	0.017
		Lung (sol.)	0.024
55	Cs^{134m} (0.13) Cs^{134} (840)	Total body	0.19
		Lung (insol.)	0.17
		Liver	0.15
		Spleen	0.13
		Kidney	0.11
		Muscle	0.26
		Bone	0.49
		Lung (sol.)	0.17
55	Cs^{134} (840)	Total body	1.1
		Lung (insol.)	0.57
		GI (S)	0.57
		GI (SI)	1.1
		GI (LI)	0.38
		Liver	0.57
		Muscle	1.1
		Spleen	0.46
		Kidney	0.46
		Lung (sol.)	0.57
		Bone	0.99
55	Cs^{135} (1.1 × 10^9)	Total body	0.066
		Lung (insol.)	0.066
		GI (S)	0.066
		GI (SI)	0.066

Z	Radionuclide (T_r in days)	Organ of reference	$\Sigma EF(\text{RBE})n$ (E in MeV)
		GI (LI)	0.066
		Liver	0.066
		Spleen	0.066
		Bone	0.33
		Muscle	0.066
		Kidney	0.066
		Lung (sol.)	0.066
55	Cs^{136}	Total body	0.65
	(13)	Lung (insol.)	0.35
		GI (S)	0.35
		GI (SI)	0.65
		GI (LI)	0.24
		Liver	0.35
		Spleen	0.29
		Muscle	0.65
		Kidney	0.29
		Bone	0.72
		Lung (sol.)	0.35
55	$Cs^{137} + Ba^{137m}$	Total body	0.59
	(1.1×10^4)	Lung (insol.)	0.41
		GI (S)	0.41
		GI (SI)	0.59
		GI (LI)	0.24
		Liver	0.41
		Spleen	0.37
		Muscle	0.59
		Bone	1.4
		Kidney	0.37
		Lung (sol.)	0.41
56	Ba^{131}	Total body	0.38
	(11.6)	Lung (insol.)	0.19
	Cs^{131}	Bone	0.11
	(10)	Liver	0.19
		Muscle	0.38
		Spleen	0.14
		Kidney	0.14
		Lung (sol.)	0.19

Z	Radionuclide (T_r in days)	Organ of reference	$\Sigma EF(\text{RBE})n$ (E in MeV)
		Bone	3.9
		Liver	0.81
		Kidney	0.81
59	Pr^{143}	Total body	0.32
	(13.7)	Lung (insol.)	0.32
		GI (S)	0.32
		GI (SI)	0.32
		GI (LI)	0.32
		Bone	1.6
		Liver	0.32
		Kidney	0.32
60	Nd^{144}	Total body	20
	(7.3×10^{17})	Lung (insol.)	20
		GI (S)	0.19
		GI (SI)	0.19
		GI (LI)	0.19
		Bone	100
		Kidney	20
		Liver	20
60	Nd^{147}	Total body	0.40
	(11.3)	Lung (insol.)	0.30
	+ drs.	Liver	0.32
		Kidney	0.31
		Bone	1.4
60	Nd^{149}	Total body	1.1
	(0.083)	Lung (insol.)	0.99
	Pm^{149}	Liver	0.99
	(2.2)	Kidney	0.97
		Bone	4.7
61	Pm^{147}	Total body	0.069
	(920)	Lung (insol.)	0.069
	Sm^{147}	Bone	0.35
	(4.8×10^{13})	Kidney	0.069
		Liver	0.069

5	Ba^{140} (12.8) La^{140} (1.68)	Total body	2.3
		Lung (insol.)	1.4
		Bone	4.2
		Liver	1.4
		Lung (sol.)	1.4
		Muscle	2.3
		Spleen	1.2
		Kidney	1.2
57	La^{140} (1.68)	Total body	1.9
		Lung (insol.)	1.1
		GI (S)	1.1
		GI (SI)	1.9
		GI (LI)	0.80
		Liver	1.1
		Bone	2.7
58	Ce^{141} (32)	Total body	0.21
		Lung (insol.)	0.18
		GI (S)	0.18
		GI (SI)	0.21
		GI (LI)	0.17
		Liver	0.18
		Bone	0.81
		Kidney	0.18
58	Ce^{143} (1.33) Pr^{143} (13.7)	Total body	0.97
		Lung (insol.)	0.83
		Liver	0.85
		Bone	3.8
		Kidney	0.82
58	Ce^{144} (290) + drs.	Total body	1.3
		Lung (insol.)	1.3
		Bone	6.3
		Liver	1.3
		Kidney	1.3
59	Pr^{142} (0.80)	Total body	0.85
		Lung (insol.)	0.81
		GI (S)	0.81
		GI (SI)	0.85
		GI (LI)	0.80
61	Pm^{149} (2.2)	Total body	0.54
		Lung (insol.)	0.44
		GI (S)	0.44
		GI (SI)	0.54
		GI (LI)	0.41
		Bone	1.9
		Kidney	0.42
		Liver	0.44
62	Sm^{147} (4.8×10^{13})	Total body	23
		Lung (insol.)	23
		GI (S)	0.22
		GI (SI)	0.22
		GI (LI)	0.22
		Bone	115
		Kidney	23
		Liver	23
62	Sm^{151} (3.7×10^{4})	Total body	0.042
		Lung (insol.)	0.042
		GI (S)	0.042
		GI (SI)	0.042
		GI (LI)	0.041
		Bone	0.13
		Kidney	0.042
		Liver	0.042
62	Sm^{153} (1.96)	Total body	0.30
		Lung (insol.)	0.26
		GI (S)	0.26
		GI (SI)	0.30
		GI (LI)	0.24
		Liver	0.26
		Bone	1.1
		Kidney	0.25
63	Eu^{152} (0.38)	Total body	0.88
		Lung (insol.)	0.71
		GI (S)	0.71
		GI (SI)	0.88
		GI (LI)	0.65
		Liver	0.71
		Bone	2.9
		Kidney	0.71

Z	Radionuclide (T_r in days)	Organ of reference	$\Sigma EF(RBE)n$ (E in MeV)
63	Eu^{152}	Total body	0.66
	(4.7×10^3)	Lung (insol.)	0.33
		GI (S)	0.33
		GI (SI)	0.66
		GI (LI)	0.20
		Kidney	0.25
		Bone	0.45
		Liver	0.33
63	Eu^{154}	Total body	1.3
	(5.8×10^3)	Lung (insol.)	0.86
		GI (S)	0.86
		GI (SI)	1.3
		GI (LI)	0.69
		Kidney	0.76
		Bone	2.7
		Liver	0.86
63	Eu^{155}	Total body	0.16
	(621)	Lung (insol.)	0.095
		GI (S)	0.095
		GI (SI)	0.16
		GI (LI)	0.075
		Kidney	0.083
		Bone	0.28
		Liver	0.095
64	Gd^{153} + Eu^{153m}	Total body	0.17
	(236)	Lung (insol.)	0.099
		GI (S)	0.099
		GI (SI)	0.17
		GI (LI)	0.072
		Bone	0.23
		Liver	0.099
64	Gd^{159}	Total body	0.36
	(0.75)	Lung (insol.)	0.33
		GI (S)	0.33
		GI (SI)	0.36
68	Er^{171}	Total body	0.65
	(0.31)	Lung (insol.)	0.49
	+ drs.	Bone	2.0
		Kidney	0.46
69	Tm^{170} + Yb^{170m}	Total body	0.34
	(127)	Lung (insol.)	0.34
		GI (S)	0.34
		GI (SI)	0.34
		GI (LI)	0.34
		Bone	1.7
		Kidney	0.34
69	Tm^{171}	Total body	0.030
	(694)	Lung (insol.)	0.030
		GI (S)	0.030
		GI (SI)	0.030
		GI (LI)	0.030
		Bone	0.15
		Kidney	0.030
70	Yb^{175}	Total body	0.16
	(4.1)	Lung (insol.)	0.15
		GI (S)	0.15
		GI (SI)	0.16
		GI (LI)	0.15
		Bone	0.71
		Kidney	0.15
71	Lu^{177}	Total body	0.17
	(6.7)	Lung (insol.)	0.16
		GI (S)	0.16
		GI (SI)	0.17
		GI (LI)	0.16
		Bone	0.76
		Kidney	0.16
72	Hf^{181} + Ta^{181m}	Total body	0.50
	(46)	Lung (insol.)	0.29

		GI (LI)	0.32
		Bone	0.75
		Liver	0.33
65	$Tb^{160} + Dy^{160m}$ (73)	Total body	0.85
		Lung (insol.)	0.48
		GI (S)	0.48
		GI (SI)	0.85
		GI (LI)	0.34
		Bone	1.1
		Kidney	0.40
66	Dy^{165} (0.097)	Total body	0.51
		Lung (insol.)	0.39
		GI (S)	0.39
		GI (SI)	0.51
		GI (LI)	0.34
		Bone	1.5
		Liver	0.39
66	Dy^{166} (3.4) + drs.	Total body	0.79
		Lung (insol.)	0.75
		Bone	3.9
		Liver	0.78
67	$Ho^{166} + Er^{166m}$ (1.1)	Total body	0.70
		Lung (insol.)	0.69
		GI (S)	0.69
		GI (SI)	0.70
		GI (LI)	0.69
		Bone	3.4
		Kidney	0.69
		Liver	0.69
68	$Er^{169} + Tm^{169m}$ (9.4)	Total body	0.37
		Lung (insol.)	0.22
		GI (S)	0.22
		GI (SI)	0.37
		GI (LI)	0.17
		Bone	0.58
		Kidney	0.19
		Liver	0.22

		GI (S)	0.29
		GI (SI)	0.50
		GI (LI)	0.22
		Spleen	0.25
		Liver	0.29
		Kidney	0.25
		Bone	0.74
73	$Ta^{182} + W^{182m}$ (112)	Total body	1.1
		Lung (insol.)	0.56
		GI (S)	0.56
		GI (SI)	1.1
		GI (LI)	0.38
		Liver	0.56
		Kidney	0.45
		Spleen	0.45
		Bone	1.0
74	W^{181} (140)	Total body	0.20
		Lung (insol.)	0.087
		GI (S)	0.087
		GI (SI)	0.20
		GI (LI)	0.047
		Liver	0.087
		Bone	0.047
74	W^{185} (74)	Total body	0.14
		Lung (insol.)	0.14
		GI (S)	0.14
		GI (SI)	0.14
		GI (LI)	0.14
		Bone	0.68
		Liver	0.14
74	W^{187} (1) + drs.	Total body	0.68
		Lung (insol.)	0.44
		Liver	0.44
		Bone	1.4
75	Re^{183} (73)	Total body	0.24
		Lung (insol.)	0.10
		GI (S)	0.10
		GI (SI)	0.24

Z	Radionuclide (T_r in days)	Organ of reference	$\Sigma EF(RBE)n$ (E in MeV)
		GI (LI)	0.055
		Thyroid	0.034
		Liver	0.10
		Skin	0.0012
		Bone	0.055
75	$Re^{186} + Os^{186m}$	Total body	0.38
	(3.79)	Lung (insol.)	0.37
		GI (S)	0.37
		GI (SI)	0.38
		GI (LI)	0.36
		Skin	0.36
		Thyroid	0.36
		Liver	0.37
		Bone	1.8
75	Re^{187}	Total body	0.012
	(1.8×10^{13})	Lung (insol.)	0.012
		GI (S)	0.012
		GI (SI)	0.012
		GI (LI)	0.012
		Skin	0.012
		Thyroid	0.012
		Liver	0.012
		Bone	0.062
75	$Re^{188} + Os^{188m}$	Total body	0.94
	(0.71)	Lung (insol.)	0.85
		GI (S)	0.85
		GI (SI)	0.94
		GI (LI)	0.82
		Thyroid	0.80
		Skin	0.78
		Liver	0.85
		Bone	3.9
76	Os^{185}	Total body	0.51
	(95)	Lung (insol.)	0.29
		GI (S)	0.29

Z	Radionuclide (T_r in days)	Organ of reference	$\Sigma EF(RBE)n$ (E in MeV)
77	Ir^{194}	Total body	0.81
	(0.79)	Lung (Insol.)	0.81
		GI (S)	0.81
		GI (SI)	0.81
		GI (LI)	0.81
		Kidney	0.81
		Liver	0.81
		Spleen	0.81
78	Pt^{191}	Total body	0.70
	(3)	Lung (insol.)	0.31
		GI (S)	0.31
		GI (SI)	0.70
		GI (LI)	0.16
		Kidney	0.22
		Liver	0.31
		Spleen	0.22
78	Pt^{193m}	Total Body	0.075
	(3.5)	Lung (insol.)	0.032
	Pt^{193}	Kidney	0.023
	(1.8×10^{5})	Liver	0.032
		Spleen	0.023
78	Pt^{193}	Total body	0.043
	(1.8×10^{5})	Lung (insol.)	0.019
		GI (S)	0.019
		GI (SI)	0.043
		GI (LI)	0.0099
		Kidney	0.014
		Spleen	0.014
		Liver	0.019
78	Pt^{197m}	Total body	0.55
	(0.056)	Lung (insol.)	0.52
	Pt^{197}	Kidney	0.50
	(0.75)	Liver	0.51
		Spleen	0.50

		GI (SI)	0.51
		GI (LI)	0.23
		Kidney	0.25
		Liver	0.29
76	Os^{191m} (0.58) + drs.	Total body	0.060
		Lung (insol.)	0.13
		Kidney	0.039
		Liver	0.049
76	Os^{191} + Ir^{191m} (16)	Total body	0.16
		Lung (insol.)	0.12
		GI (S)	0.12
		GI (SI)	0.16
		GI (LI)	0.10
		Kidney	0.11
		Liver	0.12
76	Os^{193} (1.31)	Total body	0.38
		Lung (insol.)	0.38
		GI (S)	0.38
		GI (SI)	0.38
		GI (LI)	0.38
		Kidney	0.38
		Liver	0.38
77	Ir^{190} (12)	Total body	0.37
		Lung (insol.)	0.16
		GI (S)	0.16
		GI (SI)	0.37
		GI (LI)	0.087
		Kidney	0.12
		Liver	0.16
		Spleen	0.12
77	Ir^{192} (74.5)	Total body	1.1
		Lung (insol.)	0.60
		GI (S)	0.60
		GI (SI)	1.1
		GI (LI)	0.42
		Kidney	0.50
		Spleen	0.50
		Liver	0.60
	Pt^{197} (0.75)	Total body	0.26
		Lung (insol.)	0.24
		GI (S)	0.24
		GI (SI)	0.26
		GI (LI)	0.23
		Kidney	0.23
		Liver	0.24
		Spleen	0.23
79	Au^{196} (5.6)	Total body	0.46
		Lung (insol.)	0.21
		GI (S)	0.21
		GI (SI)	0.46
		GI (LI)	0.11
		Kidney	0.15
		Spleen	0.15
		Liver	0.21
79	Au^{198} (2.7)	Total body	0.58
		Lung (insol.)	0.44
		GI (S)	0.44
		GI (SI)	0.58
		GI (LI)	0.38
		Kidney	0.41
		Spleen	0.41
		Liver	0.44
79	Au^{199} + Hg^{199m} (3.15)	Total body	0.18
		Lung (insol.)	0.13
		GI (S)	0.13
		GI (SI)	0.18
		GI (LI)	0.11
		Kidney	0.12
		Spleen	0.12
		Liver	0.13
80	Hg^{197m} (1) + drs.	Total body	0.30
		Lung (insol.)	0.20
		Kidney	0.18
		Spleen	0.17
		Liver	0.19

Z	Radionuclide (T_r in days)	Organ of reference	$\Sigma EF(\text{RBE})n$ (E in MeV)
80	Hg^{197} (2.7)	Total body	0.097
		Lung (insol.)	0.052
		GI (S)	0.052
		GI (SI)	0.097
		GI (LI)	0.036
		Kidney	0.043
		Spleen	0.043
		Liver	0.052
80	Hg^{203} (45.8)	Total body	0.25
		Lung (insol.)	0.17
		GI (S)	0.17
		GI (SI)	0.25
		GI (LI)	0.14
		Kidney	0.15
		Spleen	0.15
		Liver	0.17
81	Tl^{200} (1.13)	Total body	0.40
		Lung (insol.)	0.18
		GI (S)	0.18
		GI (SI)	0.40
		GI (LI)	0.095
		Kidney	0.13
		Muscle	0.40
		Liver	0.18
		Lung (sol.)	0.18
		Bone	0.095
81	Tl^{201} (3)	Total body	0.17
		Lung (insol.)	0.12
		GI (S)	0.12
		GI (SI)	0.17
		GI (LI)	0.10
		Kidney	0.11
		Muscle	0.17
		Liver	0.12
		Bone	0.44
		Lung (sol.)	0.12

Z	Radionuclide (T_r in days)	Organ of reference	$\Sigma EF(\text{RBE})n$ (E in MeV)
83	$Bi^{206} + Pb^{206m}$ (6.4)	Total body	1.8
		Lung (insol.)	0.80
		GI (S)	0.80
		GI (SI)	1.8
		GI (LI)	0.43
		Kidney	0.58
		Liver	0.80
		Spleen	0.58
		Bone	0.43
83	$Bi^{207} + Pb^{207m}$ (2.9×10^3)	Total body	1.0
		Lung (insol.)	0.45
		GI (S)	0.45
		GI (SI)	1.0
		GI (LI)	0.24
		Kidney	0.33
		Liver	0.45
		Spleen	0.33
		Bone	0.24
83	Bi^{210} (5) + drs.	Total body	10
		Lung (insol.)	26
		Kidney	19
		Bone	40
		Liver	13
		Spleen	17
83	Bi^{212} (0.042) + drs.	Total body	83
		Lung (insol.)	83
		GI (S)	1.8
		GI (SI)	2.2
		GI (LI)	1.7
		Kidney	82
		Liver	83
		Spleen	82
		Bone	411
84	Po^{210} (138.4)	Total body	55
		Lung (insol.)	55

81	Tl^{202} (12)	Total body	0.38
		Lung (insol.)	0.27
		GI (S)	0.27
		GI (SI)	0.38
		GI (LI)	0.23
		Kidney	0.24
		Muscle	0.38
		Liver	0.27
		Bone	0.94
		Lung (sol.)	0.27
81	Tl^{204} (1.1×10^3)	Total body	0.25
		Lung (insol.)	0.25
		GI (S)	0.25
		GI (SI)	0.25
		GI (LI)	0.25
		Kidney	0.25
		Bone	1.3
		Liver	0.25
		Muscle	0.25
		Lung (sol.)	0.25
82	Pb^{203} (2.17)	Total body	0.22
		Lung (insol.)	0.094
		GI (S)	0.094
		GI (SI)	0.22
		GI (LI)	0.051
		Kidney	0.069
		Liver	0.094
		Bone	0.051
82	Pb^{210} (7.1×10^3) + drs.	Total body	5.2
		Lung (insol.)	25
		Kidney	10
		Bone	29
		Liver	10
82	Pb^{212} (0.44) + drs.	Total body	82
		Lung (insol.)	83
		Kidney	81
		Bone	410
		Liver	83
		GI (S)	0.53
		GI (SI)	0.53
		GI (LI)	0.53
		Spleen	55
		Kidney	55
		Liver	55
		Bone	280
85	At^{211} (0.30) + drs. } 41%	Total body	61
		Lung (insol.)	61
		Thyroid	61
		Ovary	61
		Spleen	61
85	$At^{211} + Po^{211}$ (0.30) 59%	Total body	77
		Lung (insol.)	77
		GI (S)	0.76
		GI (SI)	0.79
		GI (LI)	0.75
		Thyroid	77
		Ovary	77
		Spleen	77
88	Ra^{223} (11.7) + drs.	Total body	280
		Lung (insol.)	280
		GI (S)	3.7
		GI (SI)	3.8
		GI (LI)	3.7
		Bone	280
88	Ra^{224} (3.64) + drs.	Total body	280
		Lung (insol.)	280
		Bone	280
88	Ra^{226} (5.9×10^5) + drs.	Total body	110
		Bone	110
88	Ra^{228} (2.4×10^3) + drs.	Total body	230
		Lung (insol.)	160
		Bone	190
89	Ac^{227} (8.0×10^3)	Total body	200
		Lung (insol.)	230

Z	Radionuclide (T_r in days)	Organ of reference	$\Sigma EF(\mathrm{RBE})n$ (E in MeV)
	+ drs.	Bone	1000
		Liver	62
		Kidney	62
89	Ac^{228}	Total body	230
	(0.26)	Lung (insol.)	160
	+ drs.	Bone	970
		Kidney	55
		Liver	56
90	Th^{227}	Total body	200
	(18.4)	Lung (insol.)	230
	+ drs.	Kidney	61
		Liver	61
		Bone	990
90	Th^{228}	Total body	230
	(7.0×10^2)	Lung (insol.)	240
	+ drs.	Bone	970
		Kidney	56
		Liver	56
90	Th^{230}	Total body	48
	(2.9×10^7)	Lung (insol.)	48
		GI (S)	0.47
		GI (SI)	0.47
		GI (LI)	0.47
		Bone	240
		Kidney	48
		Liver	48
90	Th^{231}	Total body	0.18
	(1.07)	Lung (insol.)	0.11
	Pa^{231}	Bone	0.56
	(1.3×10^7)	Kidney	0.14
		Liver	0.16
90	Th^{232}	Total body	62
	(5.1×10^{12})	Lung (insol.)	46
92	U^{232}	Total body	280
	(2.7×10^4)	Lung (insol.)	210
	+ drs.	Bone	1200
		Kidney	110
92	U^{233}	Total body	50
	(5.9×10^7)	Lung (insol.)	50
		GI (S)	0.49
		GI (SI)	0.49
		GI (LI)	0.49
		Kidney	50
		Bone	250
92	U^{234}	Total body	49
	(9.1×10^7)	Lung (insol.)	49
		GI (S)	0.48
		GI (SI)	0.49
		GI (LI)	0.48
		Kidney	49
		Bone	240
92	U^{235}	Total body	46
	(2.6×10^{11})	Lung (insol.)	46
	Th^{231}	Kidney	46
	(1.07)	Bone	230
92	U^{236}	Total body	47
	(8.7×10^9)	Lung (insol.)	47
		GI (S)	0.45
		GI (SI)	0.46
		GI (LI)	0.45
		Kidney	47
		Bone	230
92	U^{238}	Total body	43
	(1.6×10^{12})	Lung (insol.)	43
		GI (S)	0.43
		GI (SI)	0.43
		GI (LI)	0.43

	+ drs.	Bone	270
		Kidney	41
		Liver	41
90	Th^{234} + Pa^{234} (24.1)	Total body	0.91
		Lung (insol.)	0.90
		GI (S)	0.90
		GI (SI)	0.91
		GI (LI)	0.90
		Bone	4.5
		Kidney	0.90
		Liver	0.90
91	Pa^{230} (17.7) + drs. } 80%	Total body	0.067
		Lung (insol.)	0.022
		Kidney	0.031
		Bone	0.11
91	Pa^{230} (17.7) + drs. } 20%	Total body	290
		Lung (insol.)	300
		Bone	1600
		Kidney	150
91	Pa^{231} (1.3×10^7) + drs.	Total body	140
		Lung (insol.)	54
		Kidney	79
		Liver	63
		Bone	750
91	Pa^{233} (27.4)	Total body	0.32
		Lung (insol.)	0.18
		GI (S)	0.18
		GI (SI)	0.32
		GI (LI)	0.13
		Kidney	0.15
		Bone	0.41
		Liver	0.18
92	U^{230} (20.8) + drs.	Total body	350
		Lung (insol.)	350
		Kidney	350
		Bone	1800

		Kidney	43
		Bone	220
93	Np^{237} (8.0×10^6) Pa^{233} (27.4)	Total body	49
		Lung (insol.)	49
		Bone	250
		Kidney	49
		Liver	49
93	Np^{239} (2.33) + drs.	Total body	0.29
		Lung (insol.)	0.16
		Bone	0.98
		Kidney	0.21
		Liver	0.22
94	Pu^{238} (3.3×10^4)	Total body	57
		Lung (insol.)	57
		GI (S)	0.55
		GI (SI)	0.55
		GI (LI)	0.55
		Bone	280
		Liver	57
		Kidney	57
94	Pu^{239} (8.9×10^6)	Total body	53
		Lung (insol.)	53
		GI (S)	0.52
		GI (SI)	0.52
		GI (LI)	0.52
		Bone	270
		Liver	53
		Kidney	53
94	Pu^{240} (2.4×10^6)	Total body	53
		Lung (insol.)	53
		GI (S)	0.52
		GI (SI)	0.52
		GI (LI)	0.52
		Bone	270
		Liver	53
		Kidney	53

Z	Radionuclide (T_r in days)	Organ of reference	$\Sigma EF(\mathrm{RBE})n$ (E in MeV)
94	Pu^{241}	Total body	2.3
	(4.8×10^3)	Lung (insol.)	0.053
	+ drs.	Bone	14
		Kidney	2.5
		Liver	1.0
94	Pu^{242}	Total body	51
	(1.4×10^8)	Lung (insol.)	51
		GI (S)	0.49
		GI (SI)	0.49
		GI (LI)	0.49
		Bone	250
		Liver	51
		Kidney	51
95	$Am^{241} + Np^{237m}$	Total body	57
	(1.7×10^5)	Lung (insol.)	57
		GI (S)	0.56
		GI (SI)	0.59
		GI (LI)	0.56
		Bone	280
		Kidney	57
		Liver	57
95	Am^{243}	Total body	54
	(2.9×10^6)	Lung (insol.)	54
	+ drs.	Bone	270
		Kidney	54
		Liver	54
96	Cm^{242}	Total body	80
	(162.5)	Lung (insol.)	64
	Pu^{238}	Liver	78
	(3.3×10^4)	Bone	400
		Kidney	78
96	Cm^{244}	Total body	60
	(6.7×10^3)	Lung (insol.)	60
	Pu^{240}	Bone	300
	(2.4×10^6)	Liver	60
		Kidney	60
96	Cm^{245}	Total body	56
	(7.3×10^6)	Lung (insol.)	55
	+ drs.	Bone	280
		Kidney	56
		Liver	56
96	Cm^{246}	Total body	56
	(2.4×10^6)	Lung (insol.)	56
		GI (S)	0.54
		GI (SI)	0.54
		GI (LI)	0.54
		Bone	280
		Kidney	56
		Liver	56
97	Bk^{249}	Total body	3.8
	(290)	Lung (insol.)	0.069
	Cf^{249}	Bone	20
	(1.7×10^5)		
98	Cf^{249}	Total body	60
	(1.7×10^5)	Lung (insol.)	60
		GI (S)	0.66
		GI (SI)	0.76
		GI (LI)	0.63
		Bone	300
98	Cf^{250}	Total body	62
	(3.7×10^3)	Lung (insol.)	62
	Cm^{246}	Bone	310
	(2.4×10^6)		

96	Cm^{243} (1.3 × 10^4) + drs.	Total body	60
		Lung (insol.)	60
		Bone	300
		Liver	60
		Kidney	60
98	Cf^{252} (804)	Total body	210
		Lung (insol.)	210
		GI (S)	2.1
		GI (SI)	2.1
		GI (LI)	2.1
		Bone	1100

Table 5a. Effective energies for chains

Radionuclide	Half-life (T_r in days)	Effective energy for organs of reference				Eff. energy, ΣE(RBE), (E in MeV) for portions of GI tract*		
		Organs of Reference	ΣE(RBE)n (E in MeV)	F	ΣEF(RBE)n (E in MeV)	S	SI	LI
$_{20}Ca^{47}$	4.9	Total body	1.2	1.0	1.2	0.61	1.2	0.48
		Lung (insol.)	0.61	1.0	0.61			
		Bone	1.8	1.0	1.8			
Sc^{47}	3.43	Total body	0.26	0.90	0.23	0.21	0.26	0.19
		Lung (insol.)	0.21	0.97	0.20			
		Bone	0.89	0.91	0.81			
		Total body	Totals for Chain		1.4			
		Lung (insol.)			0.81			
		Bone			2.6			
$_{27}Co^{58m}$	0.38	Total body	0.026	1.0	0.026	0.024	0.026	0.019
		Lung (insol.)	0.024	1.0	0.024			
		Pancreas	0.019	1.0	0.019			
		Liver	0.024	1.0	0.024			
		Spleen	0.022	1.0	0.022			
		Kidney	0.022	1.0	0.022			
Co^{58}	72	Total body	0.61	0.12	0.073	0.29	0.61	0.17
		Lung (insol.)	0.29	0.63	0.18			
		Pancreas	0.17	0.12	0.020			
		Liver	0.29	0.12	0.035			
		Spleen	0.22	0.12	0.026			
		Kidney	0.22	0.12	0.026			
		Total body	Totals for Chain		0.099			
		Lung (insol.)			0.20			
		Pancreas			0.039			
		Liver			0.059			
		Spleen			0.048			
		Kidney			0.048			
$_{30}Zn^{69m}$	0.58	Total body	0.27	1.0	0.27	0.13	0.27	0.081
		Lung (insol.)	0.13	1.0	0.13			
		Prostate	0.057	1.0	0.057			
		Pancreas	0.081	1.0	0.081			
		Liver	0.13	1.0	0.13			
		Kidney	0.10	1.0	0.10			
		Ovary	0.057	1.0	0.057			
		Testis	0.057	1.0	0.057			
		Bone	0.16	1.0	0.16			
		Muscle	0.27	1.0	0.27			

* The abbreviations GI, S, SI and LI refer to gastrointestinal tract, stomach, small intestine, and large intestine (either upper or lower large intestine), respectively.

Radionuclide	Half-life (T_r in days)	Effective energy for organs of reference: Organs of Reference	$\Sigma E(RBE)n$ (E in MeV)	F	$\Sigma EF(RBE)n$ (E in MeV)	Eff. energy, $\Sigma E(RBE)$, (E in MeV) for portions of GI tract: S	SI	LI
Zn^{69}	0.036	Total body	0.37	1.0	0.37	0.37	0.37	0.37
		Lung (insol.)	0.37	1.0	0.37			
		Prostate	0.37	1.0	0.37			
		Pancreas	0.37	1.0	0.37			
		Liver	0.37	1.0	0.37			
		Kidney	0.37	1.0	0.37			
		Ovary	0.37	1.0	0.37			
		Testis	0.37	1.0	0.37			
		Bone	1.9	1.0	1.9			
		Muscle	0.37	1.0	0.37			
		Total body	Totals for Chain		0.64			
		Lung (insol.)			0.50			
		Prostate			0.43			
		Pancreas			0.45			
		Liver			0.50			
		Kidney			0.47			
		Ovary			0.43			
		Testis			0.43			
		Bone			2.1			
		Muscle			0.64			
$_{38}Sr^{85m}$ } 86%	0.049	Total body	0.14	1.0	0.14	0.066	0.14	0.039
		Lung (insol.)	0.066	1.0	0.066			
		Bone	0.039	1.0	0.039			
Sr^{85}	65	Total body	0.33	1.0	0.33	0.16	0.33	0.091
		Lung (insol.)	0.16	0.65	0.10			
		Bone	0.091	1.0	0.091			
		Total body	Totals for Chain		0.47			
		Lung (insol.)			0.17			
		Bone			0.13			
$_{38}Sr^{90}$	1.0×10^4	Total body	0.21	1.0	0.21	0.21	0.21	0.21
		Lung (insol.)	0.21	1.0	0.21			
		Bone	1.1	1.0	1.1			
Y^{90}	2.68	Total body	0.89	1.0	0.89	0.89	0.89	0.89
		Lung (insol.)	0.89	0.98	0.87			
		Bone	4.4	1.0	4.4			
		Total body	Totals for Chain		1.1			
		Lung (insol.)			1.1			
		Bone			5.5			

Radionuclide	Half-life (T_r in days)	Effective energy for organs of reference				Eff. energy, ΣE(RBE), (E in MeV) for portions of GI tract		
		Organs of reference	ΣE(RBE)n (E in MeV)	F	ΣEF(RBE)n (E in MeV)	S	SI	LI
$_{38}Sr^{91}$	0.40	Total body	0.98	1.0	0.98	0.68	0.98	0.58
		Lung (insol.)	0.68	1.0	0.68			
		Bone	2.4	1.0	2.4			
Y^{91m} } 59%	0.035	Total body	0.34	1.0	0.34	0.15	0.34	0.082
		Lung (insol.)	0.15	1.0	0.15			
		Bone	0.082	1.0	0.082			
Y^{91}	58	Total body	0.59	1.0	0.59	0.59	0.59	0.59
		Lung (insol.)	0.59	0.67	0.40			
		Bone	2.9	1.0	2.9			
		Total body	Totals for Chain		1.9			
		Lung (insol.)			1.2			
		Bone			5.4			
$_{38}Sr^{91}$ } 41%	0.40	Total body	1.8	1.0	1.8	1.6	1.8	0.97
		Lung (insol.)	1.6	1.0	1.6			
		Bone	4.5	1.0	4.5			
Y^{91}	58	Total body	0.59	1.0	0.59	0.59	0.59	0.59
		Lung (insol.)	0.59	0.67	0.40			
		Bone	2.9	1.0	2.9			
		Total body	Totals for Chain		2.4			
		Lung (insol.)			2.0			
		Bone			7.4			
$_{38}Sr^{92}$	0.11	Total body	0.96	1.0	0.96	0.45	0.96	0.37
		Lung (insol.)	0.45	1.0	0.45			
		Bone	1.1	1.0	1.1			
Y^{92}	0.15	Total body	1.6	1.0	1.6	1.5	1.6	1.4
		Lung (insol.)	1.5	1.0	1.5			
		Bone	6.9	1.0	6.9			
		Total body	Totals for Chain		2.6			
		Lung (insol.)			2.0			
		Bone			8.0			
$_{39}Y^{91m}$	0.035	Total body	0.34	1.0	0.34	0.15	0.34	0.082
		Lung (insol.)	0.15	1.0	0.15			
		Bone	0.082	1.0	0.082			
Y^{91}	58	Total body	0.59	1.0	0.59	0.59	0.59	0.59
		Lung (insol.)	0.59	0.67	0.40			
		Bone	2.9	1.0	2.9			
		Total body	Totals for Chain		0.93			
		Lung (insol.)			0.55			
		Bone			3.0			

Radionuclide	Half-life (T_r in days)	Organs of reference	$\Sigma E(RBE)n$ (E in MeV)	F	$\Sigma EF(RBE)n$ (E in MeV)	S	SI	LI
		Effective energy for organs of reference				Eff. energy, $\Sigma E(RBE)$, (E in MeV) for portions of GI tract		
$_{39}Y^{93}$ } 50%	0.42	Total body	1.7	1.0	1.7	1.5	1.7	1.4
		Lung (insol.)	1.5	1.0	1.5			
		Bone	6.5	1.0	6.5			
Zr^{93}	4.0×10^8	Total body	0.019	1.1×10^{-6}	2.1×10^{-8}	0.019	0.019	0.019
		Lung (insol.)	0.019	3.0×10^{-7}	5.7×10^{-9}			
		Bone	0.095	2.5×10^{-6}	2.4×10^{-7}			
Nb^{93m}	3.7×10^3	Total body	0.038	1.9×10^{-7}	7.2×10^{-9}	0.038	0.038	0.038
		Lung (insol.)	0.038	9.4×10^{-9}	3.6×10^{-10}			
		Bone	0.12	5.3×10^{-7}	6.4×10^{-8}			
		Total body	Totals for Chain		1.7			
		Lung (insol.)			1.5			
		Bone			6.5			
$_{39}Y^{93}$ } 50%	0.42	Total body	1.7	1.0	1.7	1.5	1.7	1.4
		Lung (insol.)	1.5	1.0	1.5			
		Bone	6.5	1.0	6.5			
Zr^{93}	4.0×10^8	Total body	0.019	1.1×10^{-6}	2.1×10^{-8}	0.019	0.019	0.019
		Lung (insol.)	0.019	3.0×10^{-7}	5.7×10^{-9}			
		Bone	0.095	2.5×10^{-6}	2.4×10^{-7}			
		Total body	Totals for Chain		1.7			
		Lung (insol.)			1.5			
		Bone			6.5			
$_{40}Zr^{93}$	4.0×10^8	Total body	0.019	1.0	0.019	0.019	0.019	0.019
		Lung (insol.)	0.019	1.0	0.019			
		Bone	0.095	1.0	0.095			
		Kidney	0.019	1.0	0.019			
		Spleen	0.019	1.0	0.019			
		Liver	0.019	1.0	0.019			
Nb^{93m}	3.7×10^3	Total body	0.030	0.17	0.0051	0.030	0.030	0.030
		Lung (insol.)	0.030	0.031	9.3×10^{-4}			
		Bone	0.078	0.21	0.016			
		Kidney	0.030	0.17	0.0051			
		Spleen	0.030	0.20	0.0060			
		Liver	0.030	0.19	0.0057			
		Total body	Totals for Chain		0.024			
		Lung (insol.)			0.020			
		Bone			0.11			
		Kidney			0.024			
		Spleen			0.025			
		Liver			0.025			
Zr^{95} Nb^{95m}	63.3	Total body	0.57	1.0	0.57	0.32	0.57	0.24
		Lung (insol.)	0.32	1.0	0.32			
		Bone	0.77	1.0	0.77			

Radionuclide	Half-life (T_r in days)	Organs of reference	$\Sigma E(RBE)n$ (E in MeV)	F	$\Sigma EF(RBE)n$ (E in MeV)	Eff. energy, $\Sigma E(RBE)$, (E in MeV) for portions of GI tract: S	SI	LI
Nb^{95}	35	Kidney	0.27	1.0	0.27	0.26	0.51	0.16
		Liver	0.32	1.0	0.32			
		Spleen	0.27	1.0	0.27			
		Total body	0.51	0.96	0.49			
		Lung (insol.)	0.26	0.77	0.20			
		Bone	0.37	0.97	0.36			
		Kidney	0.20	0.96	0.19			
		Liver	0.26	0.96	0.25			
		Spleen	0.20	0.97	0.19			
		Total body	Totals for Chain		1.1			
		Lung (insol.)			0.52			
		Bone			1.1			
		Kidney			0.46			
		Liver			0.57			
		Spleen			0.46			
$_{40}Zr^{97}$	0.71	Total body	1.2	1.0	1.2	0.94	1.2	0.85
Nb^{97m}		Lung (insol.)	0.94	1.0	0.94			
		Bone	3.8	1.0	3.8			
		Kidney	0.88	1.0	0.88			
		Liver	0.94	1.0	0.94			
		Spleen	0.88	1.0	0.88			
Nb^{97}	0.051	Total body	0.87	1.0	0.87	0.64	0.87	0.56
		Lung (insol.)	0.64	1.0	0.64			
		Bone	2.4	1.0	2.4			
		Kidney	0.60	1.0	0.60			
		Liver	0.64	1.0	0.64			
		Spleen	0.60	1.0	0.60			
		Total body	Totals for Chain		2.1			
		Lung (insol.)			1.6			
		Bone			6.2			
		Kidney			1.5			
		Liver			1.6			
		Spleen			1.5			
$_{42}Mo^{99}$	2.79	Total body	0.45	1.0	0.45	0.45	0.45	0.45
		Lung (insol.)	0.45	1.0	0.45			
		Kidney	0.45	1.0	0.45			
		Liver	0.45	1.0	0.45			
Tc^{99m} } 87%	0.25	Total body	0.080	0.80	0.064	0.035	0.080	0.020
		Lung (insol.)	0.035	1.0	0.035			
		Kidney	0.026	0.99	0.026			
		Liver	0.035	0.99	0.035			
Tc^{99}	7.3×10^7	Total body	0.094	10^{-8}	9.4×10^{-10}	0.094	0.094	0.094
		Lung (insol.)	0.094	1.6×10^{-6}	1.5×10^{-7}			

Radionuclide	Half-life (T_r in days)	Effective energy for organs of reference				Eff. energy, ΣE(RBE), (E in MeV) for portions of GI tract		
		Organs of reference	ΣE(RBE)n (E in MeV)	F	ΣEF(RBE)n (E in MeV)	S	SI	LI
		Kidney	0.094	2.6×10^{-7}	2.4×10^{-8}			
		Liver	0.094	3.9×10^{-7}	3.7×10^{-8}			
		Total body	Totals for Chain		0.51			
		Lung (insol.)			0.49			
		Kidney			0.48			
		Liver			0.48			
$_{42}Mo^{99}$ } 13%	2.79	Total body	0.71	1.0	0.71	0.40	0.71	0.29
		Lung (insol.)	0.40	1.0	0.40			
		Kidney	0.34	1.0	0.34			
		Liver	0.40	1.0	0.40			
Tc^{99}	7.3×10^{7}	Total body	0.094	1.3×10^{-8}	1.2×10^{-9}	0.094	0.094	0.094
		Lung (insol.)	0.094	1.6×10^{-6}	1.5×10^{-7}			
		Kidney	0.094	2.6×10^{-7}	2.4×10^{-8}			
		Liver	0.094	3.9×10^{-7}	3.7×10^{-8}			
		Total body	Totals for Chain		0.71			
		Lung (insol.)			0.40			
		Kidney			0.34			
		Liver			0.40			
$_{43}Tc^{96m}$	0.036	Total body	0.034	1.0	0.034	0.034	0.034	0.032
		Lung (insol.)	0.034	1.0	0.034			
		Kidney	0.034	1.0	0.034			
		Liver	0.034	1.0	0.034			
		Lung (sol.)	0.034	1.0	0.034			
		Bone	0.089	1.0	0.089			
		Skin	0.015	1.0	0.015			
Tc^{96}	4.3	Total body	1.4	0.19	0.27	0.64	1.4	0.35
		Lung (insol.)	0.64	0.98	0.63			
		Kidney	0.47	0.81	0.38			
		Liver	0.64	0.88	0.56			
		Lung (sol.)	0.64	0.54	0.35			
		Bone	0.35	0.86	0.30			
		Skin	0.0083	0.70	0.0058			
		Total Body	Totals for Chain		0.30			
		Lung (insol.)			0.66			
		Kidney			0.42			
		Liver			0.60			
		Lung (sol.)			0.38			
		Bone			0.39			
		Skin			0.021			
$_{43}Tc^{97m}$	92	Total body	0.090	1.0	0.090	0.090	0.090	0.089
		Lung (insol.)	0.090	1.0	0.090			

Radionuclide	Half-life (T_r in days)	Effective energy for organs of reference: Organs of Reference	$\Sigma E(RBE)n$ (E in MeV)	F	$\Sigma EF(RBE)n$ (E in MeV)	Eff. energy, $\Sigma E(RBE)$, (E in MeV) for portions of GI tract: S	SI	LI
		Kidney	0.090	1.0	0.090			
		Liver	0.090	1.0	0.090			
		Skin	0.071	1.0	0.071			
		Bone	0.37	1.0	0.37			
		Lung (sol.)	0.090	1.0	0.090			
Tc^{97}	3.7×10^6	Total body	0.020	2.7×10^{-7}	5.4×10^{-9}	0.020	0.020	0.019
		Lung (insol.)	0.020	3.2×10^{-5}	6.4×10^{-7}			
		Kidney	0.020	5.4×10^{-6}	1.1×10^{-7}			
		Liver	0.020	8.1×10^{-6}	1.6×10^{-7}			
		Skin	0.0011	2.7×10^{-6}	3.0×10^{-9}			
		Bone	0.019	6.8×10^{-6}	1.3×10^{-7}			
		Lung (sol.)	0.020	1.4×10^{-6}	2.8×10^{-8}			
		Total body	Totals for Chain		0.090			
		Lung (insol.)			0.090			
		Kidney			0.090			
		Liver			0.090			
		Skin			0.071			
		Bone			0.37			
		Lung (sol.)			0.090			
$_{43}Tc^{99m}$	0.25	Total body	0.080	1.0	0.080	0.035	0.080	0.020
		Lung (insol.)	0.035	1.0	0.035			
		Kidney	0.026	1.0	0.026			
		Lung (sol.)	0.035	1.0	0.035			
		Liver	0.035	1.0	0.035			
		Bone	0.020	1.0	0.020			
		Skin	0.0022	1.0	0.0022			
Tc^{99}	7.3×10^7	Total body	0.094	1.3×10^{-8}	1.2×10^{-9}	0.094	0.094	0.094
		Lung (insol.)	0.094	1.6×10^{-6}	1.5×10^{-7}			
		Kidney	0.094	2.6×10^{-7}	2.4×10^{-8}			
		Lung (sol.)	0.094	6.5×10^{-8}	6.1×10^{-9}			
		Liver	0.094	3.9×10^{-7}	3.7×10^{-8}			
		Bone	0.47	3.2×10^{-7}	1.5×10^{-7}			
		Skin	0.094	1.3×10^{-7}	1.2×10^{-8}			
		Total body	Totals for Chain		0.080			
		Lung (insol.)			0.035			
		Kidney			0.026			
		Lung (sol.)			0.035			
		Liver			0.035			
		Bone			0.020			
		Skin			0.0022			
$_{44}Ru^{97}$	2.8	Total body	0.15	1.0	0.15	0.078	0.15	0.050
		Lung (insol.)	0.078	1.0	0.078			

Radionuclide	Half-life (T_r in days)	Effective energy for organs of reference				Eff. energy, ΣE(RBE), (E in MeV) for portions of GI tract		
		Organs of Reference	ΣE(RBE)n (E in MeV)	F	ΣEF(RBE)n (E in MeV)	S	SI	LI
		Kidney	0.062	1.0	0.062			
		Bone	0.050	1.0	0.050			
Tc^{97m}	92	Total body	0.090	0.011	9.9×10^{-4}	0.090	0.090	0.089
		Lung (insol.)	0.090	0.57	0.051			
		Kidney	0.090	0.17	0.015			
		Bone	0.37	0.22	0.081			
Tc^{97}	3.7×10^{6}	Total body	0.020	2.9×10^{-9}	5.8×10^{-11}	0.020	0.020	0.019
		Lung (insol.)	0.020	1.8×10^{-5}	3.6×10^{-7}			
		Kidney	0.020	9.4×10^{-7}	1.9×10^{-8}			
		Bone	0.019	1.5×10^{-6}	2.9×10^{-8}			
		Total body	Totals for Chain		0.15			
		Lung (insol.)			0.13			
		Kidney			0.077			
		Bone			0.13			
$_{44}Ru^{103}$	41	Total body	0.38	1.0	0.38	0.21	0.38	0.14
		Lung (insol.)	0.21	1.0	0.21			
		Kidney	0.17	1.0	0.17			
		Bone	0.43	1.0	0.43			
Rh^{103m}	0.038	Total body	0.055	1.0	0.055	0.055	0.055	0.053
		Lung (insol.)	0.055	1.0	0.055			
		Kidney	0.054	1.0	0.054			
		Bone	0.19	1.0	0.19			
		Total body	Totals for Chain		0.44			
		Lung (insol.)			0.27			
		Kidney			0.22			
		Bone			0.62			
$_{44}Ru^{105}$	0.19	Total body	0.98	1.0	0.98	0.72	0.98	0.62
Rh^{105m}		Lung (insol.)	0.72	1.0	0.72			
		Kidney	0.66	1.0	0.66			
		Bone	2.6	1.0	2.6			
Rh^{105}	1.52	Total body	0.20	0.88	0.18	0.19	0.20	0.19
		Lung (insol.)	0.19	0.99	0.19			
		Kidney	0.19	0.95	0.18			
		Bone	0.95	0.91	0.86			
		Total body	Totals for Chain		1.2			
		Lung (insol.)			0.91			
		Kidney			0.84			
		Bone			3.5			
$_{46}Pd^{103}$	17	Total body	0.023	1.0	0.023	0.022	0.023	0.019
		Lung (insol.)	0.022	1.0	0.022			
		Kidney	0.021	1.0	0.021			

Radionuclide	Half-life (T_r in days)	Effective energy for organs of reference				Eff. energy, ΣE(RBE), (E in MeV) for portions of GI tract		
		Organs of reference	ΣE(RBE)n (E in MeV)	F	ΣEF(RBE)n (E in MeV)	S	SI	LI
Rh^{103m}	0.038	Spleen	0.021	1.0	0.021	0.041	0.041	0.039
		Liver	0.022	1.0	0.022			
		Total body	0.041	1.0	0.041			
		Lung (insol.)	0.041	1.0	0.041			
		Kidney	0.040	1.0	0.040			
		Spleen	0.040	1.0	0.040			
		Liver	0.041	1.0	0.041			
		Total body	Totals for Chain		0.064			
		Lung (insol.)			0.063			
		Kidney			0.061			
		Spleen			0.061			
		Liver			0.063			
$_{48}Cd^{115m}$	43	Total body	0.61	1.0	0.61	0.61	0.61	0.61
		Lung (insol.)	0.61	1.0	0.61			
		Liver	0.61	1.0	0.61			
		Kidney	0.61	1.0	0.61			
Cd^{115}	2.2	Total body	0	1.0	0	0	0	0
		Lung (insol.)	0	1.0	0			
		Liver	0	1.0	0			
		Kidney	0	1.0	0			
In^{115m}	0.19	Total body	0	0.99	0	0	0	0
		Lung (insol.)	0	1.0	0			
		Liver	0	0.99	0			
		Kidney	0	0.99	0			
In^{115}	2.2×10^{17}	Total body	0.17	2.2×10^{-16}	3.7×10^{-17}	0.17	0.17	0.17
		Lung (insol.)	0.17	5.5×10^{-16}	9.4×10^{-17}			
		Liver	0.17	2.6×10^{-16}	4.4×10^{-17}			
		Kidney	0.17	2.7×10^{-16}	4.6×10^{-17}			
		Total body	Totals for Chain		0.61			
		Lung (insol.)			0.61			
		Liver			0.61			
		Kidney			0.61			
$_{48}Cd^{116}$	2.2	Total body	0.45	1.0	0.45	0.38	0.45	0.36
		Lung (insol.)	0.38	1.0	0.38			
		Liver	0.38	1.0	0.38			
		Kidney	0.37	1.0	0.37			
In^{115m}	0.19	Total body	0.26	1.0	0.26	0.20	0.26	0.18
		Lung (insol.)	0.20	1.0	0.20			
		Liver	0.20	1.0	0.20			
		Kidney	0.19	1.0	0.19			
In^{115}	2.2×10^{17}	Total body	0.17	2.2×10^{-16}	3.7×10^{-17}	0.17	0.17	0.17
		Lung (insol.)	0.17	5.5×10^{-16}	9.4×10^{-17}			
		Liver	0.17	2.6×10^{-16}	4.4×10^{-17}			

Radionuclide	Half-life (T_r in days)	Effective energy for organs of reference: Organs of reference	ΣE(RBE)n (E in MeV)	F	ΣEF(RBE)n (E in MeV)	Eff. energy, ΣE(RBE), (E in MeV) for portions of GI tract: S	SI	LI
		Kidney	0.17	2.7×10^{-16}	4.6×10^{-17}			
		Total body	Totals for Chain		0.71			
		Lung (insol.)			0.58			
		Liver			0.58			
		Kidney			0.56			
$_{49}In^{115m}$	0.19	Total body	0.26	1.0	0.26	0.20	0.26	0.18
		Lung (insol.)	0.20	1.0	0.20			
		Kidney	0.19	1.0	0.19			
		Spleen	0.19	1.0	0.19			
		Liver	0.20	1.0	0.20			
		Thyroid	0.16	1.0	0.16			
		Bone	0.74	1.0	0.74			
		Skin	0.14	1.0	0.14			
In^{115}	2.2×10^{17}	Total body	0.17	2.2×10^{-16}	3.7×10^{-17}	0.17	0.17	0.17
		Lung (insol.)	0.17	5.5×10^{-16}	9.4×10^{-17}			
		Kidney	0.17	2.7×10^{-16}	4.6×10^{-17}			
		Spleen	0.17	2.2×10^{-16}	3.7×10^{-17}			
		Liver	0.17	2.6×10^{-16}	4.4×10^{-17}			
		Thyroid	0.17	3.8×10^{-17}	6.5×10^{-17}			
		Bone	0.85	2.6×10^{-16}	2.2×10^{-16}			
		Skin	0.17	3.0×10^{-16}	5.1×10^{-17}			
		Total body	Totals for Chain		0.26			
		Lung (insol.)			0.20			
		Kidney			0.19			
		Spleen			0.19			
		Liver			0.20			
		Thyroid			0.16			
		Bone			0.74			
		Skin			0.14			
$_{50}Sn^{113}$	112	Total body	0.028	1.0	0.028	0.024	0.028	0.018
		Lung (insol.)	0.024	1.0	0.024			
		Bone	0.018	1.0	0.018			
		Prostate	0.0023	1.0	0.0023			
		Liver	0.024	1.0	0.024			
		Thyroid	0.0023	1.0	0.0023			
In^{113m}	0.073	Total body	0.29	1.0	0.29	0.21	0.29	0.17
		Lung (insol.)	0.21	1.0	0.21			
		Bone	0.68	1.0	0.68			
		Prostate	0.16	1.0	0.16			
		Liver	0.21	1.0	0.21			
		Thyroid	0.16	0.99	0.16			

Radionuclide	Half-life (T_r in days)	Effective energy for organs of reference				Eff. energy, ΣE(RBE), (E in MeV) for portions of GI tract		
		Organs of reference	ΣE(RBE)n (E in MeV)	F	ΣEF(RBE)n (E in MeV)	S	SI	LI
		Total body	Totals for Chain		0.32			
		Lung (insol.)			0.23			
		Bone			0.70			
		Prostate			0.16			
		Liver			0.23			
		Thyroid			0.16			
$_{50}Sn^{125}$ (83%)	9.5	Total body	0.93	1.0	0.93	0.93	0.93	0.93
		Lung (insol.)	0.93	1.0	0.93			
		Bone	4.7	1.0	4.7			
		Prostate	0.93	1.0	0.93			
		Liver	0.93	1.0	0.93			
		Thyroid	0.93	1.0	0.93			
Sb^{125} (83%)	877	Total body	0.32	0.041	0.013	0.21	0.32	0.16
		Lung (insol.)	0.21	0.12	0.025			
		Bone	0.62	0.10	0.062			
		Prostate	0.14	0.041	0.0057			
		Liver	0.21	0.042	0.0088			
		Thyroid	0.14	0.0046	6.4×10^{-4}			
Te^{125m} (83%)	58	Total body	0.075	0.0085	6.4×10^{-4}	0.070	0.075	0.061
		Lung (insol.)	0.070	0.081	0.0057			
		Bone	0.21	0.035	0.0074			
		Prostate	0.055	0.0085	4.7×10^{-4}			
		Liver	0.070	0.014	9.8×10^{-4}			
		Thyroid	0.055	6.1×10^{-4}	3.4×10^{-5}			
		Total body	Totals for Chain		0.94			
		Lung (insol.)			0.96			
		Bone			4.8			
		Prostate			0.94			
		Liver			0.94			
		Thyroid			0.93			
$_{50}Sn^{125}$ (17%)	9.5	Total body	0.93	1.0	0.93	0.93	0.93	0.93
		Lung (insol.)	0.93	1.0	0.93			
		Bone	4.7	1.0	4.7			
		Prostate	0.93	1.0	0.93			
		Liver	0.93	1.0	0.93			
		Thyroid	0.93	1.0	0.93			
Sb^{125} (17%)	877	Total body	0.43	0.041	0.018	0.21	0.43	0.13
		Lung (insol.)	0.21	0.12	0.025			
		Bone	0.28	0.10	0.028			
		Prostate	0.095	0.041	0.0039			
		Liver	0.21	0.042	0.0088			
		Thyroid	0.095	0.0046	4.4×10^{-4}			

Radionuclide	Half-life (T_r in days)	Effective energy for organs of reference				Eff. energy, ΣE(RBE), (E in MeV) for portions of GI tract		
		Organs of reference	ΣE(RBE)n (E in MeV)	F	ΣEF(RBE)n (E in MeV)	S	SI	LI
		Total body	Totals for Chain		0.95			
		Lung (insol.)			0.96			
		Bone			4.7			
		Prostate			0.93			
		Liver			0.94			
		Thyroid			0.93			
$_{51}Sb^{125}$ } 83%	877	Total body	0.32	1.0	0.32	0.21	0.32	0.16
		Lung (insol.)	0.21	1.0	0.21			
		Lung (sol.)	0.21	1.0	0.21			
		Bone	0.62	1.0	0.62			
		Liver	0.21	1.0	0.21			
		Thyroid	0.14	1.0	0.14			
Te^{125m}	58	Total body	0.075	0.21	0.016	0.070	0.075	0.061
		Lung (insol.)	0.070	0.67	0.047			
		Lung (sol.)	0.070	0.31	0.022			
		Bone	0.21	0.34	0.071			
		Liver	0.070	0.34	0.024			
		Thyroid	0.055	0.13	0.0072			
		Total body	Totals for Chain		0.34			
		Lung (insol.)			0.26			
		Lung (sol.)			0.23			
		Bone			0.69			
		Liver			0.23			
		Thyroid			0.15			
$_{52}Te^{127m}$	105	Total body	0.089	1.0	0.089	0.083	0.089	0.076
		Lung (insol.)	0.083	1.0	0.083			
		Kidney	0.079	1.0	0.079			
		Testis	0.070	1.0	0.070			
		Spleen	0.079	1.0	0.079			
		Bone	0.31	1.0	0.31			
		Liver	0.083	1.0	0.083			
		Thyroid	0.070	1.0	0.070			
Te^{127}	0.39	Total body	0.24	0.97	0.23	0.24	0.24	0.24
		Lung (insol.)	0.24	1.0	0.24			
		Kidney	0.24	0.99	0.24			
		Testis	0.24	0.99	0.24			
		Spleen	0.24	0.99	0.24			
		Bone	1.2	0.99	1.2			
		Liver	0.24	0.99	0.24			
		Thyroid	0.24	0.95	0.23			
		Total body	Totals for Chain		0.32			
		Lung (insol.)			0.32			
		Kidney			0.32			

Radionuclide	Half-life (T_r in days)	Effective energy for organs of reference				Eff. energy, ΣE(RBE), (E in MeV) for portions of GI tract		
		Organs of reference	ΣE(RBE)n (E in MeV)	F	ΣEF(RBE)n (E in MeV)	S	SI	LI
		Testis	Totals for Chain		0.31			
		Spleen			0.32			
		Bone			1.5			
		Liver			0.32			
		Thyroid			0.30			
$_{52}Te^{129m}$	33	Total body	0.11	1.0	0.11	0.10	0.11	0.093
		Lung (insol.)	0.10	1.0	0.10			
		Kidney	0.096	1.0	0.096			
		Testis	0.087	1.0	0.087			
		Spleen	0.096	1.0	0.096			
		Liver	0.10	1.0	0.10			
		Bone	0.40	1.0	0.40			
		Thyroid	0.087	1.0	0.087			
Te^{129}	0.051	Total body	0.98	1.0	0.98	0.73	0.98	0.64
		Lung (insol.)	0.73	1.0	0.73			
		Kidney	0.68	1.0	0.68			
		Testis	0.60	1.0	0.60			
		Spleen	0.68	1.0	0.68			
		Liver	0.73	1.0	0.73			
		Bone	2.8	1.0	2.8			
		Thyroid	0.60	0.99	0.59			
I^{129}	6.3×10^{9}	Total body	0.089	2.2×10^{-8}	2.0×10^{-9}	0.082	0.089	0.073
		Lung (insol.)	0.082	1.9×10^{-8}	1.6×10^{-9}			
		Kidney	0.077	2.7×10^{-9}	2.1×10^{-10}			
		Testis	0.068	2.2×10^{-8}	1.5×10^{-9}			
		Spleen	0.077	2.2×10^{-9}	1.7×10^{-10}			
		Liver	0.082	5.5×10^{-9}	4.5×10^{-10}			
		Bone	0.30	3.2×10^{-9}	9.6×10^{-10}			
		Thyroid	0.068	2.2×10^{-8}	1.5×10^{-9}			
		Total body	Totals for Chain		1.1			
		Lung (insol.)			0.83			
		Kidney			0.78			
		Testis			0.69			
		Spleen			0.78			
		Liver			0.83			
		Bone			3.2			
		Thyroid			0.68			
$_{52}Te^{129}$	0.051	Total body	0.98	1.0	0.98	0.73	0.98	0.64
		Lung (insol.)	0.73	1.0	0.73			
		Kidney	0.68	1.0	0.68			
		Testis	0.60	1.0	0.60			
		Spleen	0.68	1.0	0.68			
		Liver	0.73	1.0	0.73			

Radionuclide	Half-life (T_r in days)	Effective energy for organs of reference: Organs of reference	$\Sigma E(\text{RBE})n$ (E in MeV)	F	$\Sigma EF(\text{RBE})n$ (E in MeV)	Eff. energy, $\Sigma E(\text{RBE})$, (E in MeV) for portions of GI tract: S	SI	LI
		Bone	2.8	1.0	2.8			
		Thyroid	0.60	1.0	0.60			
I^{129}	6.3×10^{9}	Total body	0.089	2.2×10^{-8}	2.0×10^{-9}	0.082	0.089	0.073
		Lung (insol.)	0.082	1.9×10^{-8}	1.6×10^{-9}			
		Kidney	0.077	2.7×10^{-9}	2.1×10^{-10}			
		Testis	0.068	2.2×10^{-8}	1.5×10^{-9}			
		Spleen	0.077	2.2×10^{-9}	1.7×10^{-10}			
		Liver	0.082	5.6×10^{-9}	4.6×10^{-10}			
		Bone	0.030	3.2×10^{-9}	9.6×10^{-11}			
		Thyroid	0.068	2.2×10^{-8}	1.5×10^{-9}			
		Total body	Totals for Chain		0.98			
		Lung (insol.)			0.73			
		Kidney			0.68			
		Testis			0.60			
		Spleen			0.68			
		Liver			0.73			
		Bone			2.8			
		Thyroid			0.60			
$_{52}Te^{131m}$	1.25	Total body	1.2	1.0	1.2	0.73	1.2	0.55
Te^{131}		Lung (insol.)	0.73	1.0	0.73			
		Kidney	0.63	1.0	0.63			
		Spleen	0.63	1.0	0.63			
		Liver	0.73	1.0	0.73			
		Bone	1.9	1.0	1.9			
		Thyroid	0.47	1.0	0.47			
I^{131}	8.05	Total body	0.44	0.94	0.41	0.30	0.44	0.25
Xe^{131m}		Lung (insol.)	0.30	0.94	0.28			
		Kidney	0.27	0.68	0.18			
		Spleen	0.27	0.63	0.17			
		Liver	0.30	0.81	0.24			
		Bone	1.0	0.71	0.71			
		Thyroid	0.23	0.94	0.22			
		Total body	Totals for Chain		1.6			
		Lung (insol.)			1.0			
		Kidney			0.81			
		Spleen			0.80			
		Liver			0.97			
		Bone			2.6			
		Thyroid			0.69			
$_{52}Te^{132}$	3.2	Total body	0.21	1.0	0.21	0.13	0.21	0.10
		Lung (insol.)	0.13	1.0	0.13			
		Kidney	0.11	1.0	0.11			
		Spleen	0.11	1.0	0.11			

Radionuclide	Half-life (T_r in days)	Organs of reference	$\Sigma E(RBE)n$ (E in MeV)	F	$\Sigma EF(RBE)n$ (E in MeV)	S	SI	LI
		Effective energy for organs of reference				Eff. energy, $\Sigma E(RBE)$, (E in MeV) for portions of GI tract		
		Testis	0.089	1.0	0.089			
		Bone	0.38	1.0	0.38			
		Liver	0.13	1.0	0.13			
		Thyroid	0.089	1.0	0.089			
I^{132}	0.097	Total body	1.7	1.0	1.7	1.0	1.7	0.76
		Lung (insol.)	1.0	1.0	1.0			
		Kidney	0.86	0.99	0.85			
		Spleen	0.86	0.99	0.85			
		Testis	0.65	0.99	0.64			
		Bone	2.7	0.99	2.7			
		Liver	1.0	0.99	0.99			
		Thyroid	0.65	1.0	0.65			
		Total body	Totals for Chain		1.9			
		Lung (insol.)			1.1			
		Kidney			0.96			
		Spleen			0.96			
		Testis			0.73			
		Bone			3.1			
		Liver			1.1			
		Thyroid			0.74			
${}_{53}I^{133}$	0.87	Total body	0.84	1.0	0.84	0.64	0.84	0.57
Xe^{133m}		Lung (insol.)	0.64	1.0	0.64			
		Thyroid	0.54	1.0	0.54			
Xe^{133}	5.27	Total body	0.17	0.016	0.0027	0.16	0.17	0.15
		Lung (insol.)	0.16	0.016	0.0026			
		Thyroid	0.14	0.016	0.0022			
		Total body	Totals for Chain		0.84			
		Lung (insol.)			0.64			
		Thyroid			0.54			
${}_{53}I^{135}$	0.28	Total body	1.2	1.0	1.2	0.70	1.2	0.54
Xe^{135m}		Lung (insol.)	0.70	1.0	0.70			
		Thyroid	0.46	1.0	0.46			
Xe^{135}	0.38	Total body	0.50	0.18	0.090	0.40	0.50	0.36
Cs^{135m}		Lung (insol.)	0.40	0.18	0.072			
		Thyroid	0.33	0.18	0.059			
Cs^{135}	1.1×10^9	Total body	0.066	1.1×10^{-8}	7.3×10^{-10}	0.066	0.066	0.066
		Lung (insol.)	0.066	1.9×10^{-8}	1.3×10^{-9}			
		Thyroid	0.066	1.1×10^{-8}	7.3×10^{-10}			
		Total body	Totals for Chain		1.3			
		Lung (insol.)			0.77			
		Thyroid			0.52			

Radionuclide	Half-life (T_r in days)	Effective energy for organs of reference				Eff. energy, ΣE(RBE), (E in MeV) for portions of GI tract		
		Organs of reference	ΣE(RBE)n (E in MeV)	F	ΣEF(RBE)n (E in MeV)	S	SI	LI
$_{55}Cs^{134m}$	0.13	Total body	0.11	1.0	0.11	0.092	0.11	0.083
		Lung (insol.)	0.092	1.0	0.092			
		Liver	0.092	1.0	0.092			
		Spleen	0.087	1.0	0.087			
		Kidney	0.087	1.0	0.087			
		Muscle	0.11	1.0	0.11			
		Bone	0.35	1.0	0.35			
		Lung (sol.)	0.092	1.0	0.092			
Cs^{134}	840	Total body	1.1	0.077	0.085	0.57	1.1	0.38
		Lung (insol.)	0.57	0.13	0.074			
		Liver	0.57	0.096	0.055			
		Spleen	0.46	0.10	0.046			
		Kidney	0.46	0.048	0.022			
		Muscle	1.1	0.14	0.15			
		Bone	0.99	0.14	0.14			
		Lung (sol.)	0.57	0.14	0.080			
		Total body	Totals for Chain		0.19			
		Lung (insol.)			0.17			
		Liver			0.15			
		Spleen			0.13			
		Kidney			0.11			
		Muscle			0.26			
		Bone			0.49			
		Lung (sol.)			0.17			
$_{56}Ba^{131}$	11.6	Total body	0.35	1.0	0.35	0.17	0.35	0.093
		Lung (insol.)	0.17	1.0	0.17			
		Bone	0.093	1.0	0.093			
		Liver	0.17	1.0	0.17			
		Muscle	0.35	1.0	0.35			
		Spleen	0.12	1.0	0.12			
		Kidney	0.12	1.0	0.12			
		Lung (sol.)	0.17	1.0	0.17			
Cs^{131}	10	Total body	0.029	0.88	0.026	0.024	0.029	0.017
		Lung (insol.)	0.024	0.92	0.022			
		Bone	0.017	0.93	0.016			
		Liver	0.024	0.90	0.022			
		Muscle	0.029	0.93	0.027			
		Spleen	0.021	0.91	0.019			
		Kidney	0.021	0.81	0.017			
		Lung (sol.)	0.024	0.93	0.022			
		Total body	Totals for Chain		0.38			
		Lung (insol.)			0.19			
		Bone			0.11			
		Liver			0.19			

Radionuclide	Half-life (T_r in days)	Effective energy for organs of reference				Eff. energy, ΣE(RBE), (E in MeV) for portions of GI tract		
		Organs of Reference	ΣE(RBE)n (E in MeV)	F	ΣEF(RBE)n (E in MeV)	S	SI	LI
		Muscle	Totals for Chain		0.38			
		Spleen			0.14			
		Kidney			0.14			
		Lung (sol.)			0.19			
$_{56}Ba^{140}$	12.8	Total body	0.40	1.0	0.40	0.34	0.40	0.32
		Lung (insol.)	0.34	1.0	0.34			
		Bone	1.5	1.0	1.5			
		Liver	0.34	1.0	0.34			
		Lung (sol.)	0.34	1.0	0.34			
		Muscle	0.40	1.0	0.40			
		Spleen	0.33	1.0	0.33			
		Kidney	0.33	1.0	0.33			
La^{140}	1.68	Total body	1.9	1.0	1.9	1.1	1.9	0.80
		Lung (insol.)	1.1	1.0	1.1			
		Bone	2.7	1.0	2.7			
		Liver	1.1	1.0	1.1			
		Lung (sol.)	1.1	1.0	1.1			
		Muscle	1.9	1.0	1.9			
		Spleen	0.92	1.0	0.92			
		Kidney	0.92	1.0	0.92			
		Total body	Totals for Chain		2.3			
		Lung (insol.)			1.4			
		Bone			4.2			
		Liver			1.4			
		Lung (sol.)			1.4			
		Muscle			2.3			
		Spleen			1.2			
		Kidney			1.2			
$_{58}Ce^{143}$	1.33	Total body	0.66	1.0	0.66	0.54	0.66	0.49
		Lung (insol.)	0.54	1.0	0.54			
		Liver	0.54	1.0	0.54			
		Bone	2.2	1.0	2.2			
		Kidney	0.51	1.0	0.51			
Pr^{143}	13.7	Total body	0.32	0.98	0.31	0.32	0.32	0.32
		Lung (insol.)	0.32	0.90	0.29			
		Liver	0.32	0.96	0.31			
		Bone	1.6	0.99	1.6			
		Kidney	0.32	0.98	0.31			
		Total body	Totals for Chain		0.97			
		Lung (insol.)			0.83			
		Liver			0.85			
		Bone			3.8			
		Kidney			0.82			

Radionuclide	Half-life (T_r in days)	Effective energy for organs of reference: Organs of Reference	ΣE(RBE)n (E in MeV)	F	ΣEF(RBE)n (E in MeV)	Eff. energy, ΣE(RBE), (E in MeV) for portions of GI tract: S	SI	LI
$_{58}Ce^{144}$	290	Total body	1.3	1.0	1.3	1.3	1.3	1.3
Pr^{144}		Lung (insol.)	1.3	1.0	1.3			
		Liver	1.3	1.0	1.3			
		Bone	6.3	1.0	6.3			
		Kidney	1.3	1.0	1.3			
Nd^{144}	7.3×10^{17}	Total body	20	9.0×10^{-16}	1.8×10^{-14}	20	20	20
		Lung (insol.)	20	1.6×10^{-16}	3.2×10^{-15}			
		Liver	20	1.8×10^{-16}	3.6×10^{-15}			
		Bone	100	2.0×10^{-15}	2.0×10^{-13}			
		Kidney	20	9.0×10^{-16}	1.8×10^{-14}			
		Total body	Totals for Chain		1.3			
		Lung (insol.)			1.3			
		Bone			6.3			
		Liver			1.3			
		Kidney			1.3			
$_{60}Nd^{147}$	11.3	Total body	0.37	1.0	0.37	0.29	0.37	0.26
		Lung (insol.)	0.29	1.0	0.29			
		Liver	0.29	1.0	0.29			
		Kidney	0.28	1.0	0.28			
		Bone	1.2	1.0	1.2			
Pm^{147}	920	Total body	0.069	0.42	0.029	0.069	0.069	0.069
		Lung (insol.)	0.069	0.12	0.0083			
		Liver	0.069	0.42	0.029			
		Kidney	0.069	0.42	0.029			
		Bone	0.35	0.62	0.22			
Sm^{147}	4.8×10^{13}	Total body	23	5.7×10^{-12}	1.3×10^{-10}	0.22	0.22	0.22
		Lung (insol.)	23	2.9×10^{-13}	6.7×10^{-12}			
		Liver	23	1.6×10^{-12}	3.7×10^{-11}			
		Kidney	23	5.7×10^{-12}	1.3×10^{-10}			
		Bone	115	1.9×10^{-11}	2.1×10^{-9}			
		Total body	Totals for Chain		0.40			
		Lung (insol.)			0.30			
		Liver			0.32			
		Kidney			0.31			
		Bone			1.4			
$_{60}Nd^{149}$	0.083	Total body	0.55	1.0	0.55	0.55	0.55	0.55
		Lung (insol.)	0.55	1.0	0.55			
		Liver	0.55	1.0	0.55			
		Kidney	0.55	1.0	0.55			
		Bone	2.8	1.0	2.8			
Pm^{149}	2.2	Total body	0.54	1.0	0.54	0.44	0.54	0.41
		Lung (insol.)	0.44	1.0	0.44			
		Liver	0.44	1.0	0.44			

Radionuclide	Half-life (T_r in days)	Effective energy for organs of reference: Organs of reference	ΣE(RBE)n (E in MeV)	F	ΣEF(RBE)n (E in MeV)	Eff. energy, ΣE(RBE), (E in MeV) for portions of GI tract: S	SI	LI
		Kidney	0.42	1.0	0.42			
		Bone	1.9	1.0	1.9			
		Total body	Totals for Chain		1.1			
		Lung (insol.)			0.99			
		Liver			0.99			
		Kidney			0.97			
		Bone			4.7			
$_{61}Pm^{147}$	920	Total body	0.069	1.0	0.069	0.069	0.069	0.069
		Lung (insol.)	0.069	1.0	0.069			
		Bone	0.35	1.0	0.35			
		Kidney	0.069	1.0	0.069			
		Liver	0.069	1.0	0.069			
Sm^{147}	4.8×10^{13}	Total body	23	1.4×10^{-11}	3.2×10^{-10}	0.22	0.22	0.22
		Lung (insol.)	23	2.5×10^{-12}	5.8×10^{-11}			
		Bone	115	3.1×10^{-11}	3.6×10^{-9}			
		Kidney	23	1.4×10^{-11}	3.2×10^{-10}			
		Liver	23	3.9×10^{-12}	9.0×10^{-11}			
		Total body	Totals for Chain		0.069			
		Lung (insol.)			0.069			
		Bone			0.35			
		Kidney			0.069			
		Liver			0.069			
$_{66}Dy^{166}$	3.4	Total body	0.094	1.0	0.094	0.094	0.094	0.094
		Lung (insol.)	0.094	1.0	0.094			
		Bone	0.47	1.0	0.47			
		Liver	0.094	1.0	0.094			
Ho^{166}	1.1	Total body	0.70	1.0	0.70	0.69	0.70	0.69
Er^{166m}		Lung (insol.)	0.69	0.96	0.66			
		Bone	3.4	1.0	3.4			
		Liver	0.69	1.0	0.69			
		Total body	Totals for Chain		0.79			
		Lung (insol.)			0.75			
		Bone			3.9			
		Liver			0.78			
$_{68}Er^{171}$	0.31	Total body	0.64	1.0	0.64	0.49	0.64	0.43
Tm^{171m}		Lung (insol.)	0.49	1.0	0.49			
		Bone	1.9	1.0	1.9			
		Kidney	0.45	1.0	0.45			
Tm^{171}	694	Total body	0.030	0.49	0.015	0.030	0.030	0.030
		Lung (insol.)	0.030	0.15	0.0045			

Radionuclide	Half-life (T_r in days)	Effective energy for organs of reference: Organs of reference	$\Sigma E(RBE)n$ (E in MeV)	F	$\Sigma EF(RBE)n$ (E in MeV)	Eff. energy, $\Sigma E(RBE)$, (E in MeV) for portions of GI tract: S	SI	LI
		Bone	0.15	0.59	0.089			
		Kidney	0.030	0.33	0.0099			
		Total body	Totals for Chain		0.65			
		Lung (insol.)			0.49			
		Bone			2.0			
		Kidney			0.46			
$_{74}W^{187}$	1.0	Total body	0.68	1.0	0.68	0.44	0.68	0.36
Re^{187m}		Lung (insol.)	0.44	1.0	0.44			
		Liver	0.44	1.0	0.44			
		Bone	1.4	1.0	1.4			
Re^{187}	1.8×10^{13}	Total body	0.012	3.9×10^{-13}	4.7×10^{-15}	0.012	0.012	0.012
		Lung (insol.)	0.012	6.7×10^{-12}	8.0×10^{-14}			
		Liver	0.012	7.8×10^{-13}	9.4×10^{-15}			
		Bone	0.062	1.9×10^{-13}	1.2×10^{-14}			
		Total body	Totals for Chain		0.68			
		Lung (insol.)			0.44			
		Liver			0.44			
		Bone			1.4			
$_{76}Os^{191m}$	0.58	Total body	0.042	1.0	0.042	0.018	0.042	0.0097
		Lung (insol.)	0.018	1.0	0.018			
		Kidney	0.013	1.0	0.013			
		Liver	0.018	1.0	0.018			
Os^{191}	16	Total body	0.16	0.11	0.018	0.12	0.16	0.10
Ir^{191m}		Lung (insol.)	0.12	0.88	0.11			
		Kidney	0.11	0.24	0.026			
		Liver	0.12	0.26	0.031			
		Total body	Totals for Chain		0.060			
		Lung (insol.)			0.13			
		Kidney			0.039			
		Liver			0.049			
$_{78}Pt^{193m}$	3.5	Total body	0.075	1.0	0.075	0.032	0.075	0.017
		Lung (insol.)	0.032	1.0	0.032			
		Kidney	0.023	1.0	0.023			
		Liver	0.032	1.0	0.032			
		Spleen	0.023	1.0	0.023			
Pt^{193}	1.8×10^{5}	Total body	0.043	1.3×10^{-4}	5.6×10^{-6}	0.019	0.043	0.0099
		Lung (insol.)	0.019	6.7×10^{-4}	1.3×10^{-5}			
		Kidney	0.014	3.3×10^{-4}	4.6×10^{-6}			
		Liver	0.019	1.1×10^{-4}	2.1×10^{-6}			
		Spleen	0.014	3.3×10^{-4}	4.6×10^{-6}			

Radionuclide	Half-life (T_r in days)	Effective energy for organs of reference				Eff. energy, ΣE(RBE), (E in MeV) for portions of GI tract		
		Organs of reference	ΣE(RBE)n (E in MeV)	F	ΣEF(RBE)n (E in MeV)	S	SI	LI
		Total body	Totals for Chain		0.075			
		Lung (insol.)			0.032			
		Kidney			0.023			
		Liver			0.032			
		Spleen			0.023			
$_{78}Pt^{197m}$	0.056	Total body	0.30	1.0	0.30	0.28	0.30	0.27
		Lung (insol.)	0.28	1.0	0.28			
		Kidney	0.27	1.0	0.27			
		Liver	0.28	1.0	0.28			
		Spleen	0.27	1.0	0.27			
Pt^{197}	0.75	Total body	0.26	0.97	0.25	0.24	0.26	0.23
		Lung (insol.)	0.24	1.0	0.24			
		Kidney	0.23	0.99	0.23			
		Liver	0.24	0.96	0.23			
		Spleen	0.23	0.99	0.23			
		Total body	Totals for Chain		0.55			
		Lung (insol.)			0.52			
		Kidney			0.50			
		Liver			0.51			
		Spleen			0.50			
$_{80}Hg^{197m}$ Au^{197m}	1.0	Total body	0.22	1.0	0.22	0.15	0.22	0.13
		Lung (insol.)	0.15	1.0	0.15			
		Kidney	0.14	1.0	0.14			
		Spleen	0.14	1.0	0.14			
		Liver	0.15	1.0	0.15			
Hg^{197}	2.7	Total body	0.097	0.78	0.076	0.052	0.097	0.036
		Lung (insol.)	0.052	0.96	0.050			
		Kidney	0.043	0.85	0.037			
		Spleen	0.043	0.78	0.034			
		Liver	0.052	0.85	0.044			
		Total body	Totals for Chain		0.30			
		Lung (insol.)			0.20			
		Kidney			0.18			
		Spleen			0.17			
		Liver			0.19			
$_{82}Pb^{210}$	7.1×10^3	Total body	0.045	1.0	0.045	0.027	0.045	0.019
		Lung (insol.)	0.027	1.0	0.027			
		Kidney	0.023	1.0	0.023			
		Bone	0.051	1.0	0.051			
		Liver	0.027	1.0	0.027			
Bi^{210} Tl^{206}	5.0	Total body	0.40	0.50	0.20	0.40	0.40	0.40
		Lung (insol.)	0.40	0.96	0.38			

Radionuclide	Half-life (T_r in days)	Effective energy for organs of reference: Organs of reference	ΣE(RBE)n (E in MeV)	F	ΣEF(RBE)n (E in MeV)	Eff. energy, ΣE(RBE), (E in MeV) for portions of GI tract: S	SI	LI
		Kidney	0.40	0.54	0.22			
		Bone	2.0	0.72	1.4			
		Liver	0.40	0.76	0.30			
Po^{210}	138.4	Total body	55	0.090	5.0	0.53	0.53	0.53
		Lung (insol.)	55	0.44	24			
		Kidney	55	0.18	9.9			
		Bone	275	0.10	28			
		Liver	55	0.18	9.9			
		Total body	Totals for Chain		5.2			
		Lung (insol.)			25			
		Kidney			10.			
		Bone			29			
		Liver			10			
$_{82}Pb^{212}$	0.44	Total body	0.29	1.0	0.29	0.24	0.29	0.22
		Lung (insol.)	0.24	1.0	0.24			
		Kidney	0.23	1.0	0.23			
		Bone	1.0	1.0	1.0			
		Liver	0.24	1.0	0.24			
Bi^{212}	0.042	Total body	83	0.99	82	1.8	2.2	1.7
Po^{212}		Lung (insol.)	83	1.0	83			
Tl^{208}		Kidney	82	0.99	81			
		Bone	410	1.0	410			
		Liver	83	1.0	83			
		Total body	Totals for Chain		82			
		Lung (insol.)			83			
		Kidney			81			
		Bone			410			
		Liver			83			
$_{83}Bi^{210}$	5	Total body	0.40	1.0	0.40	0.40	0.40	0.40
Tl^{206}		Lung (insol.)	0.40	1.0	0.40			
		Kidney	0.40	1.0	0.40			
		Bone	2.0	1.0	2.0			
		Liver	0.40	1.0	0.40			
		Spleen	0.40	1.0	0.40			
Po^{210}	138.4	Total body	55	0.18	9.9	0.53	0.53	0.53
		Lung (insol.)	55	0.46	25			
		Kidney	55	0.33	18			
		Bone	275	0.14	39			
		Liver	55	0.23	13			
		Spleen	55	0.30	17			
		Total body	Totals for Chain		10			
		Lung (insol.)			26			

Radionuclide	Half-life (T_r in days)	Effective energy for organs of reference: Organs of Reference	$\Sigma E(\text{RBE})n$ (E in MeV)	F	$\Sigma EF(\text{RBE})n$ (E in MeV)	Eff. energy, $\Sigma E(\text{RBE})$, (E in MeV) for portions of GI tract: S	SI	LI
		Kidney	Totals for Chain		19			
		Bone			40			
		Liver			13			
		Spleen			17			
$_{85}At^{211}$	0.30	Total body	61	1.0	61	0.59	0.59	0.59
		Lung (insol.)	61	1.0	61			
		Thyroid	61	1.0	61			
41%		Ovary	61	1.0	61			
		Spleen	61	1.0	61			
Bi^{207}	2.9×10^3	Total body	1.0	0.0017	0.0017	0.45	1.0	0.24
Pb^{207m}		Lung (insol.)	0.45	0.040	0.018			
		Thyroid	0.15	3.4×10^{-4}	5.1×10^{-5}			
		Ovary	0.15	0.0017	2.6×10^{-4}			
		Spleen	0.33	0.0034	0.0011			
		Total body	Totals for Chain		61			
		Lung (insol.)			61			
		Thyroid			61			
		Ovary			61			
		Spleen			61			
$_{88}Ra^{224}$	3.64	Total body	194	1.0	194	1.9	1.9	1.9
Rn^{220}		Lung (insol.)	194	1.0	194			
Po^{216}		Bone	194	1.0	194			
Pb^{212}	0.44	Total body	0.29	1.0	0.29	0.24	0.29	0.22
		Lung (insol.)	0.24	1.0	0.24			
		Bone	0.22	1.0	0.22			
Bi^{212}	0.042	Total body	83	0.99	82	1.8	2.2	1.7
Po^{212}		Lung (insol.)	83	1.0	83			
Tl^{208}		Bone	82	1.0	82			
		Total body	Totals for Chain		280			
		Lung (insol.)			280			
		Bone			280			
$_{88}Ra^{226}$	5.9×10^5	Total body	49	1.0	49	0.48	0.48	0.48
		Bone	49	1.0	49			
Rn^{222}	3.83	Total body	200	0.30	60	3.5	4.4	3.2
Po^{218}		Bone	200	0.30	60			
Pb^{214}								
Bi^{214}								
Po^{214}								
Tl^{210}								

Radionuclide	Half-life (T_r in days)	Effective energy for organs of reference				Eff. energy, ΣE(RBE), (E in MeV) for portions of GI tract		
		Organs of Reference	ΣE(RBE)n (E in MeV)	F	ΣEF(RBE)n (E in MeV)	S	SI	LI
Pb^{210}	7.1×10^3	Total body	0.045	0.051	0.0023	0.027	0.045	0.019
		Bone	0.019	0.087	0.0016			
Bi^{210}	5.0	Total body	0.40	0.025	0.010	0.40	0.40	0.40
Tl^{206}		Bone	0.40	0.063	0.025			
Po^{210}	138.4	Total body	55	0.0046	0.25	0.53	0.53	0.53
		Bone	55	0.0091	0.50			
		Total body	Totals for Chain		110			
		Bone			110			
$_{88}Ra^{228}$	2.4×10^3	Total body	0.0046	1.0	0.0046	0.0046	0.0046	0.0046
		Lung (insol.)	0.0046	1.0	0.0046			
		Bone	0.0046	1.0	0.0046			
Ac^{228}	0.26	Total body	1.1	1.0	1.1	0.74	1.1	0.62
		Lung (insol.)	0.74	1.0	0.74			
		Bone	0.62	1.0	0.62			
Th^{228}	700	Total body	56	0.99	55	0.54	0.54	0.54
		Lung (insol.)	56	0.68	38			
		Bone	56	0.99	55			
Ra^{224}	3.64	Total body	194	0.62	120	1.9	1.9	1.9
Rn^{220}		Lung (insol.)	194	0.44	85			
Po^{216}		Bone	194	0.50	97			
Pb^{212}	0.44	Total body	0.29	0.62	0.18	0.24	0.29	0.22
		Lung (insol.)	0.24	0.44	0.11			
		Bone	0.22	0.50	0.11			
Bi^{212}	0.042	Total body	83	0.62	51	1.8	2.2	1.7
Po^{212}		Lung (insol.)	83	0.44	36			
Tl^{208}		Bone	82	0.50	41			
		Total body	Totals for Chain		230			
		Lung (insol.)			160			
		Bone			190			
$_{89}Ac^{227}$	8.0×10^3	Total body	0.63	1.0	0.63	0.019	0.019	0.019
Fr^{223}		Lung (insol.)	0.63	1.0	0.63			
At^{219}		Bone	3.1	1.0	3.1			
Bi^{215}		Liver	0.63	1.0	0.63			
		Kidney	0.63	1.0	0.63			
Th^{227}	18.4	Total body	62	1.0	62	0.64	0.69	0.62
		Lung (insol.)	61	0.99	60			
		Bone	307	1.0	307			
		Liver	61	1.0	61			
		Kidney	61	1.0	61			
Ra^{223}	11.7	Total body	275	0.50	137	3.7	3.8	3.7
Rn^{219}		Lung (insol.)	275	0.60	165			

Radionuclide	Half-life (T_r in days)	Effective energy for organs of reference: Organs of reference	$\Sigma E(RBE)n$ (E in MeV)	F	$\Sigma EF(RBE)n$ (E in MeV)	Eff. energy, $\Sigma E(RBE)$, (E in MeV) for portions of GI tract: S	SI	LI
Po^{215}		Bone	1370	0.50	687			
Pb^{211}		Liver	275	1.7×10^{-4}	0.047			
Bi^{211}		Kidney	275	0.0011	0.29			
Tl^{207}								
Po^{211}								
		Total body	Totals for Chain		200			
		Lung (insol.)			230			
		Bone			1000			
		Liver			62			
		Kidney			62			
$_{89}Ac^{228}$	0.26	Total body	1.1	1.0	1.1	0.74	1.1	0.62
		Lung (insol.)	0.74	1.0	0.74			
		Bone	2.6	1.0	2.6			
		Kidney	0.67	1.0	0.67			
		Liver	0.74	1.0	0.74			
Th^{228}	700	Total body	56	0.99	55	0.54	0.54	0.54
		Lung (insol.)	56	0.68	38			
		Bone	279	0.99	276			
		Kidney	56	0.97	54			
		Liver	56	0.99	55			
Ra^{224}	3.64	Total body	194	0.62	120	1.9	1.9	1.9
Rn^{220}		Lung (insol.)	194	0.44	85			
Po^{216}		Bone	971	0.50	486			
		Kidney	194	0.0016	0.31			
		Liver	194	2.6×10^{-4}	0.051			
Pb^{212}	0.44	Total body	0.29	0.62	0.18	0.24	0.29	0.22
		Lung (insol.)	0.24	0.44	0.11			
		Bone	1.0	0.50	0.50			
		Kidney	0.23	0.0016	3.7×10^{-4}			
		Liver	0.24	2.6×10^{-4}	6.2×10^{-5}			
Bi^{212}	0.042	Total body	83	0.62	51	1.8	2.2	1.7
Po^{212}		Lung (insol.)	83	0.44	36			
Tl^{208}		Bone	411	0.50	206			
		Kidney	82	0.0016	0.13			
		Liver	83	2.6×10^{-4}	0.022			
		Total body	Totals for Chain		230			
		Lung (insol.)			160			
		Bone			970			
		Kidney			55			
		Liver			56			
$_{90}Th^{227}$	18.4	Total body	62	1.0	62	0.64	0.69	0.62
		Lung (insol.)	61	1.0	61			
		Kidney	61	1.0	61			

Radionuclide	Half-life (T_r in days)	Effective energy for organs of reference: Organs of reference	$\Sigma E(RBE)n$ (E in MeV)	F	$\Sigma EF(RBE)n$ (E in MeV)	Eff. energy, $\Sigma E(RBE)$, (E in MeV) for portions of GI tract: S	SI	LI
		Liver	61	1.0	61			
		Bone	307	1.0	307			
Ra^{223}	11.7	Total body	275	0.50	138	3.7	3.8	3.7
Rn^{219}		Lung (insol.)	275	0.61	168			
Po^{215}		Kidney	275	0.0011	0.30			
Pb^{211}		Liver	275	1.7×10^{-4}	0.047			
Bi^{211}		Bone	1370	0.50	687			
Tl^{207}								
Po^{211}								
		Total body	Totals for Chain		200			
		Lung (insol.)			230			
		Kidney			61			
		Liver			61			
		Bone			990			
$_{90}Th^{228}$	700	Total body	56	1.0	56	0.54	0.54	0.54
		Lung (insol.)	56	1.0	56			
		Bone	279	1.0	279			
		Kidney	56	1.0	56			
		Liver	56	1.0	56			
Ra^{224}	3.64	Total body	194	0.63	122	1.9	1.9	1.9
Rn^{220}		Lung (insol.)	194	0.65	126			
Po^{216}		Bone	971	0.50	485			
		Kidney	194	0.0017	0.33			
		Liver	194	2.6×10^{-4}	0.051			
Pb^{212}	0.44	Total body	0.29	0.63	0.18	0.24	0.29	0.22
		Lung (insol.)	0.24	0.65	0.16			
		Bone	1.0	0.50	0.50			
		Kidney	0.23	0.0017	3.9×10^{-4}			
		Liver	0.24	2.6×10^{-4}	6.2×10^{-5}			
Bi^{212}	0.042	Total body	83	0.63	52	1.8	2.2	1.7
Po^{212}		Lung (insol.)	83	0.65	54			
Tl^{208}		Bone	411	0.50	206			
		Kidney	82	0.0017	0.14			
		Liver	83	2.6×10^{-4}	0.021			
		Total body	Totals for Chain		230			
		Lung (insol.)			240			
		Bone			970			
		Kidney			56			
		Liver			56			
Th^{231}	1.07	Total body	0.14	1.0	0.14	0.11	0.14	0.093
		Lung (insol.)	0.11	1.0	0.11			
		Bone	0.33	1.0	0.33			

Radionuclide	Half-life (T_r in days)	Effective energy for organs of reference				Eff. energy, $\Sigma E(\mathrm{RBE})$, (E in MeV) for portions of GI tract		
		Organs of reference	$\Sigma E(\mathrm{RBE})n$ (E in MeV)	F	$\Sigma EF(\mathrm{RBE})n$ (E in MeV)	S	SI	LI
		Kidney	0.10	1.0	0.10			
		Liver	0.11	1.0	0.11			
Pa^{231}	1.3×10^7	Total body	51	8.4×10^{-4}	0.043	0.60	0.70	0.56
		Lung (insol.)	51	9.2×10^{-6}	4.7×10^{-4}			
		Bone	257	9.0×10^{-4}	0.23			
		Kidney	51	8.6×10^{-4}	0.044			
		Liver	51	8.8×10^{-4}	0.045			
		Total body	Totals for Chain		0.18			
		Lung (insol.)			0.11			
		Bone			0.56			
		Kidney			0.14			
		Liver			0.16			
${}_{90}Th^{232}$	5.1×10^{12}	Total body	41	1.0	41	0.40	0.41	0.40
		Lung (insol.)	41	1.0	41			
		Bone	205	1.0	205			
		Kidney	41	1.0	41			
		Liver	41	1.0	41			
Ra^{228}	2.4×10^3	Total body	0.0046	0.094	4.3×10^{-4}	0.0046	0.0046	0.0046
		Lung (insol.)	0.0046	0.032	1.5×10^{-4}			
		Bone	0.023	0.074	0.0017			
		Kidney	0.0046	9.7×10^{-6}	4.5×10^{-8}			
		Liver	0.0046	1.5×10^{-6}	6.9×10^{-9}			
Ac^{228}	0.26	Total body	1.1	0.094	0.10	0.74	1.1	0.62
		Lung (insol.)	0.74	0.032	0.024			
		Bone	2.6	0.074	0.19			
		Kidney	0.67	9.7×10^{-6}	6.5×10^{-6}			
		Liver	0.74	1.5×10^{-6}	1.1×10^{-6}			
Th^{228}	700	Total body	56	0.088	4.9	0.54	0.54	0.54
		Lung (insol.)	56	0.021	1.2			
		Bone	279	0.069	19			
		Kidney	56	9.0×10^{-6}	5.0×10^{-4}			
		Liver	56	1.4×10^{-6}	7.8×10^{-5}			
Ra^{224}	3.64	Total body	194	0.056	11	1.9	1.9	1.9
Rn^{220}		Lung (insol.)	194	0.014	2.7			
Po^{216}		Bone	971	0.035	34			
		Kidney	194	1.5×10^{-10}	2.9×10^{-8}			
		Liver	194	3.8×10^{-10}	7.4×10^{-8}			
Pb^{212}	0.44	Total body	0.29	0.056	0.016	0.24	0.29	0.22
		Lung (insol.)	0.24	0.014	0.0034			
		Bone	1.0	0.035	0.035			
		Kidney	0.23	1.5×10^{-10}	3.5×10^{-11}			
		Liver	0.24	3.8×10^{-10}	9.1×10^{-11}			
Bi^{212}	0.042	Total body	83	0.056	4.6	1.8	2.2	1.7
Po^{212}		Lung (insol.)	83	0.014	1.2			

Radionuclide	Half-life (T_r in days)	Effective energy for organs of reference: Organs of reference	ΣE(RBE)n (E in MeV)	F	ΣEF(RBE)n (E in MeV)	Eff. energy, ΣE(RBE), (E in MeV) for portions of GI tract: S	SI	LI
Tl^{208}		Bone	411	0.034	14			
		Kidney	82	1.5×10^{-10}	1.2×10^{-8}			
		Liver	83	3.8×10^{-10}	3.2×10^{-8}			
		Total body	Totals for Chain		62			
		Lung (insol.)			46			
		Bone			270			
		Kidney			41			
		Liver			41			
$_{91}Pa^{230}$	17.7	Total body	0.048	1.0	0.048	0.020	0.048	0.011
		Lung (insol.)	0.020	1.0	0.020			
		Kidney	0.015	1.0	0.015			
		Bone	0.011	1.0	0.011			
Th^{230} 80%	2.9×10^{7}	Total body	48	3.9×10^{-4}	0.019	0.47	0.47	0.47
		Lung (insol.)	48	4.8×10^{-5}	0.0023			
		Kidney	48	3.3×10^{-4}	0.016			
		Bone	242	4.0×10^{-4}	0.097			
Ra^{226}	5.9×10^{5}	Total body	49	5.6×10^{-7}	2.7×10^{-5}	0.48	0.48	0.48
		Lung (insol.)	49	6.6×10^{-9}	3.2×10^{-7}			
		Kidney	49	1.3×10^{-11}	6.4×10^{-10}			
		Bone	246	3.4×10^{-7}	8.4×10^{-5}			
		Total body	Totals for Chain		0.067			
		Lung (insol.)			0.022			
		Kidney			0.031			
		Bone			0.11			
$_{91}Pa^{230}$	17.7	Total body	0.13	1.0	0.13	0.13	0.13	0.13
		Lung (insol.)	0.13	1.0	0.13			
		Bone	0.64	1.0	0.64			
		Kidney	0.13	1.0	0.13			
U^{230}	20.8	Total body	348	0.83	289	3.4	3.4	3.4
Th^{226}		Lung (insol.)	348	0.85	296			
Ra^{222}		Bone	1740	0.93	1618			
Rn^{218}		Kidney	348	0.42	146			
Po^{214} 20%								
Pb^{210}	7.1×10^{3}	Total body	0.045	0.14	0.0063	0.027	0.045	0.019
		Lung (insol.)	0.027	0.014	3.8×10^{-4}			
		Bone	0.051	0.32	0.016			
		Kidney	0.023	0.029	6.7×10^{-4}			
Bi^{210}	5.0	Total body	0.40	0.071	0.028	0.40	0.40	0.40
Tl^{206}		Lung (insol.)	0.40	0.014	0.0056			
		Bone	2.0	0.23	0.46			
		Kidney	0.40	0.016	0.0064			
Po^{210}	138.4	Total body	55	0.013	0.72	0.53	0.53	0.53

Radionuclide	Half-life (T_r in days)	Effective energy for organs of reference: Organs of Reference	$\Sigma E(RBE)n$ (E in MeV)	F	$\Sigma EF(RBE)n$ (E in MeV)	Eff. energy, $\Sigma E(RBE)$, (E in MeV) for portions of GI tract: S	SI	LI
		Lung (insol.)	55	0.0063	0.35			
		Bone	275	0.033	9.1			
		Kidney	55	0.0052	0.29			
		Total body	Totals for Chain		290			
		Lung (insol.)			300			
		Bone			1600			
		Kidney			150			
$_{91}Pa^{231}$	1.3×10^7	Total body	52	1.0	52	0.60	0.70	0.56
		Lung (insol.)	51	1.0	51			
		Kidney	51	1.0	51			
		Liver	51	1.0	51			
		Bone	257	1.0	257			
Ac^{227}	8.0×10^3	Total body	0.63	0.45	0.28	0.019	0.019	0.019
Fr^{223}		Lung (insol.)	0.63	0.015	0.0095			
At^{219}		Kidney	0.63	0.45	0.28			
Bi^{215}		Liver	0.63	0.20	0.13			
		Bone	3.1	0.49	1.5			
Th^{227}	18.4	Total body	62	0.45	28	0.64	0.69	0.62
		Lung (insol.)	61	0.015	0.92			
		Kidney	61	0.45	28			
		Liver	61	0.20	12			
		Bone	307	0.49	150			
Ra^{223}	11.7	Total body	275	0.23	63	3.7	3.8	3.7
Rn^{219}		Lung (insol.)	275	0.0087	2.4			
Po^{215}		Kidney	275	4.8×10^{-4}	0.13			
Pb^{211}		Liver	275	3.3×10^{-5}	0.0091			
Bi^{211}		Bone	1370	0.25	343			
Tl^{207}								
Po^{211}								
		Total body	Totals for Chain		140			
		Lung (insol.)			54			
		Kidney			79			
		Liver			63			
		Bone			750			
$_{92}U^{230}$	20.8	Total body	348	1.0	348	3.4	3.4	3.4
Th^{226}		Lung (insol.)	348	1.0	348			
Ra^{222}		Kidney	348	1.0	348			
Rn^{218}		Bone	1740	1.0	1740			
Po^{214}								
Pb^{210}	7.1×10^3	Total body	0.045	0.17	0.0077	0.027	0.045	0.019
		Lung (insol.)	0.027	0.017	4.6×10^{-4}			
		Kidney	0.023	0.070	0.0016			

Radionuclide	Half-life (T_r in days)	Effective energy for organs of reference				Eff. energy, ΣE(RBE), (E in MeV) for portions of GI tract		
		Organs of Reference	ΣE(RBE)n (E in MeV)	F	ΣEF(RBE)n (E in MeV)	S	SI	LI
		Bone	0.051	0.34	0.017			
Bi^{210}	5.0	Total body	0.40	0.085	0.034	0.40	0.40	0.40
Tl^{206}		Lung (insol.)	0.40	0.016	0.0064			
		Kidney	0.40	0.038	0.015			
		Bone	2.0	0.25	0.50			
Po^{210}	138.4	Total body	55	0.015	0.83	0.53	0.53	0.53
		Lung (insol.)	55	0.0074	0.41			
		Kidney	55	0.013	0.72			
		Bone	275	0.035	9.6			
		Total body	Totals for Chain		350			
		Lung (insol.)			350			
		Kidney			350			
		Bone			1800			
$_{92}U^{232}$	2.7×10^4	Total body	55	1.0	55	0.54	0.54	0.53
		Lung (insol.)	55	1.0	55			
		Kidney	55	1.0	55			
		Bone	274	1.0	274			
Th^{228}	700	Total body	56	0.99	55	0.54	0.54	0.54
		Lung (insol.)	56	0.68	38			
		Kidney	56	0.97	54			
		Bone	279	0.99	276			
Ra^{224}	3.64	Total body	194	0.62	120	1.9	1.9	1.9
Rn^{220}		Lung (insol.)	194	0.44	85			
Po^{216}		Kidney	194	0.0017	0.33			
		Bone	971	0.50	485			
Pb^{212}	0.44	Total body	0.29	0.62	0.18	0.24	0.29	0.22
		Lung (insol.)	0.24	0.44	0.11			
		Kidney	0.23	0.0017	3.9×10^{-4}			
		Bone	1.0	0.50	0.50			
Bi^{212}	0.042	Total body	83	0.62	51	1.8	2.2	1.7
Po^{212}		Lung (insol.)	83	0.44	36			
Tl^{208}		Kidney	82	0.0017	0.14			
		Bone	411	0.50	206			
		Total body	Totals for Chain		280			
		Lung (insol.)			210			
		Kidney			110			
		Bone			1200			
$_{92}U^{235}$	2.6×10^{11}	Total body	46	1.0	46	0.59	0.77	0.52
		Lung (insol.)	46	1.0	46			
		Kidney	46	1.0	46			
		Bone	228	1.0	228			
Th^{231}	1.07	Total body	0.14	1.0	0.14	0.11	0.14	0.093
		Lung (insol.)	0.11	0.99	0.11			

Radionuclide	Half-life (T_r in days)	Effective energy for organs of reference				Eff. energy, ΣE(RBE), (E in MeV) for portions of GI tract		
		Organs of reference	ΣE(RBE)n (E in MeV)	F	ΣEF(RBE)n (E in MeV)	S	SI	LI
		Kidney	0.10	1.0	0.10			
		Bone	0.33	1.0	0.33			
		Total body	Totals for Chain		46			
		Lung (insol.)			46			
		Kidney			46			
		Bone			230			
$_{93}Np^{237}$	8.0×10^8	Total body	49	1.0	49	0.50	0.52	0.49
		Lung (insol.)	49	1.0	49			
		Bone	247	1.0	247			
		Liver	49	1.0	49			
		Kidney	49	1.0	49			
Pa^{233}	27.4	Total body	0.32	1.0	0.32	0.18	0.32	0.13
		Lung (insol.)	0.18	0.81	0.15			
		Bone	0.41	1.0	0.41			
		Liver	0.18	1.0	0.18			
		Kidney	0.15	1.0	0.15			
		Total body	Totals for Chain		49			
		Lung (insol.)			49			
		Bone			250			
		Liver			49			
		Kidney			49			
$_{93}Np^{239}$	2.33	Total body	0.22	1.0	0.22	0.16	0.22	0.14
Pu^{239m}		Lung (insol.)	0.16	1.0	0.16			
		Bone	0.63	1.0	0.63			
		Kidney	0.15	1.0	0.15			
		Liver	0.16	1.0	0.16			
Pu^{239}	8.9×10^6	Total body	53	0.0013	0.069	0.52	0.52	0.52
		Lung (insol.)	53	4.1×10^{-5}	0.0022			
		Bone	266	0.0013	0.35			
		Kidney	53	0.0012	0.064			
		Liver	53	0.0012	0.064			
		Total body	Totals for Chain		0.29			
		Lung (insol.)			0.16			
		Bone			0.98			
		Kidney			0.21			
		Liver			0.22			
$_{94}Pu^{241}$	4.8×10^3	Total body	0.014	1.0	0.014	0.011	0.012	0.010
		Lung (insol.)	0.013	1.0	0.013			
		Bone	0.048	1.0	0.048			
		Kidney	0.012	1.0	0.012			
		Liver	0.013	1.0	0.013			

Radionuclide	Half-life (T_r in days)	Effective energy for organs of reference				Eff. energy, ΣE(RBE), (E in MeV) for portions of GI tract		
		Organs of reference	ΣE(RBE)n (E in MeV)	F	ΣEF(RBE)n (E in MeV)	S	SI	LI
Am^{241} Np^{237m}	1.7×10^5	Total body	57	0.041	2.3	0.56	0.59	0.56
		Lung (insol.)	57	7.1×10^{-4}	0.040			
		Bone	283	0.048	14			
		Kidney	57	0.043	2.5			
		Liver	57	0.018	1.0			
		Total body	Totals for Chain		2.3			
		Lung (insol.)			0.053			
		Bone			14			
		Kidney			2.5			
		Liver			1.0			
$_{95}Am^{243}$	2.9×10^6	Total body	54	1.0	54	0.54	0.56	0.54
		Lung (insol.)	54	1.0	54			
		Bone	272	1.0	272			
		Kidney	54	1.0	54			
		Liver	54	1.0	54			
Np^{239} Pu^{239m}	2.33	Total body	0.22	1.0	0.22	0.16	0.22	0.14
		Lung (insol.)	0.16	0.98	0.16			
		Bone	0.63	1.0	0.63			
		Kidney	0.15	1.0	0.15			
		Liver	0.16	0.99	0.16			
Pu^{239}	8.9×10^6	Total body	53	7.3×10^{-4}	0.039	0.52	0.52	0.52
		Lung (insol.)	53	4.0×10^{-5}	0.0021			
		Bone	266	7.4×10^{-4}	0.20			
		Kidney	53	6.7×10^{-4}	0.036			
		Liver	53	9.1×10^{-4}	0.048			
		Total body	Totals for Chain		54			
		Lung (insol.)			54			
		Bone			270			
		Kidney			54			
		Liver			54			
$_{96}Cm^{242}$	162.5	Total body	63	1.0	63	0.62	0.62	0.61
		Lung (insol.)	63	1.0	63			
		Liver	63	1.0	63			
		Bone	315	1.0	315			
		Kidney	63	1.0	63			
Pu^{238}	3.3×10^4	Total body	57	0.29	17	0.55	0.55	0.55
		Lung (insol.)	57	0.011	0.63			
		Liver	57	0.26	15			
		Bone	284	0.29	82			
		Kidney	57	0.27	15			
		Total body	Totals for Chain		80			
		Lung (insol.)			64			

Radionuclide	Half-life (T_r in days)	Effective energy for organs of reference				Eff. energy, ΣE(RBE), (E in MeV) for portions of GI tract		
		Organs of reference	ΣE(RBE)n (E in MeV)	F	ΣEF(RBE)n (E in MeV)	S	SI	LI
		Liver	Totals for Chain		78			
		Bone			400			
		Kidney			78			
$_{96}Cm^{243}$	1.3×10^4	Total body	60	1.0	60	0.64	0.71	0.61
Pu^{239m}		Lung (insol.)	60	1.0	60			
		Bone	299	1.0	299			
		Liver	60	1.0	60			
		Kidney	60	1.0	60			
Pu^{239}	8.9×10^6	Total body	53	8.2×10^{-4}	0.043	0.52	0.52	0.52
		Lung (insol.)	53	4.1×10^{-5}	0.0022			
		Bone	266	7.9×10^{-4}	0.21			
		Liver	53	9.7×10^{-4}	0.051			
		Kidney	53	7.7×10^{-4}	0.041			
		Total body	Totals for Chain		60			
		Lung (insol.)			60			
		Bone			300			
		Liver			60			
		Kidney			60			
$_{96}Cm^{244}$	6.7×10^3	Total body	60	1.0	60	0.58	0.59	0.58
		Lung (insol.)	60	1.0	60			
		Bone	299	1.0	299			
		Liver	60	1.0	60			
		Kidney	60	1.0	60			
Pu^{240}	2.4×10^6	Total body	53	0.0033	0.17	0.52	0.52	0.52
		Lung (insol.)	53	1.5×10^{-4}	0.0080			
		Bone	266	0.0033	0.88			
		Liver	53	0.0037	0.20			
		Kidney	53	0.0031	0.16			
		Total body	Totals for Chain		60			
		Lung (insol.)			60			
		Bone			300			
		Liver			60			
		Kidney			60			
$_{96}Cm^{245}$	7.3×10^6	Total body	55	1.0	55	0.56	0.59	0.55
		Lung (insol.)	55	1.0	55			
		Bone	277	1.0	277			
		Kidney	55	1.0	55			
		Liver	55	1.0	55			
Pu^{241}	4.8×10^3	Total body	0.014	0.65	0.0091	0.011	0.012	0.010
		Lung (insol.)	0.013	0.071	9.2×10^{-4}			
		Bone	0.048	0.63	0.030			

Radionuclide	Half-life (T_r in days)	Effective energy for organs of reference				Eff. energy, ΣE(RBE), (E in MeV) for portions of GI tract		
		Organs of reference	ΣE(RBE)n (E in MeV)	F	ΣEF(RBE)n (E in MeV)	S	SI	LI
		Kidney	0.012	0.63	0.0076			
		Liver	0.013	0.76	0.010			
Am^{241}	1.7×10^5	Total body	57	0.017	0.97	0.56	0.59	0.56
Np^{237m}		Lung (insol.)	57	1.5×10^{-4}	0.0086			
		Bone	283	0.018	5.1			
		Kidney	57	0.017	0.97			
		Liver	57	0.012	0.68			
		Total body	Totals for Chain		56			
		Lung (insol.)			55			
		Bone			280			
		Kidney			56			
		Liver			56			
$_{97}Bk^{249}$	290	Total body	0.026	1.0	0.026	0.026	0.026	0.026
		Lung (insol.)	0.026	1.0	0.026			
		Bone	0.13	1.0	0.13			
Cf^{249}	1.7×10^5	Total body	60	0.064	3.8	0.66	0.76	0.63
		Lung (insol.)	60	7.1×10^{-4}	0.043			
		Bone	301	0.065	20			
		Total body	Totals for Chain		3.8			
		Lung (insol.)			0.069			
		Bone			20			
$_{98}Cf^{250}$	3.7×10^3	Total body	62	1.0	62	0.60	0.60	0.60
		Lung (insol.)	62	1.0	62			
		Bone	310	1.0	310			
Cm^{246}	2.4×10^6	Total body	56	0.0032	0.18	0.54	0.54	0.54
		Lung (insol.)	56	5.0×10^{-5}	0.0028			
		Bone	278	0.0037	1.0			
		Total body	Totals for Chain		62			
		Lung (insol.)			62			
		Bone			310			

Table 6. Element distribution in total body of the standard man
(Average chemical composition of the adult human body)

% by wt LUNG	Element		Per cent by weight	Approximate amount in 70 kg man (g)
66.7 (assume)	Oxygen	(O)	65.0	45,500
18.4	Carbon	(C)	18.0	12,600
10.2	Hydrogen	(H)	10.0	7000
3.1	Nitrogen	(N)	3.0	2100
1.3×10^{-2}	Calcium	(Ca)	1.5	1050
.111	Phosphorus	(P)	1.0	700
.25 (assume)	Sulfur	(S)	0.25	175
.21	Potassium	(K)	0.2	140
.19	Sodium	(Na)	0.15	105
.26	Chlorine	(Cl)	0.15	105
.01	Magnesium	(Mg)	0.05	35
.03	Iron	(Fe)	0.0057	4
.0014	Zinc	(Zn)	0.0033	2.3
0.00073	Rubidium	(Rb)	0.0017	1.2
1.2×10^{-5}	Strontium	(Sr)	2×10^{-4}	0.14
1.3×10^{-4}	Copper	(Cu)	1.4×10^{-4}	0.1
24×10^{-4}	Aluminum	(Al)	1.4×10^{-4}	0.1
6.8×10^{-5}	Lead	(Pb)	1.1×10^{-4}	0.08
7.4×10^{-5}	Tin	(Sn)	4.3×10^{-5}	0.03
—	Iodine	(I)	4.3×10^{-5}	0.03
7×10^{-5}	Cadmium	(Cd)	4.3×10^{-5}	0.03
1.8×10^{-5}	Manganese	(Mn)	3×10^{-5}	0.02
1.5×10^{-5}	Barium	(Ba)	2.3×10^{-5}	0.016
9×10^{-6}	Arsenic	(As)	$<1.4 \times 10^{-4}$	<0.1
1×10^{-5}	Antimony	(Sb)	$<1.3 \times 10^{-4}$	<0.09
$< 8 \times 10^{-5}$	Lanthanum	(La)	$<7 \times 10^{-5}$	<0.05
$< 8 \times 10^{-5}$	Niobium	(Nb)	$<7 \times 10^{-5}$	<0.05
2.8×10^{-4}	Titanium	(Ti)	$<2.1 \times 10^{-5}$	<0.015
$< 2.7 \times 10^{-5}$	Nickel	(Ni)	$<1.4 \times 10^{-5}$	<0.01
$< 9 \times 10^{-6}$	Boron	(B)	$<1.4 \times 10^{-5}$	<0.01
2×10^{-5}	Chromium	(Cr)	$<8.6 \times 10^{-6}$	<0.006
$< 8 \times 10^{-6}$	Ruthenium	(Ru)	$<8.6 \times 10^{-6}$	<0.006
$< 6 \times 10^{-6}$	Thallium	(Tl)	$<8.6 \times 10^{-6}$	<0.006
$< 4 \times 10^{-5}$	Zirconium	(Zr)	$<8.6 \times 10^{-6}$	<0.006
$< 8 \times 10^{-6}$	Molybdenum	(Mo)	$<7 \times 10^{-6}$	<0.005
6×10^{-6}	Cobalt	(Co)	$<4.3 \times 10^{-6}$	<0.003
$< 2 \times 10^{-6}$	Beryllium	(Be)	$<3 \times 10^{-6}$	<0.002
$< 8 \times 10^{-6}$	Gold	(Au)	$<1.4 \times 10^{-6}$	<0.001
$< .8 \times 10^{-6}$	Silver	(Ag)	$<1.4 \times 10^{-6}$	<0.001
$< 3 \times 10^{-6}$	Lithium	(Li)	$<1.3 \times 10^{-6}$	$<9 \times 10^{-4}$
$< 4 \times 10^{-6}$	Bismuth	(Bi)	$<4.3 \times 10^{-7}$	$<3 \times 10^{-4}$
$< 7 \times 10^{-6}$	Vanadium	(V)	$<1.4 \times 10^{-7}$	$<10^{-4}$
?	Uranium	(U)	3×10^{-8}	2×10^{-5}
? 4×10^{-5}	Cesium	(Cs)	$<1.4 \times 10^{-8}$	$<10^{-5}$
$< 1.1 \times 10^{-6}$	Gallium	(Ga)	$<3 \times 10^{-9}$	$<2 \times 10^{-6}$
?	Radium	(Ra)	1.4×10^{-13}	10^{-10}

5×10^{-4}	Bromine
6×10^{-5}	Fluorine
.013	Silicon

*Table 7. Elements in the body organs of standard man** (μg/g of wet tissue)

Tissue	Elements										
	Ag	Al	As	Au	B	Ba	Be	Bi	Br	Ca	Cd
Adrenal (6)	0.016	0.62	<1.4	<0.16	<0.11	0.025	<0.01	<0.05		44	<0.4
Aorta (75)	0.015	0.8	<2.8	<0.2	<0.1	0.15	<0.03	<0.15		970	<0.6
Blood		0.16(s)								50	
Bone (99)	<0.1	<0.44	0.01(N)	<2.5	<3	1.63			0.3(N)	148000(w)	N.D.
Brain (94)	0.045	0.29	<4	<0.13	<0.14	<0.01	<0.04	<0.05		110	<0.9
Breast (7)	<0.002	0.4	<2.5	<0.09	<0.08	0.015	<0.03	<0.03		64	<0.2
Gastrointestinal tract											
Esophagus (39)	<0.004	0.82	<2.1	<0.08	<0.07	0.05	<0.02	<0.03		120	<0.5
Stomach (88)	<0.006	0.52	<1.7	<0.07	<0.14	0.038	<0.02	<0.5		115	<0.43
Duodenum (51)	<0.006	0.75	<1.7	<0.07	<0.06	0.038	<0.02	<0.12		86	<0.56
Jejunum (66)	<0.004	0.57	<2.1	<0.13	<0.12	0.04	<0.02	<0.5		76	<0.6
Ileum (68)	<0.005	2	<0.9	<0.1	<0.04	0.088	<0.01	<0.04		135	<0.26
Cecum (31)	<0.009	1.26	<1.2	<0.09	<0.05	0.12	<0.01	<0.1		155	<0.32
Sigmoid colon (72)	<0.007	1.05	<0.9	<0.05	<0.04	0.09	<0.01	<0.04		115	<0.26
Rectum (33)	<0.004	0.74	<0.9	<0.03	<0.03	0.054	<0.01	<0.07		140	<0.24
Heart (96)	<0.006	0.3	<2.6	<0.09	<0.09	0.01	<0.03	<0.04	1.8(s)	53	<0.6
Kidney (102)	<0.01	0.41	0.03(N)	<0.12	<0.12	0.027	<0.03	<0.02	0.4(N)	115	32
Larynx (31)	<0.015	0.61	<4	<0.13	<0.13	0.215	<0.04	<0.08		1920	<0.9
Liver (102)	0.018	0.71	0.1(N)	<0.12	<0.14	<0.013	<0.03	<0.07	2.4(s)	70	2.44
Lung (102)	<0.008	24	0.09(N)	<0.08	<0.09	0.183	<0.02	<0.04	5(s)	130	0.7
Muscle									4.5(s)		
Diaphragm (42)	<0.004	0.35	<1.8	<0.06	<0.06	<0.03	<0.018	<0.05		74	<0.43
Pectoral (21)	<0.005	0.20	<2.7	<0.09	<0.09	<0.011	<0.03	<0.04		37	<0.6
Psoas (86)	<0.007	0.34	<3.0	<0.10	<0.10	<0.014	<0.03	<0.05		49	<0.7
Omentum (35)	0.002	1.26	<0.26	<0.01	<0.01	<0.026	<0.003	<0.12		40	<0.09
Ovary (9)	<0.005	0.7	0.01(N)	<0.07	<0.09	0.04	<0.03	<0.04	0.33(N)	220	<0.6
Pancreas (95)	<0.007	0.47	<2.4	<0.11	<0.11	0.026	<0.02	<0.06		120	1.2
Prostate (27)	0.021	0.89	<2.9	<0.2	<0.15	0.05	<0.03	<0.04		320	<0.76
Skin (18)	0.013	2.8	<1.2	<0.05	<0.12	0.161	<0.01	<0.03		150	<0.28
Spleen (97)	<0.006	1.1	0.02(N)	<0.1	<0.12	<0.022	<0.03	<0.052	4.2(s)	84	<0.74
Testis (53)	<0.005	0.5	0.04(N)	<0.11	<0.09	0.011	<0.03	<0.08	0.33(N)	100	<0.6
Thymus (2)	0.002	0.23	<1.2	<0.04	<0.04	0.009	<0.01	<0.02		63	<0.28
Thyroid (11)	<0.04	1.2	<3.1	<0.1	<0.1	0.26	<0.03	<0.1		260	<0.8
Tongue (3)	<0.005	0.62	<3.2	<0.11	<0.11	0.04	<0.03	<4.4		175	<0.75
Trachea (35)	<0.02	1.85	<3.4	<0.47	<0.13	0.113	<0.03	<0.19		950	<0.8
Urinary bladder (70)	<0.003	0.61	<1.4	<0.1	<0.11	0.03	<0.01	<0.02		130	<0.38
Uterus (17)	<0.005	0.44	<2.6	<0.09	<0.09	0.05	<0.03	<0.04		185	<0.61
Vagina (7)	<0.005	0.3	<2.6	<0.09	<0.09	0.03	<0.03	<0.04		200	<0.58

* Unless otherwise indicated all of these values are taken from the studies of TIPTON *et al.* (Ti–1 through Ti–7) see bibliography. The number in parentheses after the name of the tissue indicates the number of samples of that tissue analyzed. Reports consulted were by TIETZ *et al.*, STITCH, SOWDEN and STITCH, KOCH, SHELDON *et al.* and KEHOE *et al.* (See further references on next two pages.)

(N) Determined by neutron activation (Led- 1 see bibliography).
(F) Determined by flame photometry (Gro- 1, see bibliography).

Table 7—cont.

Tissue	Elements										
	Cl	Co	Cr	Cs	Cu	F	Fe	Ga	I	K	La
Adrenal (6)		<0.04	0.07	<0.7	1.1		43	<0.005		1100	<0.4
Aorta (75)		<0.07	0.06	<0.02	1.3		46	<0.009		1370	<0.9
Blood	2800(S)				1(S)	0.3(S)	450(E)		0.07(S)	1800(S)	
Bone (99)	1700(E)	0.6(N)	<0.49	6(N)	0.6	200(G)	115		0.3(E)	880	
Brain (94)	1300(E)	<0.05	<0.01	<0.03	5.8	0.5(E)	48	<0.01	0.1(E)	3300	<1.3
Breast (7)		<0.02	0.03		0.36		4.4	<0.003		310	<0.3
Gastrointestinal tract	600								0.4(E)		
Esophagus (39)		<0.03	0.05	<0.01	1.3		34	<0.007		1510	<0.7
Stomach (88)		<0.04	0.03	<0.01	1.7		29	<0.006		1520	<0.6
Duodenum (51)		<0.04	0.03		2.3		39	<0.006		1520	<0.6
Jejunum (66)		<0.04	0.03	<0.02	2		33	<0.007		1600	<0.7
Ileum (68)		<0.04	0.04		1.9		28	<0.003		1230	<0.3
Cecum (31)		<0.26	0.047		1.4		23	<0.004		1060	<0.4
Sigmoid colon (72)		<0.1	0.05	<0.01	1.5		21	<0.003		1320	<0.3
Rectum (33)		<0.06	0.04		1.2		28	<0.003		1580	<0.3
Heart (96)	1250(E)	<0.04	0.02	<0.02	3.51	0.5(E)	50	<0.009	0.9(E)	2500	<0.1
Kidney (102)	2100(E)	0.2(N)	0.03	0.34(N)	2.9	0.8(E)	76	<0.01	0.2(E)	2030	<1
Larynx (31)		<0.05	0.07	<0.03	1.1		28	<0.013		1530	<1.3
Liver (102)	1250(E)	0.3(N)	0.02	0.6(N)	8.6		185	<0.011	1.1(E)	3100	<1.1
Lung (102)	2550(E)	0.06(N)	0.2	0.4(N)	1.3	0.6(E)	300	<0.011		2120	<0.8
Muscle	600(E)					0.4(E)			0.9(E)		
Diaphragm (42)		<0.13	0.04	<0.3	1.35		44	<0.006		2600	<0.6
Pectoral (21)		<0.04	0.03		0.71		28	<0.003		2830	<0.9
Psoas (86)		<0.10	0.03		0.9		36	<0.01		3330	<1
Omentum (35)		<0.01	0.04	<0.002	0.34		28	<0.001		400	<0.09
Ovary (9)		0.02(N)	0.14	0.13(N)	1.06		35	<0.009	0.9(E)	1350	<0.9
Pancreas (95)	1600(E)	<0.05	0.04	0.04	1.7		39	<0.008	0.5(E)	2800	<0.8
Prostate (27)		<0.07	0.05	<0.02	1.4		30	<0.01		2200	<1.0
Skin (18)	2600(E)	<0.02	0.33	<0.01	0.90		16	<0.005	1(E)	800	<0.4
Spleen (97)	1550(E)	0.1(N)	0.02	0.6(N)	1.22	0.3(E)	330	<0.01		3500	<1.1
Testis (53)	2330(E)	0.05(N)	0.03	0.3(N)	1		27	<0.009		2100	<0.9
Thymus (2)		<0.02	0.01		0.42		19	<0.004		540	<0.4
Thyroid (11)	1700(E)	<0.08	0.03	<0.02	1.1		66	<0.01	350(E)	1100	<1
Tongue (3)		<0.04	0.06		1.43		33	<0.011		2800	<1.1
Trachea (35)		<0.05	0.07	<0.02	1.2		47	<0.011		2200	<1.1
Urinary bladder (70)		<0.02	0.04	<0.01	0.95		25	<0.005		1730	<0.5
Uterus (17)		<0.07	0.24	<0.02	0.95		27	<0.009		1730	<0.9
Vagina (7)		<0.14	0.07		0.90		32	<0.009		1500	<0.9

(E) M. Everett, *Medical Biochemistry* (2nd Ed.). Hoeber, New York (1946).
(B) E. J. King and T. H. Belt, The physiological and pathological aspects of silica. *Physiol. Rev.*, *18*, 329–365 (1938).
(S) W. S. Spector (Ed.) *Handbook of Biological Data.* Division of Biology and Agriculture; The National Academy of Sciences; The National Research Council; Wright Air Development Center Technical Report 56–273 (October, 1956).

Table 7—cont.

Tissue	Elements										
	Li	Mg	Mn	Mo	Na	Nb	Ni	P	Pb	Ra	Rb
Adrenal (6)		50	0.19	0.57		<0.45	0.28	1000	0.13		
Aorta (75)	0.02	230	0.12	<0.09	2400[(F)]	<0.9	<0.15	1100	2.51		9.9
Blood	0.02[(s)]	43	0.14[(s)]		1750[(E)]			380	0.3[(s)]		
Bone (99)	0.003	980	<0.1	<1.5	5×10^3		<2	8×10^4[(E)]	6.6	1.7×10^{-8}[(H)]	10
Brain (94)	<0.007	140	0.26	<0.1	1700[(F)]	<1.3	<0.1	3300	<0.4		28
Breast (7)		20	0.03	<0.03		<0.3	<0.07	140	0.04		
Gastrointestinal tract											
Esophagus (39)	0.013	120	0.12	<0.08	1900[(F)]	<0.7	<0.09	850	0.16		7.2
Stomach (88)	0.009	100	0.31	<0.06	1300[(F)]	<0.6	<0.06	1160	0.19		8.6
Duodenum (51)	0.009	100	0.47	<0.06		<0.6	<0.08	1230	0.4		8.6
Jejunum (66)	0.009	120	0.61	<0.07	1600[(F)]	<0.7	<0.06	1460	0.32		23
Ileum (68)		150	0.38	<0.05		<0.3	<0.13	1000	0.28		
Cecum (31)		200	0.93	<0.04		<0.4	0.24	680	0.28		
Sigmoid colon (72)	0.01	175	0.45	<0.03	1600[(F)]	<0.3	0.15	800	0.18		5.9
Rectum (33)		180	0.43	<0.03		<0.3	0.14	760	0.49		
Heart (96)	0.008	160	0.19	<0.09	1300[(F)]	<0.9	<0.12	1600	<0.2		15.1
Kidney (102)	0.008	130	0.85	0.40	2200[(F)]	<1	<0.09	1700	1.24		10.7
Larynx (31)	0.03	300	0.19	<0.13	2700[(F)]	<1.3	<0.17	1700	2.2		12.6
Liver (102)	<0.006	165	1.3	1.13	1400[(F)]	<1.1	<0.11	2700	2		63
Lung (102)	<0.03	95	0.18	<0.08	1900[(F)]	<0.8	<0.27	1110	0.68		7.3
Muscle											
Diaphragm (42)		140	0.13	<0.06	1600[(F)]	<0.6	<0.08	1200	0.17		
Pectoral (21)		145	0.05	<0.09	1900[(F)]	<0.9	<0.11	1440	0.19		
Psoas (86)	<0.005	190	0.05	<0.1		<1	<0.11	1700	0.14		31
Omentum (35)	0.005	22	0.05	<0.01	350[(F)]	<0.09	0.04	170	0.14		2.0
Ovary (9)	0.011	86	0.17	<0.09		<0.9	<0.1	940	0.13		4.5
Pancreas (95)	<0.005	165	1.16	<0.08	1400[(F)]	<0.8	<0.09	2500	0.72		62
Prostate (27)	0.013	175	0.22	<0.1	2000[(F)]	<1	<0.1	1100	0.91		6.9
Skin (18)	0.021	73	0.2	<0.05	920[(F)]	<0.4	0.44	310	0.55		2.0
Spleen (97)	<0.006	130	0.11	<0.11	1200[(F)]	<1.1	<0.1	2200	0.67		43
Testis (53)	0.009	115	0.14	<0.09	2100[(F)]	<0.9	<0.09	1400	0.15		12
Thymus (2)		27	0.04	<0.04		<0.4	<0.04	370	0.07		
Thyroid (11)	0.023	73	0.23	<0.1	2200[(F)]	<1.0	<0.11	520	0.14		4.2
Tongue (3)		175	0.23	<0.11		<1.1	0.24	1300	<0.06		
Trachea (35)	0.044	260	0.18	<0.11	3000[(F)]	<1.1	0.18	880	1.1		21
Urinary bladder (70)	0.014	130	0.14	<0.05	1600[(F)]	<0.5	<0.08	740	0.17		6.6
Uterus (17)	0.004	110	0.10	<0.09	2000[(F)]	<0.9	<0.23	1000	0.19		5.6
Vagina (7)		85	0.09	<0.09		<0.9	<0.13	6100	0.16		

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(W) B. HARROW, *Textbook of Biochemistry* (3rd Ed.). Saunders, Philadelphia (1943).

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Table 7—cont.

Tissue	Elements										
	Ru	Sb	Si	Sn	Sr	Te	Ti	Tl	V	Zn	Zr
Adrenal (6)	<0.05	<0.9	125(B)	0.19	0.02		<0.13	<0.05	<0.005	8.4	<0.5
Aorta (75)	<0.09	<2.8		0.41	0.43		<0.17	<0.09	<0.01	26	<0.9
Blood			2.5(s)	0.23(s)						8.3(s)	
Bone (99)		0.2(N)		<1.3	15	321(N)	<1		<1.5	66	
Brain (94)	<0.13	<4.0	26(B)	<0.1	0.04		<0.15	<0.13	<0.01	13	<1.3
Breast (7)	<0.04	<2.5		0.26	0.06		<0.05	<0.04	<0.004	2.8	<0.4
Gastrointestinal tract			41(B)								
Esophagus (39)	<0.07	<2.1		0.8	0.1		<0.12	<0.07	<0.007	22	<0.7
Stomach (88)	<0.06	<1.7		0.35	0.12		<0.07	<0.06	<0.012	18	<0.6
Duodenum (51)	<0.06	<1.7		0.54	0.12		<0.08	<0.06	<0.007	20	<0.6
Jejunum (66)	<0.07	<2.1		0.52	0.15		<0.08	<0.07	<0.008	20	<0.7
Ileum (68)	<0.03	<0.9		1.13	0.22		<0.06	<0.03	<0.018	21	<0.3
Cecum (31)	<0.04	<1.2		2.2	0.31		<0.06	<0.04	<0.015	22	<0.4
Sigmoid colon (72)	<0.03	<0.9		0.6	0.25		<0.1	<0.03	<0.047	18	<0.3
Rectum (33)	<0.03	<0.9		0.94	0.19		<0.08	<0.03	<0.037	26	<0.3
Heart (96)	<0.09	<2.6	25(B)	<0.15	0.05		<0.09	<0.09	<0.009	27	<0.9
Kidney (102)	<0.1	0.3(N)	21(B)	0.28	0.08	62(N)	<0.14	<0.1	<0.011	48	<1
Larynx (31)	<0.1	<4		0.18	1.0		<0.17	<0.13	<0.013	29	<1.3
Liver (102)	<0.1	0.2(N)	24(B)	0.4	0.03	1075(N)	<0.14	<0.11	<0.014	46	<1
Lung (102)	<0.08	0.1(N)	130(B)	0.74	0.12	13(N)	2.8	<0.08	<0.071	14	<0.8
Muscle			12(B)								
Diaphragm (42)	<0.06	<1.8		<0.09	0.06		<0.07	<0.06	<0.006	43	<0.6
Pectoral (21)	<0.09	<2.7		<0.21	0.02		<0.10	<0.09	<0.009	46	<0.9
Psoas (86)	<0.1	<3.0		<0.11	0.03		<0.10	<0.1	<0.01	51	<1
Omentum (35)	<0.01	<0.26		0.03	0.04		0.07	<0.01	<0.002	3.3	<0.0[illegible]
Ovary (9)	<0.09	0.03(N)	18(B)	1.15	0.25	14(N)	<0.1	<0.09	<0.009	13	<0.9
Pancreas (95)	<0.08	<2.4	34(B)	<0.27	0.07		<0.11	<0.08	<0.008	27	<0.[illegible]
Prostate (27)	<0.1	<2.9	70(B)	0.31	0.24		<0.16	<0.1	<0.01	87	<1
Skin (18)	<0.04	<1.2	55(B)	0.28	0.1		0.61	<0.04	<0.008	6	<0.[illegible]
Spleen (97)	<0.11	0.1(N)	34(B)	0.24	0.05	260(N)	<0.18	<0.11	<0.013	19	<1.1
Testis (53)	<0.09	0.05(N)	31(B)	0.21	0.06	42(N)	<0.1	<0.08	<0.009	15	<0.9
Thymus (2)	<0.04	<1.2	260(B)	0.05	0.05		<0.06	<0.04	<0.004	4.2	<0.4
Thyroid (11)	<0.1	<3.1	45(B)	0.28	0.13		<0.49	<0.1	<0.01	27	<1
Tongue (3)	<0.11	<3.2		0.14	0.07		<0.11	<0.11	<0.011	29	<1.1
Trachea (35)	<0.11	<3.4		0.51	0.48		<0.26	<0.11	<0.01	15	<1.1
Urinary bladder (70)	<0.05	<1.4	19(B)	0.25	0.15		<0.09	<0.05	<0.006	22	<0.5
Uterus (17)	<0.09	<2.6		0.1	0.15		<0.1	<0.09	<0.009	20	<0.9
Vagina (7)	<0.09	<2.6		0.2	0.17		<0.1	<0.09	<0.009	16	<0.9

Table 8. Organs of standard man

Mass and effective radius of organs of the adult human body

	Mass, *m* (g)	Per cent of total body*	Effective radius, *X* (cm)
Total body*	70,000	100	30
Muscle	30,000	43	30
Skin and subcutaneous tissue†	6100	8.7	0.1
Fat	10,000	14	20
Skeleton			
Without bone marrow	7000	10	5
Red marrow	1500	2.1	
Yellow marrow	1500	2.1	
Blood	5400	7.7	
Gastrointestinal tract*	2000	2.9	30
Contents of GI tract			
Lower large intestine	150		5
Stomach	250		10
Small intestine	1100		30
Upper large intestine	135		5
Liver	1700	2.4	10
Brain	1500	2.1	15
Lungs (2)	1000	1.4	10
Lymphoid tissue	700	1.0	
Kidneys (2)	300	0.43	7
Heart	300	0.43	7
Spleen	150	0.21	7
Urinary bladder	150	0.21	
Pancreas	70	0.10	5
Salivary glands (6)	50	0.071	
Testes (2)	40	0.057	3
Spinal Cord	30	0.043	1
Eyes (2)	30	0.043	0.25
Thyroid gland	20	0.029	3
Teeth	20	0.029	
Prostate gland	20	0.029	3
Adrenal glands or suprarenal (2)	20	0.029	3
Thymus	10	0.014	
Ovaries (2)	8	0.011	3
Hypophysis (Pituitary)	0.6	8.6×10^{-6}	0.5
Pineal Gland	0.2	2.9×10^{-6}	0.04
Parathyroids (4)	0.15	2.1×10^{-6}	0.06
Miscellaneous (blood vessels, cartilage, nerves, etc.)	390	0.56	

* Does not include contents of the gastrointestinal tract.
† The mass of the skin alone is taken to be 2000 grams.

Table 9. Intake and excretion of the standard man

Water balance

Intake (cm^3/day)		Excretion (cm^3/day)	
Food	1000	Urine	1400
Fluids	1200	Sweat	600
Oxidation	300	From lungs	300
		Feces	200
Total	2500	Total	2500

Air balance

	O_2 (vol. %)	CO_2 (vol. %)	N_2 + others (vol. %)
Inspired air	20.94	0.03	79.03
Expired air	16	4.0	80
Alveolar air (inspired)	15	5.6	—
Alveolar air (expired)	14	6.0	—

Vital capacity of lungs	3–4 liters (men) 2–3 liters (women)
Air inhaled during 8 hr work day	10^7 cm^3/day
Air inhaled during 16 hr not at work	10^7 cm^3/day
Total	2×10^7 cm^3/day
Interchange area of lungs	50 m^2
Area of upper respiratory tract, trachea, bronchi	20 m^2
Total surface area of respiratory tract	70 m^2

Total water in body = 4.3×10^4 g.
Average life span of man = 70 years.
Occupational exposure time of man = 8 hours/day; 40 hours/week; 50 weeks/year; 50 years total time.

Table 10. Particulates in respiratory tract of the standard man

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 shown 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 from the lungs and swallowed in the first 24 hrs, making a total of 62½ per cent swallowed. The remaining 12½ per cent is retained in the lungs with a half-life of 120 days, it being assumed that this portion is taken up into body fluids.

Table 11. Gastrointestinal tract of the standard man

Portion of GI tract that is the critical tissue	Mass of contents (g)	Time food remains, τ (day)	Fraction from lung to GI tract, f_a (sol.)	(insol.)
Stomach (S)	250	1/24	0.50	0.625
Small intestine (SI)	1100	4/24	0.50	0.625
Upper large intestine (ULI)	135	8/24	0.50	0.625
Lower large intestine (LLI)	150	18/24	0.50	0.625

Table 12. Biological and related physical constants

References are to Bibliography for Biological Data, Pergamon Press

Gen.* ref.	Element and radio-nuclides	Average daily ingestion I (g/day)	Organ of reference, mass (g) effective radius (cm)	Average concentration, C (g/g wet tissues)	Half-life (days): Physical T_r	Half-life (days): Biological T_b	Half-life (days): Effective T	Fraction from GI tract to blood f_1	Fraction in organ of reference of that in total body f_2: Element	f_2: Radio-nuclide	Fraction from blood to organ of reference f'_2	Fraction reaching organ of reference: By ingestion f_w	Fraction reaching organ of reference: By inhalation f_a
Z			Ch-1			eq. 44, 45	eq. 49			eq. 41, 42		eq. 47	eq. 46
1	H	300 (Hw-1)	Total body 7×10^4 g 30 cm	0.1 (Ch-1)		12 (Ln-11 Ln-12)		1.0 (G)	1.0 (D)		1.0 (D)	1.0	1.0 (Ln-20)
	H^3				4.5×10^3		12			1.0 (D)			
	H		Body water 4.3×10^4 g (Ln-11)	0.11 (Ch-1)		12 (Ln-11 Ln-12)			1.0 (D)		1.0 (Ln-20 Hy-9)	1.0 (Ln-20 Hy-9)	1.0 (Ln-20 Hy-9)
	H^3				4.5×10^3		12			1.0 (D)			
2	He		Total body 7×10^4 g 30 cm					1.0 (G)	1.0 (D)		1.0 (D)	1.0	0.75
3	Li	2×10^{-3} (Mow-1)	Total body 7×10^4 g 30 cm	$<1.3\times10^{-8}$ (Ti-1 through Ti-7)		2 (eq. 48)		1.0 (compared to Na Ra-1 Rn-1)	1.0 (D)		1.0 (D)	1.0	0.75
			Ovaries 8 g 3 cm	$<1.1\times10^{-8}$ (Ti-1 through Ti-7)		2 (eq. 48)			10^{-4} (Ti-1 through Ti-7)		10^{-4} (Same as f_2)	10^{-4}	7.5×10^{-5}
			Testes 40 g 3 cm	$<9\times10^{-9}$ (Ti-1 through Ti-7)		2 (eq. 48)			4.2×10^{-4} (Ti-1 through Ti-7)		4.2×10^{-4} (same as f_2)	4.2×10^{-4}	3.2×10^{-4}

4	Be		Total body 7×10^4 g 30 cm	$<3 \times 10^{-8}$ (Ti-1 through Ti-7)		180		2×10^{-8} (Ha-12)	1.0 (D)		1.0 (D)	2×10^{-3}	0.25
	Be^7				53.6		41			1.0 (D)			
	Be		Kidneys 300 g 7 cm	$<3 \times 10^{-8}$ (Ti-1 through Ti-7)		120			0.02 (Ha-16 Ha-21 Ha-23 Vc-1)		0.03 (Ha-16 Ha-21 Ha-23 Vc-1)	6×10^{-5}	7.5×10^{-3}
	Be^7				53.6		37			0.027			
	Be		Liver 1.7×10^3 g 10 cm	$<3 \times 10^{-8}$ (Ti-1 through Ti-7)		270			0.15 (Ha-16 Ha-21 Ha-23 Vc-1)		0.1 (Ha-16 Ha-21 Ha-23 Vc-1)	2×10^{-4}	0.025
	Be^7				53.6		45			0.11			
	Be		Spleen 150 g 7 cm	$<3 \times 10^{-8}$ (Ti-1 through Ti-7)		540			6×10^{-3} (Ha-16 Ha-21 Ha-23 Vc-1)		2×10^{-3} (Ha-16 Ha-21 Ha-23 Vc-1)	4×10^{-6}	5×10^{-4}
	Be^7				53.6		49			2.4×10^{-3}			
	Be		Bone 7×10^3 g 5 cm			450 (Ha-16 Ha-21 Ha-65)			0.8 (Ha-16 Ha-21 Ha-23 Vc-1)		0.32 (Ha-16 Ha-21 Ha-23 Vc-1)	6.4×10^{-4}	0.08
	Be^7				53.6		48			0.37			
5	B	6×10^{-3} (Ti-3 Un-1)	Total body 7×10^4 g 30 cm	$<1.4 \times 10^{-7}$ (Ti-1 through Ti-7)		0.5 (eq. 48)		0.9 (Un-1)	1.0 (D)		1.0 (D)	0.9	0.7

* Reference equations unless otherwise indicated.

Gen.* ref. Z	Element and radio-nuclides	Average daily ingestion I (g/day)	Organ of reference, mass (g) effective radius (cm)	Average concen-tration, C (g/g wet tissues)	Half-life (days)			Fraction from GI tract to blood f_1	Fraction in organ of reference of that in total body f_2		Fraction from blood to organ of reference f_2'	Fraction reaching organ of reference	
					Physical T_r	Bio-logical T_b	Effective T		Element	Radio-nuclide		By ingestion f_w	By inhalation f_a
			Ch-1			eq. 44, 45	eq. 49			eq.41,42		eq. 47	eq. 46
	B		Liver 1.7×10^3 g 10 cm	$<1.4 \times 10^{-7}$ (Ti-1 through (Ti-7)		0.5			0.13 (Ti-1 through (Ti-7)		0.13 (same as f_2)	0.12	0.09
			Brain 1.5×10^3 g 15 cm	$<1.4 \times 10^{-7}$ (Ti-1 through Ti-7)		0.5			0.07 (Ti-1 through Ti-7)		0.07 (same as f_2)	0.06	0.05
			Pancreas 70 g 5 cm	$<1.1 \times 10^{-7}$ (Ti-1 through Ti-7)		0.5			0.03 (Ti-1 through Ti-7)		0.03 (same as f_2)	0.03	0.02
6	C	400 (Hw-1)	Total body 7×10^4 g 30 cm	0.18 (Ch-1)		10 (Na-2)		1.0 (Hw-1)	1.0 (D)		1.0 (D)	1.0	0.75
	C^{14}				2×10^6		10			1.0 (D)			
	C		Fat 10^4 g	0.75 (Ev-1)		12 (Ss-3)			0.6 (Hw-1)		0.5 (eq. 47)	0.5 (Hw-1 G)	0.38
	C^{14}				2×10^6		12			0.6			
	C		Bone 7×10^3 g 5 cm	0.13 (Ev-1)		40 (Se-1) Br-2 Dk-1)			0.1 (Hw-1 Ev-1)		0.025 (Sk-2)	0.025	0.02
	C^{14}				2×10^6		40			0.1			
7	N	16 (Ev-1)	Total body 7×10^4 g 30 cm	0.03 (Ch-1)		90 (eq. 48)		1.0 (Sp-1 Ev-1)	1.0 (D)		1.0 (D)	1.0	0.75

8	O	2300 (Hw-1 Ch-1)	Total body 7×10^4 g 30 cm	0.65 (Ch-1)		14 (eq. 48)		1.0 (G)	1.0 (D)		1.0 (D)	1.0	0.75
9	F	10^{-3} (Un-1 Gd-1)	Total body 7×10^4 g 30 cm	2×10^{-5} (Ev-1 Gd-1)		808		1.0 (compared to Cl, Br and I)	1.0 (D)		1.0 (D)	1.0	0.75
	F^{18}				0.078		0.078			1.0 (D)			
	F		Bone and teeth 7×10^3 g 5 cm	2×10^{-4} (Ev-1)		1450 (eq. 48)			0.95 (Ev-1)		0.53 (Wa-2)	0.53	0.4
	F^{18}				0.078		0.078			0.53			
10	Ne		Total body 7×10^4 g 30 cm					1.0 (G)	1.0 (D)		1.0 (D)	1.0	0.75
11	Na	4 (Ev-1 Sh-1)	Total body 7×10^4 g 30 cm	1.5×10^{-3} (Ch-1)		11 (Rh-1 Ln-18)		1.0 (Gr-14)	1.0 (D)		1.0 (D)	1.0	0.75
	Na^{22}				950		11			1.0 (D)			
	Na^{24}				0.63		0.6			1.0 (D)			
12	Mg	0.53 (Shr-2)	Total body 7×10^4 g 30 cm	5×10^{-4} (Ch-1)		180 (eq. 48)		0.1 (Ev-1)	1.0 (D)		1.0 (D)	0.1	0.3
			Bone 7×10^3 g 5 cm	9.8×10^{-4} (Ti-1 through Ti-7)		180 (eq. 48)			0.5 (Ti-1 through Ti-7)		0.5 (same as f_2)	0.05	0.15
13	Al	2.3×10^{-3} (Ti-3 Ud-1)	Total body 7×10^4 g 30 cm	1.4×10^{-6} (Ti-1 through Ti-7)		550 (eq. 48)		0.1 (Mz-2 G)	1.0 (D)		1.0 (D)	0.1	0.3

* Reference equations unless otherwise indicated

Gen.* ref.	Element and radio-nuclides	Average daily ingestion I (g/day)	Organ of reference, mass (g) effective radius (cm)	Average concen-tration, C (g/g wet tissues)	Half-life (days)			Fraction from GI tract to blood f_1	Fraction in organ of reference of that in total body f_2		Fraction from blood to organ of reference f'_2	Fraction reaching organ of reference	
					Physical T_r	Bio-logical T_b	Effective T		Element	Radio-nuclide		By ingestion f_w	By inhalation f_a
Z			Ch-1			eq. 44, 45	eq. 49			eq. 41, 42		eq. 47	eq. 46
	Al		Lungs 10^3 g 10 cm	2.4×10^{-5} (Ti-1 through Ti-7)		600 (eq. 48)			0.14 (Sha-1 Ti-1 through Ti-7)		0.14 (same as f_2)	0.013	0.04
			Spleen 150 g 7 cm	1.1×10^{-6} (Ti-1 through Ti-7)		500 (eq. 48)			2×10^{-3} (Sha-1, Ti-1 through Ti-7)		2×10^{-3} (same as f_2)	2×10^{-4}	6×10^{-4}
14	Si	0.03 (Kg-1 Kg-2 G)	Total body 7×10^4 g 30 cm	3×10^{-5} (Kg-2)		60		0.85 (readily absor-bed, G)	1.0 (D)		1.0 (D)	0.85	0.68
	Si^{31}				0.11		0.11			1.0 (D)			
	Si		Lungs 10^3 g 10 cm	1.3×10^{-4} (Kg-2)		60 (eq. 48)			0.1 (Kg-2)		0.1 (same as f_2)	0.09	0.07
	Si^{31}				0.11		0.11			0.1			
	Si		Adrenals 20 g 3 cm	2.6×10^{-5} (Kg-2)		60			10^{-3} (Kg-2)		10^{-3} (same as f_2)	8.5×10^{-4}	7×10^{-4}
	Si^{31}				0.11		0.11			10^{-3}			
	Si		Testes 40 g 3 cm	3×10^{-5} (Kg-2)		60			5×10^{-4} (Kg-2)		5×10^{-4} (same as f_2)	4.3×10^{-4}	3.4×10^{-4}
	Si^{31}				0.11		0.11			5×10^{-4}			

	Si Si^{31}		Ovaries 8 g 3 cm	1.7×10^{-5} (Kg-2)	0.11	60	0.11		6×10^{-5} (Kg-2)	6×10^{-5}	6×10^{-5} (same as f_2)	5×10^{-5}	4×10^{-5}
	Si Si^{31}		Skin 2×10^3 g 0.1 cm	5.5×10^{-5} (Kg-2)	0.11	60	0.11		0.04 (Kg-2)	0.04	0.04 (same as f_2)	0.03	0.03
15	P P^{32}	1.4 (Shr-2 Ev-1 Sun-3)	Total body 7×10^4 g 30 cm	0.01 (Ch-1)	14.3	257	13.5	0.75 (Kw-1)	1.0 (D)	1.0 (D)	1.0 (D)	0.75 (Kw-1)	0.63
	P P^{32}		Liver 1.7×10^3 g 10 cm	2.7×10^{-3} (Ti-1 through Ti-7)	14.3	18	8		5×10^{-3} (Ti-1 through Ti-7)	0.04	0.07	0.05 (Kw-1)	0.04
	P P^{32}		Bone 7×10^3 g 5 cm	0.05 (Ev-1)	14.3	1155 (eq. 48)	14.1		0.9 (He-1)	0.5	0.5 (Ph-4)	0.375	0.32
	P P^{32}		Brain 1.5×10^3 g 15 cm	3.2×10^{-3} (Ti-1 through Ti-7)	14.3	257	13.5		7×10^{-3} (Ti-1 through Ti-7)	7×10^{-3}	7×10^{-3} (same as f_2)	5.3×10^{-3}	4.4×10^{-3}
16	S S^{35}	1.3 (Hw-1 Sun-1)	Total body 7×10^4 g 30 cm	2.5×10^{-3} (Ch-1)	87.1	90 (eq. 48)	44.3	1.0 (Dd-6)	1.0 (D)	1.0 (D)	1.0 (D)	1.0	0.75
	S		Bone 7×10^3 g 5 cm	2.4×10^{-3} (Sh-1)		600			0.2 (Dd-6 Sh-1)		0.03 (eq. 47)	0.03 (Dd-6)	0.02

* Reference equations unless otherwise indicated.

Gen.* ref. Z	Element and radio-nuclides	Average daily ingestion I (g/day)	Organ of reference, mass (g) effective radius (cm)	Average concen-tration, C (g/g wet tissues)	Half-life (days) Physical T_r	Half-life (days) Bio-logical T_b	Half-life (days) Effective T	Fraction from GI tract to blood f_1	Fraction in organ of reference of that in total body f_2 Element	Fraction in organ of reference of that in total body f_2 Radio-nuclide	Fraction from blood to organ of reference f_2'	Fraction reaching organ of reference By ingestion f_w	Fraction reaching organ of reference By inhalation f_a
			Ch-1			eq. 44, 45	eq. 49			eq. 41, 42		eq. 47	eq. 46
	S^{35}				87.1		76.1			0.05			
	S		Skin 2×10^3g 0.1 cm	9.5×10^{-3} (Sh-1)		1530			0.17 (Sh-1)		0.01 (eq. 47)	0.01 (Dd-6)	7.5×10^{-3}
	S^{35}				87.1		82.4			0.02			
	S		Testes 40 g 3 cm			623			9×10^{-3} (Dd-6)		1.3×10^{-3}	1.3×10^{-3} (Dd-6)	9.8×10^{-4}
	S^{35}				87.1		76.4			2×10^{-3}			
17	Cl	6.7 (Ev-1)	Total body 7×10^4 g 30 cm	1.5×10^{-3} (Ch-1)		29		1.0	1.0 (D)		1.0 (D)	1.0	0.75
	Cl^{36}				1.2×10^8		29			1.0 (D)			
	Cl^{38}				0.026		0.026			1.0 (D)			
18	A		Total body 7×10^4 g 30 cm					1.0 (G)	1.0 (D)		1.0 (D)	1.0	0.75
	A^{37}				34.1					1.0 (D)			
	A^{41}				0.076					1.0 (D)			
19	K	3 (Jl-1)	Total body 7×10^4 g 30 cm	2×10^{-3} (Ch-1)		58		1.0 (He-1)	1.0 (D)		1.0 (D)	1.0	0.75
	K^{42}				0.52		0.52			1.0 (D)			

	K		Muscle 3×10^{4} g 30 cm	2.9×10^{-3} (Ti-1 through Ti-7)		58 (Ln-18)			0.65 (Ti-1 through Ti-7)		0.65 (same as f_2)	0.65	0.49
	K^{42}				0.52		0.52			0.65			
	K		Spleen 150 g 7 cm	3.5×10^{-3} (Ti-1 through Ti-7)		58			4×10^{-3} (Ti-1 through Ti-7)		4×10^{-3} (same as f_2)	4×10^{-3}	3×10^{-3}
	K^{42}				0.52		0.52			4×10^{-3}			
	K		Brain 1.5×10^{3} g 15 cm	3.3×10^{-3} (Ti-1 through Ti-7)		58			0.04 (Ti-1 through Ti-7)		0.04 (same as f_2)	0.04	0.03
	K^{42}				0.52		0.52			0.04			
	K		Liver 1.7×10^{3} g 10 cm	3.1×10^{-3} (Ti-1 through Ti-7)		58			0.02 (Ti-1 through Ti-7)		0.02 (same as f_2)	0.02	0.015
	K^{42}				0.52		0.52			0.02			
20	Ca	1.0 (Shr-2 Ev-1 Jl-1)	Total body 7×10^{4} g 30 cm	0.015 (Ch-1)		1.64×10^{4}		0.6 (Pit-1)	1.0 (D)		1.0 (D)	0.6	0.55
	Ca^{45}				164		162			1.0 (D)			
	Ca^{47}				4.9		4.9			1.0 (D)			
	Ca		Bone 7×10^{3} g 5 cm	0.148 (Ev-1 Hw-1)		1.8×10^{4} (No-2 compared to Sr and Ra)			0.99 (Ev-1 Hr-1)		0.9 (Co-9 Br-10)	0.54	0.5
	Ca^{45}				164		162			0.9			
	Ca^{47}				4.9		4.9			0.9			
21	Sc		Total body 7×10^{4} g 30 cm			30 (Ha-84 Ha-88)		10^{-4} (Ha-84 Ha-88)	1.0 (D)		1.0 (D)	10^{-4}	0.25

* Reference equations unless otherwise indicated.

Gen.* ref.	Element and radio-nuclides	Average daily ingestion I (g/day)	Organ of reference, mass (g) effective radius (cm)	Average concentration, C (g/g wet tissues)	Half-life (days) Physical T_r	Half-life (days) Biological T_b	Half-life (days) Effective T	Fraction from GI tract to blood f_1	Fraction in organ of reference of that in total body f_2 Element	Fraction in organ of reference of that in total body f_2 Radio-nuclide	Fraction from blood to organ of reference f'_2	Fraction reaching organ of reference By ingestion f_w	Fraction reaching organ of reference By inhalation f_a
Z			Ch-1			eq. 44, 45	eq. 49			eq. 41, 42		eq. 47	eq. 46
	Sc^{46}				85		22			1.0 (D)			
	Sc^{47}				3.43		3.1			1.0 (D)			
	Sc^{48}				1.83		1.7			1.0 (D)			
	Sc		Liver 1.7×10^3 g 10 cm			36			0.18 (Ha-84 Ha-88)		0.15 (Ha-84 Ha-88)	1.5×10^{-5}	0.04
	Sc^{46}				85		25			0.17			
	Sc^{47}				3.43		3.1			0.15			
	Sc^{48}				1.83		1.7			0.15			
	Sc		Kidneys 300 g 7 cm			75			0.05 (Ha-84 Ha-88)		0.02 (Ha-84 Ha-88)	2×10^{-6}	5×10^{-3}
	Sc^{46}				85		40			0.04			
	Sc^{47}				3.43		3.3			0.02			
	Sc^{48}				1.83		1.8			0.02			
	Sc		Bone 7×10^3 g 5 cm			33			0.22 (Ha-84 Ha-88)		0.2 (Ha-84 Ha-88)	2×10^{-5}	0.05
	Sc^{46}				85		24			0.22			
	Sc^{47}				3.43		3.1			0.2			
	Sc^{48}				1.83		1.7			0.2			
22	Ti	5.4×10^{-4} (Ti-3)	Total body 7×10^4 g 30 cm	2.1×10^{-7} (Ti-1 through Ti-7)		320		10^{-4} (compared to Zr)	1.0 (D)		1.0 (D)	10^{-4}	0.25

			Lungs 10^3 g 10 cm	2.8×10^{-6} (Ti-1 through Ti-7)		320 (eq. 48)			0.2 (Ti-1 through Ti-7)		0.2 (same as f_2)	2×10^{-5}	0.05
			Spleen 150 g 7 cm	$<1.8 \times 10^{-7}$ (Ti-1 through Ti-7)		320			0.01 (Ti-1 through Ti-7)		0.01 (same as f_2)	10^{-6}	2.5×10^{-3}
			Pancreas 70 g 5 cm	$<1.1 \times 10^{-7}$ (Ti-1 through Ti-7)		320			5×10^{-4} (Ti-1 through Ti-7)		5×10^{-4} (same as f_2)	5×10^{-8}	1.3×10^{-4}
23	V		Total body 7×10^4 g 30 cm	$<1.3 \times 10^{-8}$ (Ti-1 through Ti-7)		42 (Ha-16 Ha-95)		0.02 (Ha-95)	1.0 (D)		1.0 (D)	0.02	0.26
	V^{48}				16.1		11.6			1.0 (D)			
	V		Kidneys 300 g 7 cm	$<1.1 \times 10^{-8}$ (Ti-1 through (Ti-7)		74			0.07 (Ha-16 Ha-95)		0.04 (Ha-16 Ha-95)	8×10^{-4}	0.01
	V^{48}				16.1		13.2			0.05			
	V		Spleen 150 g 7 cm	$<1.3 \times 10^{-8}$ (Ti-1 through Ti-7)		90			0.02 (Ha-16 Ha-95)		0.01 (Ha-16 Ha-95)	2×10^{-4}	2.6×10^{-3}
	V^{48}				16.1		13.7			0.01			
	V		Liver 1.7×10^3 g 10 cm	$<1.4 \times 10^{-8}$ (Ti-1 through Ti-7)		70			0.1 (Ha-16 Ha-95)		0.06 (Ha-16 Ha-95)	1.2×10^{-3}	0.02
	V^{48}				16.1		13.1			0.07			

* Reference equations unless otherwise indicated.

Gen.* ref.	Element and radio-nuclides	Average daily ingestion I (g/day)	Organ of reference, mass (g) effective radius (cm)	Average concentration, C (g/g wet tissues)	Half-life (days) Physical T_r	Biological T_b	Effective T	Fraction from GI tract to blood f_1	Fraction in organ of reference of that in total body f_2 Element	Radio-nuclide	Fraction from blood to organ of reference f_2'	Fraction reaching organ of reference By ingestion f_w	By inhalation f_a
Z			Ch-1			eq. 44, 45	eq. 49			eq. 41, 42		eq. 47	eq. 46
	V		Bone 7×10^3 g 5 cm	$<1.5 \times 10^{-6}$ (Ti-1 through Ti-7)		135			0.45 (Ha-16 Ha-95)		0.14 (Ha-16 Ha-95)	2.8×10^{-3}	0.04
	V^{48}				16.1		14.4			0.17			
24	Cr	1.5×10^{-4} (Ti-3)	Total body 7×10^4 g 30 cm	$<8.6 \times 10^{-8}$ (Ti-1 through Ti-7)		616		<0.005 (Co-19)	1.0 (D)		1.0 (D)	<0.005	0.25
	Cr^{51}				27.8		26.6			1.0 (D)			
	Cr		Lungs 10^3 g 10 cm	2×10^{-7} (Ti-1 through Ti-7)		616			0.04 (Sha-1 Ti-1 through Ti-7)		0.04 (same as f_2)	2×10^{-4}	0.01
	Cr^{51}				27.8		26.6			0.05			
	Cr		Prostate 20 g 3 cm	5×10^{-8} (Ti-1 through Ti-7)		616 (eq. 48)			9×10^{-4} (Sha-1 Ti-1 through Ti-7)		9×10^{-1} (same as f_2)	4.5×10^{-6}	2.3×10^{-4}
	Cr^{51}				27.8		26.6			9×10^{-4}			
	Cr		Thyroid 20 g 3 cm	3×10^{-8} (Ti-1 through Ti-7)		616			9×10^{-4} (Sha-1 Ti-1 through Ti-7)		9×10^{-4} (same as f_2)	4.5×10^{-6}	2.3×10^{-4}
	Cr^{51}				27.8		26.6			9×10^{-4}			

	Cr^{51}		Kidneys 300 g 7 cm	3×10^{-8} (Ti-1 through Ti-7)	27.8	616	26.6		2.7×10^{-3} (Sha-1 Ti-1 through Ti-7)	2.7×10^{-3}	2.7×10^{-3} (same as f_2)	1.3×10^{-5}	6.8×10…
25	Mn	3.1×10^{-3} (Ti-3)	Total body 7×10^{4} g 30 cm	3×10^{-7} (Ch-1)		17 (Bn-2 Bn-3 Bn-4)		0.1 (Un-1)	1.0 (D)		1.0 (D)	0.1	0.3
	Mn^{52}				5.55		4.2			1.0 (D)			
	Mn^{54}				300		16.2			1.0 (D)			
	Mn^{56}				0.11		0.11			1.0 (D)			
	Mn		Pancreas 70 g 5 cm	1.2×10^{-6} (Ti-1 through Ti-7)		5.7			0.01 (Bn-2 Bn-3 Bn-4 Bn-6)		0.03 (Bn-2 Bn-3 Bn-4)	3×10^{-3}	9×10^{-3}
	Mn^{52}				5.55		2.8			0.02			
	Mn^{54}				300		5.6			0.01			
	Mn^{56}				0.11		0.11			0.03			
	Mn		Liver 1.7×10^{3} g 10 cm	1.3×10^{-6} (Ti-1 through Ti-7)		25 (Bn-2 Bn-3 Bn-4)			0.35 (Bn-2 Bn-3 Bn-4 Bn-6)		0.24 (Bn-2 Bn-3) Bn-4)	0.02	0.07
	Mn^{52}				5.55		4.5			0.26			
	Mn^{54}				300		23			0.35			
	Mn^{56}				0.11		0.11			0.24			
	Mn		Kidneys 300 g 7 cm	8.5×10^{-7} (Ti-1 through Ti-7)		6.8			0.02 (Bn-2 Bn-3 Bn-4 Bn-6)		0.05 (Bn-2 Bn-3 Bn-4)	5×10^{-3}	0.02
	Mn^{52}				5.55		3.1			0.04			
	Mn^{54}				300		6.6			0.02			
	Mn^{56}				0.11		0.11			0.05			
26	Fe	0.027 (Ti-3)	Total body 7×10^{4} g 30 cm	5.7×10^{-5} (Ch-1)		800		0.1 (Bad-1)	1.0 (D)		1.0 (D)	0.1	0.3

* Reference equations unless otherwise indicated.

Gen.* ref.	Element and radio-nuclides	Average daily ingestion I (g/day)	Organ of reference, mass (g) effective radius (cm)	Average concen-tration, C (g/g wet tissues)	Half-life (days) Physical T_r	Bio-logical T_b	Effective T	Fraction from GI tract to blood f_1	Fraction in organ of reference of that in total body f_2 Element	Radio-nuclide	Fraction from blood to organ of reference f_2'	Fraction reaching organ of reference By ingestion f_w	By inhalation f_a
Z			Ch-1			eq. 44, 45	eq. 49			eq.41,42		eq. 47	eq. 46
	Fe^{55}				1.1×10^3		463			1.0 (D)			
	Fe^{59}				45.1		42.7			1.0 (D)			
	Fe		Spleen 150 g 7 cm	3.3×10^{-4} (Ti-1 through Ti-7)		600 (eq. 48)			0.02 (Ti-1 through Ti-7)		0.02 (Ha-29)	2×10^{-3}	6×10^{-3}
	Fe^{55}				1.1×10^3		388			0.02			
	Fe^{59}				45.1		41.9			0.02			
	Fe		Lungs 10^3 g 10 cm	3×10^{-4} (Ti-1 through Ti-7)		3.2×10^3			0.08 (Ti-1 through Ti-7)		0.02 (Ha-29)	2×10^{-3}	6×10^{-3}
	Fe^{55}				1.1×10^3		819			0.035			
	Fe^{59}				45.1		44.5			0.021			
	Fe		Liver 1.7×10^3 g 10 cm	1.9×10^{-4} (Ti-1 through Ti-7)		554			0.09 (Ti-1 through Ti-7)		0.13 (Ha-29)	0.013	0.04
	Fe^{55}				1.1×10^3		368			0.1			
	Fe^{59}				45.1		41.7			0.13			
	Fe		Bone 7×10^3 g 5 cm	1.2×10^{-4} (Ti-1 through Ti-7)		1680			0.21 (Ti-1 through Ti-7)		0.1 (Ha-29)	0.01	0.03
	Fe^{55}				1.1×10^3		665			0.14			
	Fe^{59}				45.1		43.9			0.1			
27	Co	7×10^{-6}	Total body	$<4.3\times10^{-8}$		9.5		0.3	1.0 (D)		1.0 (D)	0.3	0.4

		(Ti-3)	7×10^{4} g 30 cm	(Ti-1 through Ti-7)		(Ma-2)		(Gd-1)					
	Co^{57}				270		9.2			1.0 (D)			
	Co^{58m}				0.38		0.37			1.0 (D)			
	Co^{58}				72		8.4			1.0 (D)			
	Co^{60}				1.9×10^{3}		9.5			1.0 (D)			
	Co		Liver 1.7×10^{3} g 10 cm	3×10^{-7} (Led-1)		9.5 (Ma-2)			0.5 (Ma-2)		0.04 (eq. 47)	7×10^{-3} (Ma-2)	0.02
	Co^{57}				270		9.2			0.02			
	Co^{58m}				0.38		0.37			0.02			
	Co^{58}				72		8.4			0.02			
	Co^{60}				1.9×10^{3}		9.5			0.02			
	Co		Spleen 150 g 7 cm	10^{-7} (Led-1)		9.5 (Ma-2)			0.07 (Ma-2 Co-1 Co-5)		1.4×10^{-3} (eq. 47)	4.2×10^{-4} (Ma-2)	5.6×10^{-4}
	Co^{57}				270		9.2			1.4×10^{-3}			
	Co^{58m}				0.38		0.37			1.4×10^{-3}			
	Co^{58}				72		8.4			1.4×10^{-3}			
	Co^{60}				1.9×10^{3}		9.5			1.4×10^{-3}			
	Co		Pancreas 70 g 5 cm	$<5\times10^{-8}$ (Ti-1 through Ti-7)		9.5 (Ma-2)			0.03 (Co-1 Co-5)		2×10^{-3} (Co-22)	6×10^{-4}	8×10^{-4}
	Co^{57}				270		9.2			2×10^{-3}			
	Co^{58m}				0.38		0.37			2×10^{-3}			
	Co^{58}				72		8.4			2×10^{-3}			
	Co^{60}				1.9×10^{3}		9.5			2×10^{-3}			
28	Ni	4×10^{-4} (Ti-3)	Total Body 7×10^{4} g 30 cm	$<1.4\times10^{-7}$ (Ti-1 through Ti-7		667		0.3 (Ps-1)	1.0 (D)		1.0 (D)	0.3	0.4

* Reference equations unless otherwise indicated.

T_r T_b T_e

Gen.* ref.	Element and radio-nuclides	Average daily ingestion I (g/day)	Organ of reference, mass (g) effective radius (cm)	Average concentration, C (g/g wet tissues)	Half-life (days) Physical T_r	Half-life (days) Biological T_b	Half-life (days) Effective T	Fraction from GI tract to blood f_1	Fraction in organ of reference of that in total body f_2 Element	Fraction in organ of reference of that in total body f_2 Radio-nuclide	Fraction from blood to organ of reference f	Fraction reaching organ of reference By ingestion f_w	Fraction reaching organ of reference By inhalation f_a
Z			Ch-1			eq. 44, 45	eq. 49			eq.41,42		eq. 47	eq. 46
	Ni^{59}				2.9×10^7		667			1.0 (D)			
	Ni^{63}				2.9×10^4		652			1.0 (D)			
	Ni^{65}				0.11		0.11			1.0 (D)			
	Ni		Bone 7×10^3 g 5 cm	$<2\times10^{-6}$ (Ti-1 through Ti-7)		800 (eq. 48)			0.6 (Ps-1)		0.5 (eq. 47)	0.15 (Ps-1)	0.2
	Ni^{59}				2.9×10^7		800 779			0.6			
	Ni^{63}				2.9×10^4					0.6			
	Ni^{65}				0.11		0.11			0.5			
	Ni		Liver 1.7×10^3 g 10 cm	$<10^{-7}$ (Ti-1 through Ti-7)		500			0.05 (Ps-1)		0.07 (eq. 47)	0.02 (Ps-1)	0.03
	Ni^{59}				2.9×10^7		500			0.05			
	Ni^{63}				2.9×10^4		492			0.05			
	Ni^{65}				0.11		0.11			0.07			
29	Cu	3×10^{-3} (Ti-3)	Total body 7×10^4 g 30 cm	1.4×10^{-6} (Ch-1)		80		0.28 (Co-3 Co-6)	1.0 (D)		1.0 (D)	0.28	0.39
	Cu^{64}				0.53		0.53			1.0 (D)			
	Cu		Spleen 150 g	1.2×10^{-6} (Ti-1		2			2×10^{-3} (Ti-1		0.07 (Ash-1)	0.02	0.03

	Cu^{64}		7 cm	through Ti-7)	0.53		0.42		through Ti-7)	0.055			
	Cu		Kidneys 300 g 7 cm	2.9×10^{-6} (Ti-1 through Ti-7)		16			0.01 (Ti-1 through Ti-7)		0.05 (Ash-1)	0.01	0.02
	Cu^{64}				0.53		0.51			0.05			
	Cu		Liver 1.7×10^3 g 10 cm	8.6×10^{-6} (Ti-1 through Ti-7)		150 (eq. 48)			0.15 (Ti-1 through Ti-7)		0.08 (Ash-1)	0.02	0.03
	Cu^{64}				0.53		0.53			0.08			
	Cu		Heart 300 g 7 cm	3.5×10^{-6} (Ti-1 through Ti-7)		80			0.01 (Ti-1 through Ti-7)		0.01 (Ash-1)	3×10^{-3}	4×10^{-3}
	Cu^{64}				0.53		0.53			0.01			
	Cu		Brain 1.5×10^3 g 15 cm	5.8×10^{-6} (Ti-1 through Ti-7)		800			0.1 (Ti-1 through Ti-7)		0.01 (Ash-1)	3×10^{-3}	4×10^{-3}
	Cu^{64}				0.53		0.53			0.01			
30	Zn	0.017 (Ev-1 Sh-1)	Total body 7×10^4 g 30 cm	3.3×10^{-5} (Ch-1 Ti-1 through Ti-7)		933 (eq. 48)		0.1 (Sh-1)	1.0 (D)		1.0 (D)	0.1	0.3
	Zn^{65}				245		194			1.0 (D)			
	Zn^{69m}				0.58		0.58			1.0 (D)			
	Zn^{69}				0.036		0.036			1.0 (D)			

* Reference equations unless otherwise indicated.

Gen.* ref.	Element and radio-nuclides	Average daily ingestion I (g/day)	Organ of reference, mass (g) effective radius (cm)	Average concentration, C (g/g wet tissues)	Half-life (days) Physical T_r	Half-life (days) Biological T_b	Half-life (days) Effective T	Fraction from GI tract to blood f_1	Fraction in organ of reference of that in total body f_2 Element	f_2 Radio-nuclide	Fraction from blood to organ of reference f'	Fraction reaching organ of reference By ingestion f_w	Fraction reaching organ of reference By inhalation f_a
			Ch-1			eq. 44, 45	eq. 49			eq. 41, 42		eq. 47	eq. 46
	Zn		Prostate 20 g 3 cm	8.7×10^{-5} (Ti-1 through Ti-7)		14 (eq. 48)			9×10^{-4} (Ti-1 through Ti-7)		0.06 (Gu-1 Sn-2)	6×10^{-3}	0.02
	Zn^{65} Zn^{69m} Zn^{69}				245 0.58 0.036		13 0.56 0.036			4×10^{-3} 0.06 0.06			
	Zn		Bone 7×10^{3} g 5 cm	6.6×10^{-5} (Ti-1 through Ti-7)		1300			0.21 (Ti-1 through Ti-7)		0.15 (Sn-2)	0.015	0.045
	Zn^{65} Zn^{69m} Zn^{69}				245 0.58 0.036		206 0.58 0.036			0.16 0.15 0.15			
	Zn		Kidneys 300 g 7 cm	4.8×10^{-5} (Ti-1 through Ti-7)		149			6.4×10^{-3} (Ti-1 through Ti-7)		0.04 (Sn-2)	4×10^{-3}	0.012
	Zn^{65} Zn^{69m} Zn^{69}				245 0.58 0.036		93 0.58 0.036			0.02 0.04 0.04			
	Zn		Muscle 3×10^{4} g 30 cm	4.7×10^{-5} (Ti-1 through Ti-7)		1959			0.63 (Ti-1 through Ti-7)		0.3 (Sn-2)	0.03	0.09
	Zn^{65} Zn^{69m} Zn^{69}				245 0.58 0.036		218 0.58 0.036			0.34 0.3 0.3			
	Zn		Liver 1.7×10^{3} g	4.6×10^{-5} (Ti-1		91			0.034 (Ti-1		0.35 (Sn-2	0.035	0.11

			10 cm	through Ti-7)					through Ti-7)				
	Zn^{65} Zn^{69m} Zn^{69}				245 0.58 0.036		66 0.58 0.036			0.12 0.35 0.35			
	Zn		Pancreas 70 g 5 cm	2.7×10^{-5} (Ti-1 through Ti-7)		25			8×10^{-4} (Ti-1 through Ti-7)		0.03 (Sn-2)	3×10^{-3}	9×10^{-3}
	Zn^{65}				245		23			$3.5\times$ 10^{-3}			
	Zn^{69m} Zn^{69}				0.58 0.036		0.57 0.036			0.03 0.03			
	Zn		Testes 40 g 3 cm	1.5×10^{-5} (Ti-1 through Ti-7)		270			$2.6\times$ 10^{-4} (Ti-1 through Ti-7)		9×10^{-4} (Sn-2)	9×10^{-5}	2.7×10^{-4}
	Zn^{65} Zn^{69m} Zn^{69}				245 0.58 0.036		128 0.58 0.036			6×10^{-4} 9×10^{-4} 9×10^{-4}			
	Zn		Ovaries 8 g 3 cm	1.3×10^{-5} (Ti-1 through Ti-7)		107			$4.6\times$ 10^{-5} (Ti-1 through Ti-7)		4×10^{-4} (Sn-2)	4×10^{-5}	1.2×10^{-4}
	Zn^{65}				245		74			$1.5\times$ 10^{-4}			
	Zn^{69m} Zn^{69}				0.58 0.036		0.58 0.036			4×10^{-4} 4×10^{-4}			
31	Ga		Total body 7×10^{4} g 30 cm	$<3\times10^{-11}$ (Du-1)		6 (Bm-1)		$<10^{-3}$ (Du-4 Pk-1)	1.0 (D)		1.0 (D)	10^{-3}	0.25
	Ga^{72}				0.59		0.54			1.0 (D)			
	Ga		Liver 1.7×10^{3} g 10 cm	$<10^{-8}$ (Ti-1 through Ti-7)		4.8			0.2 (Ha-20)		0.25 (Bm-1 Ha-20)	2.5×10^{-4}	0.063

* Reference equations unless otherwise indicated.

Gen.* ref.	Element and radionuclide[2]	Average daily ingestion I (g/day)	Organ of reference, mass (g) effective radius (cm)	Average concentration, C (g/g wet tissues)	Half-life (days) Physical T_r	Biological T_b	Effective T	Fraction from GI tract to blood f_1	Fraction in organ of reference of that in total body f_2 Element	Radionuclide	Fraction from blood to organ of reference f_2'	Fraction reaching organ of reference By ingestion f_w	By inhalation f_a
			Ch-1			eq. 44, 45	eq. 49			eq. 41, 42		eq. 47	eq. 46
					0.59		0.53			0.25			
			Bone 7×10^3 g 5 cm	$<1\times10^{-6}$ (Du-1)		12			0.6 (Ha-20)		0.3 (Bm-1 Ha-20)	3×10^{-1}	0.075
	Ga^{72}				0.59		0.56			0.31			
	Ga		Spleen 150 g 7 cm	$<10^{-8}$ (Ti-1 through Ti-7)		6			0.01 (Ha-20)		0.01 (Ha-20)	10^{-5}	2.5×10^{-3}
	Ga^{72}				0.59		0.54			0.01			
	Ga		Kidneys 300 g 7 cm	$<10^{-8}$ (Ti-1 through Ti-7)		9			0.03 (Ha-20)		0.02 (Ha-20)	2×10^{-5}	5×10^{-3}
	Ga^{72}				0.59		0.55			0.02			
	Ga		Total body 7×10^4 g 30 cm			1		<0.01 (Ha-21)	1.0 (D)		1.0 (D)	0.01	0.26
	Ga^{71}				12		0.92			1.0 (D)			
32	Ge		Kidneys 300 g 7 cm			12 (Ha-12)			0.36 (Ha-21)		0.03 (Ha-21)	3×10^{-4}	8×10^{-3}
	Ge^{71}				12		6			0.2			
	Ge		Liver 1.7×10^3 g 10 cm			7.5			0.15 (Ha-21)		0.02 (Ha-21)	2×10^{-4}	5×10^{-3}
	Ge^{71}				12		4.6			0.1			
	G												
	G												

33	s		Total body 7×10^4 g 30 cm	$<1.4 \times 10^{-6}$ (Ti-1 through Ti-7)		280 (Ha-17)		0.03 (Mo-1)	1.0 (D)		1.0 (D)	0.03	0.27
	As^{73}				76		60			1.0 (D)			
	As^{74}				17.5		16.5			1.0 (D)			
	As^{76}				1.1		1.1			1.0 (D)			
	As^{77}				1.6		1.6			1.0 (D)			
	As		Kidneys 300 g 7 cm	3×10^{-8} (Lcd-1)		550			0.02 (Ha-17)		0.01 (Ha-17)	3×10^{-4}	2.7×10^{-3}
	As^{73}				76		67			0.01			
	As^{74}				17.5		17			0.01			
	As^{76}				1.1		1.1			0.01			
	As^{77}				1.6		1.6			0.01			
	As		Liver 1.7×10^3 g 10 cm	10^{-7} (Lcd-1)		550			0.06 (Ha-17)		0.03 (Ha-17)	9×10^{-4}	8×10^{-3}
	As^{73}				76		67			0.034			
	As^{74}				17.5		17			0.031			
	As^{76}				1.1		1.1			0.03			
	As^{77}				1.6		1.6			0.03			
34	Se		Total body 7×10^4 g 30 cm			11 (Ha-15 Ha-22)		0.9 (Un-1 Gd-1 G)	1.0 (D)		1.0 (D)	0.9	0.7
	Se^{75}				127		10.1			1.0 (D)			
	Se		Kidneys 300 g 7 cm			11 (Ha-15 Ha-22)			0.04 (Ha-15 Ha-22)		0.04 (Ha-15)	0.04	0.03
	Se^{75}				127		10.1			0.04			
	Se		Liver			24			0.15		0.07	0.06	0.05

* Reference equations unless otherwise indicated.

Gen.* ref.	Element and radio-nuclides	Average daily ingestion I (g/day)	Organ of reference, mass (g) effective radius (cm)	Average concen-tration, C (g/g wet tissues)	Half-life (days) Physical T_r	Half-life (days) Bio-logical T_b	Half-life (days) Effective T	Fraction from GI tract to blood f_1	Fraction in organ of reference of that in total body f_2 Element	Fraction in organ of reference of that in total body f_2 Radio-nuclide	Fraction from blood to organ of reference f_2'	Fraction reaching organ of reference By ingestion f_w	Fraction reaching organ of reference By inhalation f_a
			Ch-1			eq. 44, 45	eq. 49			eq. 41, 42		eq. 47	eq. 46
	Se^{75}		1.7×10^{3} g 10 cm		127		20		(Ha-15 Ha-22)	0.14	(Ha-15)		
	Se		Spleen 150 g 7 cm			18 (Ha-15 Ha-22)			8×10^{-3} (Ha-15) Ha-22)		5×10^{-3} (Ha-15)	4.5×10^{-3}	3.5×10^{-3}
	Se^{75}				127		16			8×10^{-3}			
35	Br	0.017 (Ev-1)	Total body 7×10^{4} g 30 cm	1.7×10^{-6} (Dx-1)		8 (eq. 48)		1.0 (com-pared to I)	1.0 (D)		1.0 (D)	1.0	0.75
	Br^{82}				1.5		1.3			1.0 (D)			
36	Kr		Total body 7×10^{4} g 30 cm					1.0 (G)	1.0 (D)		1.0 (D)	1.0	0.75
	Kr^{85m}				0.18								
	Kr^{85}				3.9×10^{3}								
	Kr^{87}				0.054								
37	Rb		Total body 7×10^{4} g 30 cm	1.7×10^{-5} (Ti-1 through Ti-7)		45		1.0 (Ha-21 Rh-1)	1.0 (D)		1.0 (D)	1.0	0.75
	Rb^{86}				18.6		13.2			1.0 (D)			
	Rb^{87}				1.8×10^{13}		45			1.0 (D)			
	Rb		Muscle 3×10^{4} g	3.1×10^{-5} (Ti-1		80 (Ln-18			0.8 (Ha-21)		0.45 (Ha-21)	0.45	0.34

			30 cm	through Ti-7)		Rh-1)							
	Rb^{86} Rb^{87}				18.6 1.8×10^{13}		15.1 80			0.52 0.8			
	Rb		Liver 1.7×10^{3} g 10 cm	6.3×10^{-5} (Ti-1 through Ti-7)		63			0.07 (Ha-21)		0.05 (Ha-21)	0.05	0.04
	Rb^{86} Rb^{87}				18.6 1.8×10^{13}		14.4 63			0.06 0.07			
	Rb		Spleen 150 g 7 cm	4.3×10^{-5} (Ti-1 through Ti-7)		45			4×10^{-3} (Ha-21)		4×10^{-3} (Ha-21)	4×10^{-3}	3×10^{-3}
	Rb^{86} Rb^{87}				18.6 1.8×10^{13}		13.2 45			4×10^{-3} 4×10^{-3}			
	Rb		Pancreas 70 g 5 cm	6.2×10^{-5} (Ti-1 through Ti-7)		60			4×10^{-3} (Ha-21)		3×10^{-3} (Ha-21)	3×10^{-3}	2.3×10^{-3}
	Rb^{86}				18.6		14.3			3.6×10^{-3}			
	Rb^{87}				1.8×10^{13}		60			4×10^{-3}			
38	Sr	10^{-3} (Ti-3)	Total body 7×10^{4} g 30 cm	2×10^{-6} (Ti-1 through Ti-7)		1.3×10^{4}		0.3 (Pit-1)	1.0 (D)		1.0 (D)	0.3	0.4
	Sr^{85m}				0.049		0.049			1.0 (D)			
	Sr^{85}				65		64.7			1.0 (D)			
	Sr^{89}				50.5		50.3			1.0 (D)			
	Sr^{90}				10^{4}		5700			1.0 (D)			
	Sr^{91}				0.4		0.4			1.0 (D)			
	Sr^{92}				0.11		0.11			1.0 (D)			

* Reference equations unless otherwise indicated.

Gen.* ref.	Element and radio-nuclides	Average daily ingestion I (g/day)	Organ of reference, mass (g) effective radius (cm)	Average concen-tration, C (g/g wet tissues)	Half-life (days) Physical T_r	Half-life (days) Bio-logical T_b	Half-life (days) Effective T	Fraction from GI tract to blood f_1	Fraction in organ of reference of that in total body f_2: Element	Fraction in organ of reference of that in total body f_2: Radio-nuclide	Fraction from blood to organ of reference f'_2	Fraction reaching organ of reference: By ingestion f_w	Fraction reaching organ of reference: By inhalation f_a
			Ch-1			eq. 44, 45	eq. 49			eq. 41, 42		eq. 47	eq. 46
	Sr		Bone 7×10^3 g 5 cm	1.5×10^{-5} (Ti-1 through Ti-7)		1.8×10^4 (No-2 compared to Ca and Ra)			0.95 (Ti-1 through Ti-7)		0.3 (Dur-3)	0.09	0.12
	Sr^{85m}				0.049		0.049			0.71	0.7 (Tm-3)	0.21	0.28
	Sr^{85}				65		64.8			0.99	0.7 (Tm-3)	0.21	0.28
	Sr^{89}				50.5		50.4			0.99	0.7 (Tm-3)	0.21	0.28
	Sr^{90}				10^4		6.4×10^3			0.99	0.3 (Dur-3)	0.09	0.12
	Sr^{91}				0.4		0.4			0.76	0.7 (Tm-3)	0.21	0.28
	Sr^{92}				0.11		0.11			0.72	0.7 (Tm-3)	0.21	0.28
39	Y		Total body 7×10^4 g 30 cm			1.4×10^4		$<10^{-4}$ (Ha-50 Su-3)	1.0 (D)		1.0 (D)	10^{-4}	0.25
	Y^{90}				2.68		2.68			1.0 (D)			
	Y^{91m}				0.035		0.035			1.0 (D)			
	Y^{91}				58		58			1.0 (D)			
	Y^{92}				0.15		0.15			1.0 (D)			
	Y^{93}				0.42		0.42			1.0 (D)			

	Y		Bone 7×10^3 g 5 cm			1.8×10^4 Compared to Sr (Tm-1 Jy-2)			0.97 (Tm-1)		0.75 (Tm-1)	7.5×10^{-5}	0.19
	Y^{90}				2.68		2.68			0.75			
	Y^{91m}				0.035		0.035			0.75			
	Y^{91}				58		58			0.75			
	Y^{92}				0.15		0.15			0.75			
	Y^{93}				0.42		0.42			0.75			
40	Zr		Total body 7×10^4 g 30 cm	$<8.6 \times 10^{-8}$ (Ti-1 through Ti-7)		450		$<10^{-4}$ (Ha-51 Ha-62)	1.0 (D)		1.0 (D)	10^{-4}	0.25
	Zr^{93}				4×10^8		450			1.0 (D)			
	Zr^{95}				63.3		55.5			1.0 (D)			
	Zr^{97}				0.71		0.71			1.0 (D)			
	Zr		Bone 7×10^3 g 5 cm			1000 (compared to 4 f rare earths)			0.8 (Ha-16 Ha-21)		0.36 (Ha-21)	3.6×10^{-5}	0.09
	Z^{93}				4×10^8		1000			0.8			
	Zr^{95}				63.3		59.5			0.38			
	Zr^{97}				0.71		0.71			0.36			
	Zr		Kidneys 300 g 7 cm	$<10^{-6}$ (Ti-1 through Ti-7)		900			0.04 (Ha-16 Ha-21)		0.02 (Ha-21)	2×10^{-6}	5×10^{-3}
	Zr^{93}				4×10^8		900			0.04			
	Zr^{95}				63.3		59			0.02			
	Zr^{97}				0.71		0.71			0.02			

* Reference equations unless otherwise indicated.

Gen.* ref.	Element and radio-nuclides	Average daily ingestion I (g/day)	Organ of reference, mass (g) effective radius (cm)	Average concen-tration, C (g/g wet tissues)	Half-life (days) Physical T_r	Half-life (days) Bio-logical T_b	Half-life (days) Effective T	Fraction from GI tract to blood f_1	Fraction in organ of reference of that in total body f_2 Element	Fraction in organ of reference of that in total body f_2 Radio-nuclide	Fraction from blood to organ of reference f_2'	Fraction reaching organ of reference By ingestion f_w	Fraction reaching organ of reference By inhalation f_a
Z			Ch-1			eq. 44, 45	eq. 49			eq. 41, 42		eq. 47	eq. 46
	Zr		Spleen 150 g 7 cm	$<10^{-6}$ (Ti-1 through Ti-7)		900			0.01 (Ha-16 Ha-21)		6×10^{-3} (Ha-21)	6×10^{-7}	1.5×10^{-3}
	Zr^{93}				4×10^{8}		900			0.01			
	Zr^{95}				63.3		59			6.4×10^{-3}			
	Zr^{97}				0.71		0.71			6×10^{-3}			
	Zr		Liver 1.7×10^{3} g 10 cm	$<10^{-6}$ (Ti-1 through Ti-7)		320			0.05 (Ha-16 Ha-21)		0.07 (Ha-21)	7×10^{-6}	0.02
	Zr^{93}				4×10^{8}		320			0.05			
	Zr^{95}				63.3		53			0.07			
	Zr^{97}				0.71		0.71			0.07			
41	Nb		Total body 7×10^{4} g 30 cm	$<7\times10^{-7}$ (Ti-1 through Ti-7)		760		$<10^{-4}$ (Ha-62)	1.0 (D)		1.0 (D)	10^{-4}	0.25
	Nb^{93m}				3.7×10^{3}		630			1.0 (D)			
	Nb^{95}				35		33.5			1.0 (D)			
	Nb^{97}				0.051		0.051			1.0 (D)			
	Nb		Bone 7×10^{3} g 5 cm			1000 (Ha-55 Ha-62			0.5 (Ha-26)		0.38 (Ha-26)	3.8×10^{-5}	0.1

	Nb^{93m} Nb^{95} Nb^{97}				3.7×10^3 35 0.051	com-pared to 4 f rare earths)	787 33.8 0.051			0.47 0.39 0.38			
	Nb		Spleen 150 g 7 cm	$< 10^{-6}$ (Ti-1 through Ti-7)		950			0.01 (Ha-26)		8×10^{-3} (Ha-26)	8×10^{-7}	2×10^{-3}
	Nb^{93m} Nb^{95} Nb^{97}				3.7×10^3 35 0.051		756 33.8 0.051			9.6×10^{-3} 8.2×10^{-3} 8×10^{-3}			
	Nb		Kidneys 300 g 7 cm	$< 10^{-6}$ (Ti-1 through Ti-7)		760			0.02 (Ha-26)		0.02 (Ha-26)	2×10^{-6}	5×10^{-3}
	Nb^{93m} Nb^{95} Nb^{97}				3.7×10^3 35 0.051		640 33.5 0.051			0.02 0.02 0.02			
	Nb		Liver 1.7×10^3 g 10 cm	$< 10^{-6}$ (Ti-1 through Ti-7)		845			0.1 (Ha-26)		0.09 (Ha-26)	9×10^{-6}	0.02
	Nb^{93m} Nb^{95} Nb^{97}				3.7×10^3 35 0.051		688 33.6 0.051			0.1 0.09 0.09			
42	Mo	4.5×10^{-4} (Ti-3)	Total body 7×10^4 g 30 cm	$<7 \times 10^{-8}$ (Ti-1 through Ti-7)		5		0.8 (Co-3 Co-4)	1.0 (D)		1.0 (D)	0.8	0.65
	Mo^{99}				2.79		1.8			1.0 (D)			
	Mo		Liver 1.7×10^3 g 10 cm	1.1×10^{-6} (Ti-1 through Ti-7)		45			0.9 (Ti-1 through Ti-7)		0.1 (Bn-7 Bn-8)	0.08	0.065
	Mo^{99}				2.79		2.66			0.15			

* Reference equations unless otherwise indicated.

Gen.* ref.	Element and radio-nuclides	Average daily ingestion I (g/day)	Organ of reference, mass (g) effective radius (cm)	Average concentration, C (g/g wet tissues)	Half-life (days) Physical T_r	Half-life (days) Biological T_b	Half-life (days) Effective T	Fraction from GI tract to blood f_1	Fraction in organ of reference of that in total body f_2 Element	Fraction in organ of reference of that in total body f_2 Radionuclide	Fraction from blood to organ of reference f_2'	Fraction reaching organ of reference By ingestion f_w	Fraction reaching organ of reference By inhalation f_a
			Ch-1			eq. 44, 45	eq. 49			eq.41,42		eq. 47	eq. 46
	Mo		Kidneys 300 g 7 cm	4×10^{-7} (Ti-1 through Ti-7)		3			0.05 (Ti-1 through Ti-7)		0.08 (Bn-7 Bn-8)	0.06	0.05
	Mo^{99}				2.79		1.5			0.065			
43	Tc		Total body 7×10^4 g 30 cm			1 (Ha-21)		0.5 (Ha-21)	1.0 (D)		1.0 (D)	0.5	0.5
	Tc^{96m}				0.036		0.036			1.0 (D)			
	Tc^{96}				4.3		0.8			1.0 (D)			
	Tc^{97m}				92		0.99			1.0 (D)			
	Tc^{97}				3.7×10^6		1			1.0 (D)			
	Tc^{99m}				0.25		0.2			1.0 (D)			
	Tc^{99}				7.7×10^7		1			1.0 (D)			
	Tc		Kidneys 300 g 7 cm			20			0.2 (Ha-21)		0.01 (Ha-21)	5×10^{-3}	5×10^{-3}
	Tc^{96m}				0.036		0.036			0.01			
	Tc^{96}				4.3		3.5			0.04			
	Tc^{97m}				92		16			0.16			
	Tc^{97}				3.7×10^6		20			0.2			
	Tc^{99m}				0.25		0.25			0.01			
	Tc^{99}				7.7×10^7		20			0.2			
	Tc		Lungs 10^3 g 10 cm			5 (Ha-21)			4.5×10^{-3}		9×10^{-4} (Ha-21)	4.5×10^{-4}	4.5×10^{-4}

c^{96m}			0.036		36			9.2×10^{-4}			
Tc^{96}			4.3		2.3			2.6×10^{-3}			
Tc^{97m}			92		4.7			4.3×10^{-3}			
Tc^{97}			3.7×10^{6}		5			4.5×10^{-3}			
Tc^{99m}			0.25		0.24			1.1×10^{-3}			
Tc^{99}			7.7×10^{7}		5			4.5×10^{-3}			
Tc	Skin 2×10^{3} g 0.1 cm			10			0.1 (Ha-21)		0.01 (Ha-21)	5×10^{-3}	5×10^{-3}
Tc^{96m}			0.036		0.036			0.01			
Tc^{96}			4.3		3			0.04			
Tc^{97m}			92		9			0.09			
Tc^{97}			3.7×10^{6}		10			0.1			
Tc^{99m}			0.25		0.24			0.01			
Tc^{99}			7.7×10^{7}		10			0.1			
Tc	Liver 1.7×10^{3} g 10 cm			30			0.09 (Ha-21)		3×10^{-3} (Ha-21)	1.5×10^{-3}	1.5×10^{-3}
Tc^{96m}			0.036		0.036			3×10^{-3}			
Tc^{96}			4.3		3.8			0.01			
Tc^{97m}			92		23			0.07			
Tc^{97}			3.7×10^{6}		30			0.09			
Tc^{99m}			0.25		0.25			0.004			
Tc^{99}			7.7×10^{7}		30			0.09			
Tc	Bone 7×10^{3} g 5 cm			25			0.05 (Ha-21)		2×10^{-3} (Ha-21)	10^{-3}	10^{-3}
Tc^{96m}			0.036		0.036			2×10^{-3}			
Tc^{96}			4.3		3.7			9×10^{-3}			
Tc^{97m}			92		20			0.04			
Tc^{97}			3.7×10^{6}		25			0.05			
Tc^{99m}			0.25		0.25			2.5×10^{-3}			
Tc^{99}			7.7×10^{7}		25			0.05			

*Reference equations unless otherwise indicated.

Gen.* ref.	Element and radio-nuclides	Average daily ingestion I (g/day)	Organ of reference, mass (g) effective radius (cm)	Average concentration, C (g/g wet tissues)	Half-life (days) Physical T_r	Half-life (days) Biological T_b	Half-life (days) Effective T	Fraction from GI tract to blood f_1	Fraction in organ of reference of that in total body f_2 Element	Fraction in organ of reference of that in total body f_2 Radio-nuclide	Fraction from blood to organ of reference f_2'	Fraction reaching organ of reference By ingestion f_w	Fraction reaching organ of reference By inhalation f_a
Z			Ch-1			eq. 44, 45	eq. 49			eq. 41, 42		eq. 47	eq. 46
44	Ru		Total body 7×10^4 g 30 cm	$<8.6 \times 10^{-8}$ (Ti-1 through Ti-7)		7.3		0.03 (Kt-2 Th-20 Hy-3)	1.0 (D)		1.0 (D)	0.03	0.27
	Ru^{97}				2.8		2.0			1.0 (D)			
	Ru^{103}				41		6.2			1.0 (D)			
	Ru^{105}				0.19		0.19			1.0 (D)			
	Ru^{106}				365		7.2			1.0 (D)			
	Ru		Kidneys 300 g 7 cm	$<10^{-7}$ (Ti-1 through Ti-7)		2.5 (Hy-3)			0.07 (Hy-3 Ha-89)		0.2 (Hy-3)	6×10^{-3} (Hy-3)	0.05 (Hy-3)
	Ru^{97}				2.8		1.3			0.13			
	Ru^{103}				41		2.4			0.08			
	Ru^{105}				0.19		0.18			0.19			
	Ru^{106}				365		2.48			0.07			
	Ru		Bone 7×10^3 g 5 cm			16			0.17 (Bn-11)		0.08 (Bn-11)	2.4×10^{-3}	0.02
	Ru^{97}				2.8		2.4			0.095			
	Ru^{103}				41		12			0.15			
	Ru^{105}				0.19		0.19			0.08			
	Ru^{106}				365		15			0.17			
45	Rh		Total body			10.4		0.2	1.0		1.0	0.2	0.35

		7×10^4 g 30 cm					(compared to Co and Ir)	(D)		(D)		
	Rh^{103m}			0.038		0.038			1.0 (D)			
	Rh^{105}			1.52		1.33			1.0 (D)			
	Rh	Kidneys 300 g 7 cm			28 (Ha-89)			0.08 (Ha-85 Ha-89)		0.03 (Ha-89)	6×10^{-3}	0.01
	Rh^{103m}			0.038		0.038			0.03			
	Rh^{105}			1.52		1.44			0.03			
	Rh	Spleen 150 g 7 cm			20.8			0.02 (Ha-85 Ha-89)		0.01 (Ha-89)	2×10^{-3}	3.5×10^{-3}
	Rh^{103m}			0.038		0.038			0.01			
	Rh^{105}			1.52		1.42			0.01			
	Rh	Bone 7×10^3 g 5 cm			16.6			0.08 (Ha-85 Ha-89)		0.05 (Ha-89)	0.01	0.02
	Rh^{103m}			0.038		0.038			0.05			
	Rh^{105}			1.52		1.39			0.05			
	Rh	Liver 1.7×10^3 g 10 cm			18.2			0.07 (Ha-85 Ha-89)		0.04 (Ha-89)	8×10^{-3}	0.014
	Rh^{103m}			0.038		0.038			0.04			
	Rh^{105}			1.52		1.4			0.04			
46	Pd	Total body 7×10^4 g 30 cm			5 (Ha-89)		0.2 (compared to Ni and Pt)	1.0 (D)		1.0 (D)	0.2	0.35
	Pd^{103}			17		3.9			1.0 (D)			
	Pd^{109}			0.57		0.51			1.0 (D)			
	Pd	Kidneys 300 g 7 cm			30			0.48 (Ha-89)		0.08 (Ha-89)	0.02	0.03
	Pd^{103}			17		11			0.23			
	Pd^{109}			0.57		0.56			0.09			

* Reference equations unless otherwise indicated.

Gen.* ref.	Element and radio-nuclides	Average daily ingestion I (g/day)	Organ of reference, mass (g) effective radius (cm)	Average concen-tration, C (g/g wet tissues)	Half-life (days) Physical T_r	Half-life (days) Bio-logical T_b	Half-life (days) Effective T	Fraction from GI tract to blood f_1	Fraction in organ of reference of that in total body f_2 Element	Fraction in organ of reference of that in total body f_2 Radio-nuclide	Fraction from blood to organ of reference f'_2	Fraction reaching organ of reference By ingestion f_w	Fraction reaching organ of reference By inhalation f_a
Z			Ch-1			eq. 44, 45	eq. 49			eq.41,42		eq. 47	eq. 46
	Pd		Liver 1.7×10^3 g 10 cm			19			0.34 (Ha-89)		0.09 (Ha-89)	0.02	0.03
	Pd^{103}				17		9			0.21			
	Pd^{109}				0.57		0.55			0.1			
	Pd		Spleen 150 g 7 cm			15			0.03 (Ha-89)		0.01 (Ha-89)	2×10^{-3}	3.5×10^{-3}
	Pd^{103}				17		8			0.02			
	Pd^{109}				0.57		0.55			0.01			
47	Ag	8.8×10^{-5} (SUN-1)	Total body 7×10^4g 30 cm	$<1.4\times10^{-8}$ (Ti-1 through Ti-7)		5		0.01 (Ha-96)	1.0 (D)		1.0 (D)	0.01	0.26
	Ag^{105}				40		4.4			1.0 (D)			
	Ag^{110m}				270		4.9			1.0 (D)			
	Ag^{111}				7.5		3			1.0 (D)			
	Ag		Bone 7×10^3 g 5 cm	$<10^{-7}$ (Ti-1 through Ti-7)		30			0.3 (Ha-96)		0.05 (Ha-96)	5×10^{-4}	0.013
	Ag^{105}				40		17			0.19			
	Ag^{110m}				270		27			0.28			
	Ag^{111}				7.5		6			0.1			

	Ag^{105} Ag^{110m} Ag^{111}		Liver 1.7×10^3 g 10 cm	1.8×10^{-8} (Ti-1 through Ti-7)	40 270 7.5	15	11 14.2 5		0.09 (Ha-96)	0.075 0.09 0.05	0.03 (Ha-96)	3×10^{-4}	7.7×10^{-3}
	Ag Ag^{105} Ag^{110m} Ag^{111}		Kidneys 300 g 7 cm	$< 10^{-8}$ (Ti-1 through Ti-7)	40 270 7.5	10	8 10 4		0.04 (Ha-96)	0.04 0.04 0.03	0.02 (Ha-96)	2×10^{-4}	5×10^{-3}
48	Cd Cd^{109} Cd^{115m} Cd^{115}		Total body 7×10^4 g 30 cm	4.3×10^{-7} (Ti-1 through Ti-7)	475 43 2.2	200	140 35 2.2	$<2.5 \times 10^{-3}$ (Ha-101)	1.0 (D)	1.0 (D) 1.0 (D) 1.0 (D)	1.0 (D)	2.5×10^{-3}	0.25
	Cd Cd^{109} Cd^{115m} Cd^{115}		Kidneys 300 g 7 cm	3.2×10^{-5} (Ti-1 through Ti-7)	475 43 2.2	300	184 38 2.2		0.15 (Ha-101)	0.13 0.11 0.1	0.1 (Ha-21 Ha-101)	2.5×10^{-4}	0.025
	Cd Cd^{109} Cd^{115m} Cd^{115}		Liver 1.7×10^3 g 10 cm	2.4×10^{-6} (Ti-1 through Ti-7)	475 43 2.2	200 (Ha-21)	140 35 2.2		0.76 (Ha-101)	0.76 0.75 0.76	0.75 (Ha-21 Ha-101)	1.9×10^{-3}	0.19

* Reference equations unless otherwise indicated.

Gen.* ref.	Element and radio-nuclides	Average daily ingestion I (g/day)	Organ of reference, mass (g) effective radius (cm)	Average concen-tration, C (g/g wet tissues)	Half-life (days) Physical T_r	Half-life (days) Bio-logical T_b	Half-life (days) Effective T	Fraction from GI tract to blood f_1	Fraction in organ of reference of that in total body f_2: Element	Fraction in organ of reference of that in total body f_2: Radio-nuclide	Fraction from blood to organ of reference f_2'	Fraction reaching organ of reference: By ingestion f_w	Fraction reaching organ of reference: By inhalation f_a
Z			Ch-1			eq. 44, 45	eq. 49			eq. 41, 42		eq. 47	eq. 46
49	In		Total body 7×10^4 g 30 cm			48		$<2\times10^{-3}$ (Ha-19 Ha-101)	1.0 (D)		1.0 (D)	2×10^{-3}	0.25
	In^{113m}				0.073		0.073			1.0 (D)			
	In^{114m}				49		24			1.0 (D)			
	In^{115m}				0.19		0.19			1.0 (D)			
	In^{115}				2.2×10^{17}		48			1.0 (D)			
	In		Kidneys 300 g 7 cm			60			0.05 (Ha-19)		0.04 (Ha-19 Ha-101)	8×10^{-5}	0.01
	In^{113m}				0.073		0.073			0.04			
	In^{114m}				49		27			0.045			
	In^{115m}				0.19		0.19			0.04			
	In^{115}				2.2×10^{17}		60			0.05			
	In		Spleen 150 g 7 cm			48 (Ha-19)			0.02 (Ha-19)		0.02 (Ha-19 Ha-101)	4×10^{-5}	5×10^{-3}
	In^{113m}				0.073		0.073			0.02			
	In^{114m}				49		24			0.02			
	In^{115m}				0.19		0.19			0.02			
	In^{115}				2.2×10^{17}		48			0.02			

	In^{113m}		Liver 1.7×10^3 g 10 cm		0.073	58	0.073		0.17 (Ha-19)	0.14	0.14 (Ha-19 Ha-101)	2.8×10^{-4}	0.04
	In^{114m}				49		26			0.15			
	In^{115m}				0.19		0.19			0.14			
	In^{115}				2.2×10^{17}		58			0.17			
	In		Skin 2×10^3 g 0.1 cm			67			0.25 (Ha-19)		0.18 (Ha-19)	3.6×10^{-4}	0.05
	In^{113m}				0.073		0.073			0.18			
	In^{114m}				49		26			0.21			
	In^{115m}				0.19		0.19			0.18			
	In^{115}				2.2×10^{17}		67			0.25			
	In		Bone 7×10^3 g 5 cm			57			0.2 (Ha-19)		0.17 (Ha-19 Ha-101)	3.4×10^{-4}	0.04
	In^{113m}				0.073		0.073			0.17			
	In^{114m}				49		26			0.18			
	In^{115m}				0.19		0.19			0.17			
	In^{115}				2.2×10^{17}		57			0.2			
	In		Thyroid 20 g 3 cm			8.4			7×10^{-5} (Ha-19)		4×10^{-4} (Ha-19)	8×10^{-7}	10^{-4}
	In^{113m}				0.073		0.073			4×10^{-4}			
	In^{114m}				49		7.2			1.2×10^{-4}			
	In^{115m}				0.19		0.19			4×10^{-4}			
	In^{115}				2.2×10^{17}		8.4			7×10^{-5}			
50	Sn	0.017 (Sun-3)	Total body 7×10^4 g 30 cm	$4,3\times10^{-7}$ (Ti-1 through Ti-7)		35		0.05 (Sun-3 Kn-2 G)	1.0 (D)		1.0 (D)	0.05	0.28
	Sn^{113}				112		27			1.0 (D)			

* Reference equations unless otherwise indicated.

Gen.* ref.	Element and radio-nuclides	Average daily ingestion I (g/day)	Organ of reference, mass (g) effective radius (cm)	Average concentration, C (g/g wet tissues)	Half-life (days)			Fraction from GI tract to blood f_1	Fraction in organ of reference of that in total body f_2		Fraction from blood to organ of reference f_2'	Fraction reaching organ of reference	
					Physical T_r	Biological T_b	Effective T		Element	Radionuclide		By ingestion f_w	By inhalation f_a
Z			Ch-1			eq. 44, 45	eq. 49			eq. 41, 42		eq. 47	eq. 46
	Sn^{125}				9.5		7.5			1.0 (D)			
	Sn		Bone 7×10^3 g 5 cm	$< 1.3 \times 10^{-6}$ (Ti-1 through Ti-7)		100 (Ha-18)			0.86 (Ha-18 Ha-20)		0.3 (Ha-18)	0.02	0.08
	Sn^{113}				112		53			0.59			
	Sn^{125}				9.5		8.7			0.35			
	Sn		Thyroid 20 g 3 cm	2.8×10^{-7} (Ti-1 through Ti-7)		70			2×10^{-4} (Ha-18 Ha-20)		10^{-4}	5×10^{-6}	2.8×10^{-5}
	Sn^{113}				112		43			1.6×10^{-4}			
	Sn^{125}				9.5		8.4			10^{-4}			
	Sn		Liver 1.7×10^3 g 10 cm	4×10^{-7} (Ti-1 through Ti-7)		70			0.02 (Ha-18 Ha-20)		0.01 (Ha-18)	5×10^{-4}	2.8×10^{-3}
	Sn^{113}				112		43			0.02			
	Sn^{125}				9.5		8.4			0.01			
	Sn		Prostate 40 g 3 cm	3×10^{-7} (Ti-1 through Ti-7)		35			1.6×10^{-3} (Ha-18 Ha-20)		1.6×10^{-3} (Ha-18)	8×10^{-5}	4.4×10^{-4}
	Sn^{113}				112		27			1.6×10^{-3}			
	Sn^{125}				9.5		7.5			1.6×10^{-3}			

51			Total body 7×10^4 g 30 cm	$< 1.3 \times 10^{-6}$ (Ti-1 through Ti-7)		38 (Ha-19)		0.03 (Ha-19)	1.0 (D)		1.0 (D)	0.03	0.27
	Sb^{122}				2.8		2.6			1.0 (D)			
	Sb^{124}				60		23			1.0 (D)			
	Sb^{125}				876		36			1.0 (D)			
	Sb		Bone 7×10^3 g 5 cm	2×10^{-7} (Led-1)		100			0.26 (Ha-19)		0.1 (Ha-19)	3×10^{-3}	0.03
	Sb^{122}				2.8		2.7			0.1			
	Sb^{124}				60		38			0.16			
	Sb^{125}				876		90			0.25			
	Sb		Lungs 10^3 g 10 cm	10^{-7} (Led-1)		100			0.08 (Ha-19)		0.03 (Ha-19)	9×10^{-4}	8×10^{-3}
	Sb^{122}				2.8		2.7			0.03			
	Sb^{124}				60		38			0.05			
	Sb^{125}				876		90			0.07			
	Sb		Thyroid 20 g 3 cm	$< 3 \times 10^{-6}$ (Ti-1 through Ti-7)		4			3×10^{-6} (Ha-19)		3×10^{-5} (Ha-19)	9×10^{-7}	8×10^{-6}
	Sb^{122}				2.8		1.6			2×10^{-5}			
	Sb^{124}				60		3.8			5×10^{-6}			
	Sb^{125}				876		4			3×10^{-6}			
	Sb		Liver 1.7×10^3 g 10 cm	2×10^{-7} (Led-1)		38			2×10^{-3} (Ha-19)		2×10^{-3} (Ha-19)	6×10^{-5}	5×10^{-4}

* Reference equations unless otherwise indicated.

Gen.* ref.	Element and radio-nuclides	Average daily ingestion I (g/day)	Organ of reference, mass (g) effective radius (cm)	Average concentration, C (g/g wet tissues)	Half-life (days) Physical T_r	Half-life (days) Biological T_b	Half-life (days) Effective T	Fraction from GI tract to blood f_1	Fraction in organ of reference of that in total body f_2 Element	Fraction in organ of reference of that in total body f_2 Radio-nuclide	Fraction from blood to organ of Reference f_2'	Fraction reaching organ of reference By ingestion f_w	Fraction reaching organ of reference By inhalation f_a
Z			Ch-1			eq. 44, 45	eq. 49			eq. 41, 42		eq. 47	eq. 46
	Sb^{122}				2.8		2.6			2×10^{-3}			
	Sb^{124}				60		23			2×10^{-3}			
	Sb^{125}				876		36			2×10^{-3}			
52	Te		Total body 7×10^4 g 30 cm			15		0.25 (Ha-9)	1.0 (D)		1.0 (D)	0.25	0.38
	Te^{125m}				58		12			1.0 (D)			
	Te^{127m}				105		13			1.0 (D)			
	Te^{127}				0.39		0.38			1.0 (D)			
	Te^{129m}				33		10			1.0 (D)			
	Te^{129}				0.051		0.051			1.0 (D)			
	Te^{131m}				1.25		1.15			1.0 (D)			
	Te^{132}				3.2		2.6			1.0 (D)			
	Te		Kidneys 300 g 7 cm			30			0.14 (Ha-26)		0.07 (Ha-26)	0.02	0.03
	Te^{125m}				58		20			0.12			
	Te^{127m}				105		23			0.12			

			0.39		[illegible]		0.07			
Te^{129m}			33		16		0.11			
Te^{129}			0.051		0.051		0.07			
Te^{131m}			1.25		1.2		0.07			
Te^{132}			3.2		2.9		0.07			
Te	Spleen 150 g 7 cm			30 (Ha-26)		0.02 (Ha-26)		0.01 (Ha-26)	2.5×10^{-3}	3.8×10^{-3}
Te^{125m}			58		20		0.02			
Te^{127m}			105		23		0.02			
Te^{127}			0.39		0.39		0.01			
Te^{129m}			33		16		0.02			
Te^{129}			0.051		0.051		0.01			
Te^{131m}			1.25		1.2		0.01			
Te^{132}			3.2		2.9		0.01			
Te	Bone 7×10^3 g 5 cm	3×10^{-4} (Led-1)		30 (Ha-26)		0.18 (Ha-9 Ha-26)		0.09 (Ha-9 Ha-26)	0.023	0.034
Te^{125m}			58		20		0.15			
Te^{127m}			105		23		0.16			
Te^{127}			0.39		0.39		0.09			
Te^{129m}			33		16		0.14			
Te^{129}			0.051		0.051		0.09			
Te^{131m}			1.25		1.2		0.09			
Te^{132}			3.2		2.9		0.1			
Te	Liver 1.7×10^3 g 10 cm	10^{-3} (Led-1)		30		0.1 (Ha-9 Ha-26)		0.05 (Ha-9 Ha-26)	0.01	0.02
Te^{125m}			58		20		0.08			
Te^{127m}			105		23		0.09			
Te^{127}			0.39		0.39		0.05			
Te^{129m}			33		16		0.08			
Te^{129}			0.051		0.051		0.05			
Te^{131m}			1.25		1.2		0.05			
Te^{132}			3.2		2.9		0.06			
Te	Thyroid			9		6×10^{-4}		10^{-3}	2.5×10^{-4}	3.8×10^{-4}

* Reference equations unless otherwise indicated.

Gen.* ref.	Element and radio-nuclides	Average daily ingestion I (g/day)	Organ of reference, mass (g) effective radius (cm)	Average concentration, C (g/g wet tissues)	Half-life (days) Physical T_r	Half-life (days) Biological T_b	Half-life (days) Effective T	Fraction from GI tract to blood f_1	Fraction in organ of reference of that in total body f_2 Element	Fraction in organ of reference of that in total body f_2 Radio-nuclide	Fraction from blood to organ of reference f_2'	Fraction reaching organ of reference By ingestion f_w	Fraction reaching organ of reference By inhalation f_a
Z			Ch-1			eq. 44, 45	eq. 49			eq. 41, 42		eq. 47	eq. 46
			20 g 3 cm						(Ha-9 Ha-26)		(Ha-9 Ha-26)		
	Te^{125m}				58		7.8			6.5×10^{-4}			
	Te^{127m}				105		8.3			6×10^{-4}			
	Te^{127}				0.39		0.37			9.7×10^{-4}			
	Te^{129m}				33		7.1			7×10^{-4}			
	Te^{129}				0.051		0.051			10^{-3}			
	Te^{131m}				1.25		1.1			9.6×10^{-4}			
	Te^{132}				3.2		2.4			10^{-3}			
	Te		Testes 40 g 3 cm	4.2×10^{-5} (Lcd-1)		30			6×10^{-3} (Ja-2)		3×10^{-3} (Ja-2)	7.5×10^{-4}	1.1×10^{-3}
	Te^{125m}				58		20			5×10^{-3}			
	Te^{127m}				105		23			5×10^{-3}			
	Te^{127}				0.39		0.39			3×10^{-3}			
	Te^{129m}				33		16			5×10^{-3}			
	Te^{129}				0.051		0.051			3×10^{-3}			
	Te^{131m}				1.25		1.2			3×10^{-3}			
	Te^{132}				3.2		2.9			3×10^{-3}			

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		mass / radius		T_r	T_b	T_e	f_1		f_2	f_2'	f_w	f_a
	2×10^{-4} (Un-1)	Total body 7×10^4 g 30 cm	5.7×10^{-7} (Ch-1)		138		1.0 (Un-1)	1.0 (D)		1.0 (D)	1.0	0.75
I^{126}				13.3		12.1			1.0 (D)			
I^{129}				6.3×10^9		138			1.0 (D)			
I^{131}				8		7.6			1.0 (D)			
I^{132}				0.097		0.097			1.0 (D)			
I^{133}				0.87		0.87			1.0 (D)			
I^{134}				0.036		0.036			1.0 (D)			
I^{135}				0.28		0.28			1.0 (D)			
I		Thyroid 20 g 3 cm	4×10^{-4} (Ev-1)		138 (eq. 48)			0.2 (Ev-1)		0.3 (Goo-1 Lar-1 Ke-2)	0.3	0.23
I^{126}				13.3		12.1			0.2			
I^{129}				6.3×10^9		138			0.2			
I^{131}				8		7.6			0.2			
I^{132}				0.097		0.097			0.2			
I^{133}				0.87		0.87			0.2			
I^{134}				0.036		0.036			0.2			
I^{135}				0.28		0.28			0.2			
I		Kidneys 300 g 7 cm			7			0.002 (Ho-5 Ho-10)		0.04 (Ho-5 Ho-10)	0.04	0.03
I^{126}				13.3		4.58			0.015			
I^{129}				6.3×10^9		7			0.002			
I^{131}				8		3.73			0.02			
I^{132}				0.097		0.096			0.04			
I^{133}				0.87		0.77			0.035			
I^{134}				0.036		0.035			0.04			
I^{135}				0.28		0.27			0.05			

* Reference equations unless otherwise indicated.

Gen.* ref.	Element and radio-nuclides	Average daily ingestion I (g/day)	Organ of reference, mass (g) effective radius (cm)	Average concen-tration, C (g/g wet tissues)	Half-life (days) Physical T_r	Half-life (days) Bio-logical T_b	Half-life (days) Effective T	Fraction from GI tract to blood f_1	Fraction in organ of reference of that in total body f_2 Element	Fraction in organ of reference of that in total body f_2 Radio-nuclide	Fraction from blood to organ of reference f_2'	Fraction reaching organ of reference By ingestion f_w	Fraction reaching organ of reference By inhalation f_a
			Ch-1			eq. 44, 45	eq. 49			eq. 41, 42		eq. 47	eq. 46
	I		Liver 1.7×10^3 g 10 cm			7			0.006 (Ho-5 Ho-10)		0.12 (Ho-5 Ho-10)	0.12	0.09
	I^{126}				13.3		4.58			0.045			
	I^{129}				6.3×10^9		7			0.006			
	I^{131}				8		3.73			0.06			
	I^{132}				0.097		0.096			0.12			
	I^{133}				0.87		0.77			0.11			
	I^{134}				0.036		0.035			0.12			
	I^{135}				0.28		0.27			0.12			
	I		Spleen 150 g 7 cm			7			2.5×10^{-4} (Ho-5 Ho-10)		5×10^{-3} (Ho-5 Ho-10)	5×10^{-3}	3.8×10^{-3}
	I^{126}				13.3		4.58			0.002			
	I^{129}				6.3×10^9		7			2.5×10^{-4}			
	I^{131}				8		3.73			0.0025			
	I^{132}				0.097		0.096			0.005			
	I^{133}				0.87		0.77			0.004			
	I^{134}				0.036		0.035			0.005			
	I^{135}				0.28		0.27			0.005			
	I		Testes 40 g 3 cm			7			2.5×10^{-4} (Ho-5 Ho-10)		5×10^{-3} (Ho-5 Ho-10)	5×10^{-3}	0.0038
	I^{126}				13.3		4.58			0.002			

	20				6.3×10^{9}		,			2.5×10^{-4}			
	I^{131}				8		3.73			2.5×10^{-3}			
	I^{132}				0.097		0.096			0.005			
	I^{133}				0.87		0.77			0.004			
	I^{134}				0.036		0.035			0.005			
	I^{135}				0.28		0.27			0.005			
	I		Bone 7×10^{3} g 5 cm			14			0.007 (Ho-5 Ho-10)		0.07 (Ho-5 Ho-10)	0.07	0.053
	I^{126}				13.3		6.8			0.04			
	I^{129}				6.3×10^{9}		14			0.007			
	I^{131}				8		5.1			0.13			
	I^{132}				0.097		0.096			0.07			
	I^{133}				0.87		0.82			0.067			
	I^{134}				0.036		0.036			0.07			
	I^{135}				0.28		0.27			0.068			
54	Xe		Total body 7×10^{4} g 30 cm					1.0 (G) ↑ guesstimate	1.0 (D)		1.0 (D)	1.0	0.75
	Xe^{131m}				12					1.0 (D)			
	Xe^{133}				5.27					1.0 (D)			
	Xe^{135}				0.38					1.0 (D) = definition			
55	Cs		Total body 7×10^{4} g 30 cm	$<1.4\times10^{-10}$ (Ti-1 through Ti-7)		70		1.0 (Ha-1 Kt-2)	1.0 (D)		1.0 (D)	1.0	0.75
	Cs^{131}				10		8.75			1.0 (D)			
	Cs^{134m}				0.13		0.13			1.0 (D)			
	Cs^{134}				840		65			1.0 (D)			
	Cs^{135}				1.1×10^{9}		70			1.0 (D)			

* Reference equations unless otherwise indicated.

Gen.* ref.	Element and radio-nuclides	Average daily ingestion I (g/day)	Organ of reference, mass (g) effective radius (cm)	Average concentration, C (g/g wet tissues)	Half-life (days) Physical T_r	Half-life (days) Biological T_b	Half-life (days) Effective T	Fraction from GI tract to blood f_1	Fraction of organ of reference of that in total body f_2 Element	Fraction of organ of reference of that in total body f_2 Radio-nuclide	Fraction from blood to organ of reference f'_2	Fraction reaching organ of reference By ingestion f_w	Fraction reaching organ of reference By inhalation f_a
			Ch-1			eq. 44, 45	eq. 49			eq.41,42		eq. 47	eq. 46
	Cs^{136}				13		11			1.0 (D)			
	Cs^{137}				1.1×10^4		70			1.0 (D)			
	Cs		Muscle 3×10^4 g 30 cm	$<3\times10^{-7}$ (Ti-1 through Ti-7)		140 (Ln-18 Rh-1)			0.8 (Ha-26 Rh-1)		0.4 (Ha-26)	0.4	0.3
	Cs^{131}				10		9.3			0.43			
	Cs^{134m}				0.13		0.13			0.40			
	Cs^{134}				840		120			0.74			
	Cs^{135}				1.1×10^9		140			0.80			
	Cs^{136}				13		11.9			0.43			
	Cs^{137}				1.1×10^4		138			0.79			
	Cs		Lungs 10^3 g 10 cm	4×10^{-7} (Led-1)		140			6×10^{-3} (Ha-26)		3×10^{-3} (Ha-26)	3×10^{-3}	2.3×10^{-3}
	Cs^{131}				10		9.3			3×10^{-3}			
	Cs^{134m}				0.13		0.13			3×10^{-3}			
	Cs^{134}				840		120			6×10^{-3}			
	Cs^{135}				1.1×10^9		140			6×10^{-3}			
	Cs^{136}				13		11.9			3×10^{-3}			
	Cs^{137}				1.1×10^4		138			6×10^{-3}			
	Cs		Kidneys 300 g 7 cm	3×10^{-7} (Led-1)		42			6×10^{-3} (Ha-26)		0.01 (Ha-26)	0.01	7.5×10^{-3}

	Cs^{131}				10		8			9×10^{-3}			
	Cs^{134m}				0.13		0.13			0.01			
	Cs^{134}				840		40			6×10^{-3}			
	Cs^{135}				1.1×10^{9}		42			6×10^{-3}			
	Cs^{136}				13		10			9×10^{-3}			
	Cs^{137}				1.1×10^{4}		42			6×10^{-3}			
	Cs		Spleen 150 g 7 cm	6×10^{-7} (Led-1)		98			7×10^{-3} (Ha-26)		5×10^{-3} (Ha-26)	5×10^{-3}	3.8×10^{-3}
	Cs^{131}				10		9.1			5×10^{-3}			
	Cs^{134m}				0.13		0.13			5×10^{-3}			
	Cs^{134}				840		88			7×10^{-3}			
	Cs^{135}				1.1×10^{9}		98			7×10^{-3}			
	Cs^{136}				13		11.5			5×10^{-3}			
	Cs^{137}				1.1×10^{4}		97			7×10^{-3}			
	Cs		Liver 1.7×10^{3} g 10 cm	6×10^{-7} (Led-1)		90			0.09 (Ha-26)		0.07 (Ha-26)	0.07	0.05
	Cs^{131}				10		9			0.07			
	Cs^{134m}				0.13		0.13			0.07			
	Cs^{134}				840		81			0.09			
	Cs^{135}				1.1×10^{9}		90			0.09			
	Cs^{136}				13		11.4			0.07			
	Cs^{137}				1.1×10^{4}		89			0.09			
	Cs		Bone 7×10^{3} g 5 cm	6×10^{-6} (Led-1)		140			0.08 (Ha-26)		0.04 (Ha-26)	0.04	0.03
	Cs^{131}				10		9.3			0.04			
	Cs^{134m}				0.13		0.13			0.04			
	Cs^{134}				840		120			0.07			
	Cs^{135}				1.1×10^{9}		140			0.08			
	Cs^{136}				13		11.9			0.04			
	Cs^{137}				1.1×10^{4}		138			0.08			
56	Ba	9×10^{-4} (Ti-3)	Total body 7×10^{4} g 30 cm	2.3×10^{-7} (Ti-1 through		65		0.05 (Pit-1 Har-4)	1.0 (D)		1.0 (D)	0.05	0.28

* Reference equations unless otherwise indicated.

Gen.* ref.	Element and radio-nuclides	Average daily ingestion I (g/day)	Organ of reference, mass (g) effective radius (cm)	Average concen-tration, C (g/g wet tissues)	Half-life (days) Physical T_r	Half-life (days) Biological T_b	Half-life (days) Effective T	Fraction from GI tract to blood f_1	Fraction in organ of reference of that in total body f_2 Element	Fraction in organ of reference of that in total body f_2 Radio-nuclide	Fraction from blood to organ of reference f'_2	Fraction reaching organ of reference By ingestion f_w	Fraction reaching organ of reference By inhalation f_a
			Ch-1			eq. 44, 45	eq. 49			eq. 41, 42		eq. 47	eq. 46
	Ba^{131}			Ti-7)	11.6		9.8			1.0 (D)			
	Ba^{140}				12.8		10.7			1.0 (D)			
	Ba		Bone 7×10^3 g 5 cm	1.6×10^{-6} (Ti-1 through Ti-7)		65 (Ha-51 eq. 48)			0.7 (Ha-51 Ti-1 through Ti-7)		0.7 (Do-1)	0.035	0.19
	Ba^{131}				11.6		9.8			0.7			
	Ba^{140}				12.8		10.7			0.7			
	Ba		Lungs 10^3 g 10 cm	1.8×10^{-7} (Ti-1 through Ti-7)		6500			0.02 (Ti-1 through Ti-7)		2×10^{-4} (Ha-51)	10^{-5}	5.5×10^{-5}
	Ba^{131}				11.6		11.6			2.4×10^{-4}			
	Ba^{140}				12.8		12.8			2.4×10^{-4}			
	Ba		Muscle 3×10^4 g 30 cm	1.8×10^{-8} (Ti-1 through Ti-7)		2000			0.09 (Ti-1 through Ti-7)		3×10^{-3} (Ha-51)	1.5×10^{-4}	8.3×10^{-4}
	Ba^{131}				11.6		11.5			3.5×10^{-3}			
	Ba^{140}				12.8		12.7			3.6×10^{-3}			
	Ba		Kidneys 300 g 7 cm	2.7×10^{-8} (Ti-1 through		8.5			1.3×10^{-5}		10^{-4} (Ha-51)	5×10^{-6}	2.8×10^{-5}

	Ba^{131} Ba^{140}			Ti-7)	11.6 12.8		4.9 5.1		(Ti-1 through Ti-7)	5×10^{-5} 5×10^{-5}			
	Ba Ba^{131} Ba^{140}		Spleen 150 g 7 cm	$<2.2 \times 10^{-8}$ (Ti-1 through Ti-7)	11.6 12.8	13	6.1 6.4		10^{-5} (Ti-1 through Ti-7)	3×10^{-5} 3×10^{-5}	5×10^{-5} (Ha-51)	2.5×10^{-6}	1.4×10^{-5}
	Ba Ba^{131} Ba^{140}		Liver 1.7×10^3 g 10 cm	$<1.3 \times 10^{-8}$ (Ti-1 through Ti-7)	11.6 12.8	975	11.5 12.6		9×10^{-3} (Ti-1 through Ti-7)	7×10^{-4} 7×10^{-4}	6×10^{-4} (Ha-51)	3×10^{-5}	1.7×10^{-4}
	Ba Ba^{131} Ba^{140}		Testes 40 g 3 cm	10^{-8} (Ti-1 through Ti-7)	11.6 12.8	6.2	4.1 4.2		9.6×10^{-5} (Ti-1 through Ti-7)	4×10^{-4} 4×10^{-4}	10^{-3} (Ha-51)	5×10^{-5}	2.8×10^{-4}
	Ba Ba^{131} Ba^{140}		Ovaries 8 g 3 cm	4×10^{-8} (Ti-1 through Ti-7)	11.6 12.8	4.9	3.4 3.5		3×10^{-5} (Ti-1 through Ti-7)	1.4×10^{-4} 1.3×10^{-4}	4×10^{-4} (Ha-51)	2×10^{-5}	10^{-4}
57	La La^{140}		Total body 7×10^4 g 30 cm	$<7 \times 10^{-7}$ (Ti-1 through Ti-7)	1.68	500	1.68	$<10^{-4}$ (Ha-55)	1.0 (D)	1.0 (D)	1.0 (D)	10^{-4}	0.25
	La La^{140}		Bone 7×10^3 g 5 cm		1.68	1000 (Ha-55)	1.68		0.8 (Ha-9 Ha-10)	0.4	0.4 (Ha-9)	4×10^{-5}	0.1
	La		Liver	$<10^{-6}$		400			0.12		0.15	1.5×10^{-5}	0.04

* Reference equations unless otherwise indicated.

Gen.* ref.	Element and radio-nuclides	Average daily ingestion I (g/day)	Organ of reference, mass (g) effective radius (cm)	Average concentration, C (g/g wet tissues)	Half-life (days) Physical T_r	Half-life (days) Biological T_b	Half-life (days) Effective T	Fraction from GI tract to blood f_1	Fraction in organ of reference of that in total body f_2 Element	f_2 Radio-nuclide	Fraction from blood to organ of reference f_2'	Fraction reaching organ of reference By ingestion f_w	By inhalation f_a
			Ch-1			eq. 44, 45	eq. 49			eq. 41, 42		eq. 47	eq. 46
	La^{140}		1.7×10^3 g 10 cm	(Ti-1 through Ti-7)	1.68		1.68		(Ha-9 Ha-10)	0.15	(Ha-9)		
58	Ce		Total body 7×10^4 g 30 cm			563		$<10^{-4}$ (Ha-36 Ha-55)	1.0 (D)		1.0 (D)	10^{-4}	0.25
	Ce^{141}				32		30			1.0 (D)			
	Ce^{143}				1.33		1.33			1.0 (D)			
	Ce^{144}				290		191			1.0 (D)			
	Ce		Bone 7×10^3 g 5 cm			1500 (Ha-55)			0.8 (Ha-33 Ha-36 Ha-86)		0.3 (At-2 Ha-33 Ha-36 Ha-86)	3×10^{-5}	0.075
	Ce^{141}				32		31			0.31			
	Ce^{143}				1.33		1.33			0.30			
	Ce^{144}				290		243			0.38			
	Ce		Liver 1.7×10^3 g 10 cm			293			0.13 (Ha-33 (Ha-36 Ha-86)		0.25 (At-2 Ha-33 Ha-36 Ha-86)	2.5×10^{-5}	0.06
	Ce^{141}				32		29			0.24			
	Ce^{143}				1.33		1.32			0.25			
	Ce^{144}				290		146			0.19			
	Ce		Kidneys 300 g 7 cm			563			0.02 (Ha-33 Ha-36 Ha-86)		0.02 (At-2 Ha-33 Ha-36 Ha-86)	2×10^{-6}	5×10^{-3}
	Ce^{141}				32		30			0.02			
	Ce^{143}				1.33		1.33			0.02			
	Ce^{144}				290		191			0.02			

59	Pr Pr^{142} Pr^{143}		Total body 7×10^4 g 30 cm		0.8 13.7	750	0.8 13.5	$<10^{-4}$ (Ha-36 Ha-55)	1.0 (D)	1.0 (D) 1.0 (D)	1.0 (D)	10^{-4}	0.25
	Pr Pr^{142} Pr^{143}		Bone 7×10^3 g 5 cm		0.8 13.7	1500 (Ha-55)	0.8 13.6		0.8 (Ha-33 Ha-36 Ha-86)	0.4 0.4	0.4 (Ha-33) Ha-36 Ha-86)	4×10^{-5}	0.1
	Pr Pr^{142} Pr^{143}		Liver 1.7×10^3 g 10 cm		0.8 13.7	375	0.8 13.2		0.1 (Ha-33 Ha-36 Ha-86)	0.2 0.2	0.2 (Ha-33) Ha-36 Ha-86)	2×10^{-5}	0.05
	Pr Pr^{142} Pr^{143}		Kidneys 300 g 7 cm		0.8 13.7	750	0.8 13.5		0.02 (Ha-33) Ha-36 Ha-86)	0.02 0.02	0.02 (Ha-33 Ha-36 Ha-86)	2×10^{-6}	5×10^{-3}
60	Nd Nd^{144} Nd^{147} Nd^{149}		Total body 7×10^4 g 30 cm		7.3×10^{17} 11.3 0.083	656	656 11.1 0.083	$<10^{-4}$ (Ha-36 Ha-55)	1.0 (D)	1.0 (D) 1.0 (D) 1.0 (D)	1.0 (D)	$<10^{-4}$	0.25
	Nd Nd^{144} Nd^{147} Nd^{149}		Bone 7×10^3 g 5 cm		7.3×10^{17} 11.3 0.083	1500 (Ha-55)	1500 11.2 0.083		0.8 (Ha-32 Ha-33 Ha-36 Ha-86)	0.8 0.35 0.35	0.35 (Ha-33 Ha-36 Ha-48 Ha-86)	3.5×10^{-5}	0.09
	Nd Nd^{144}		Liver 1.7×10^3 g 10 cm		7.3×10^{17}	131	131		0.1 (Ha-33 Ha-36	0.1	0.5 (Ha-33 Ha-36	5×10^{-5}	0.13

* Reference equations unless otherwise indicated.

Gen.* ref.	Element and radio-nuclides	Average daily ingestion I (g/day)	Organ of reference, mass (g) effective radius (cm)	Average concen-tration, C (g/g wet tissues)	Half-life (days)			Fraction from GI tract to blood f_1	Fraction in organ of reference of that in total body f_2		Fraction from blood to organ of reference f'_2	Fraction reaching organ of reference	
					Physical T_r	Bio-logical T_b	Effective T		Element	Radio-nuclide		By ingestion f_w	By inhalation f_a
			Ch-1			eq. 44, 45	eq. 49			eq. 41, 42		eq. 47	eq. 46
	Nd^{147} Nd^{149}				11.3 0.083		10 0.083		Ha-86)	0.45 0.5	Ha-48 Ha-86)		
	Nd Nd^{144} Nd^{147} Nd^{149}		Kidneys 300 g 7 cm		7.3×10^{17} 11.3 0.083	656	656 11.1 0.083		0.05 (Ha-33 Ha-36 Ha-86)	0.05 0.05 0.05	0.05 (Ha-33 Ha-36 Ha-48, Ha-86)	5×10^{-6}	0.01
61	Pm Pm^{147} Pm^{149}		Total body 7×10^4 g 30 cm		920 2.2	656	383 2.2	$<10^{-4}$ (Ha-36 Ha-55)	1.0 (D)	1.0 (D) 1.0 (D)	1.0 (D)	10^{-4}	0.25
	Pm Pm^{147} Pm^{149}		Bone 7×10^3 g 5 cm		920 2.2	1500 (Ha-55)	570 2.2		0.8 (Ha-36 Ha-55 Ha-62)	0.52 0.35	0.35 (Ha-33 Ha-36 Ha-86)	3.5×10^{-5}	0.09
	Pm Pm^{147} Pm^{149}		Liver 1.7×10^3 g 10 cm		920 2.2	656	383 2.2		0.06 (Ha-36 Ha-55 Ha-62)	0.06 0.06	0.06 (Ha-33 Ha-36 Ha-86)	6×10^{-6}	0.02
	Pm Pm^{147} Pm^{149}		Kidneys 300 g 7 cm		920 2.2	656	383 2.2		0.02 (Ha-36 Ha-55 Ha-62)	0.02 0.02	0.02 (Ha-33 Ha-36 Ha-86)	2×10^{-6}	5×10^{-3}

62	Sm		Total body 7×10^4 g 30 cm			656		$<10^{-4}$ (Ha-36 Ha-55)	1.0 (D)		1.0 (D)	10^{-4}	0.25
	Sm^{147}				4.8×10^{13}		656			1.0 (D)			
	Sm^{151}				3.7×10^4		645			1.0 (D)			
	Sm^{153}				1.96		1.95			1.0 (D)			
	Sm		Bone 7×10^3 g 5 cm			1500 (Ha-55)			0.8 (Ha-18 Ha-33)		0.35 (Ha-18 Ha-33)	3.5×10^{-5}	0.09
	Sm^{147}				4.8×10^{13}		1500			0.8			
	Sm^{151}				3.7×10^4		1442			0.78			
	Sm^{153}				1.96		1.96			0.35			
	Sm		Liver 1.7×10^3 g 10 cm			187			0.1 (Ha-18 Ha-33)		0.35 (Ha-18 Ha-33)	3.5×10^{-5}	0.09
	Sm^{147}				4.8×10^{13}		187			0.1			
	Sm^{151}				3.7×10^4		186			0.1			
	Sm^{153}				1.96		1.94			0.35			
	Sm		Kidneys 300 g 7 cm			656			0.02 (Ha-18 Ha-33)		0.02 (Ha-18 Ha-33)	2×10^{-6}	5×10^{-3}
	Sm^{147}				4.8×10^{13}		656			0.02			
	Sm^{151}				3.7×10^4		645			0.02			
	Sm^{153}				1.96		1.95			0.02			
63	Eu		Total body 7×10^4 g 30 cm			635		$<10^{-4}$ (Ha-36 Ha-55)	1.0 (D)		1.0 (D)	10^{-4}	0.25
	Eu^{152}				0.38		0.38						
	Eu^{152}				4.7×10^3		559			1.0 (D)			
	Eu^{154}				5.8×10^3		572			1.0 (D)			
	Eu^{155}				621		314			1.0 (D)			

* Reference equations unless otherwise indicated.

Gen.* ref.	Element and radio-nuclides	Average daily ingestion I (g/day)	Organ of reference, mass (g) effective radius (cm)	Average concentration, C (g/g wet tissues)	Half-life (days) Physical T_r	Half-life (days) Biological T_b	Half-life (days) Effective T	Fraction from GI tract to blood f_1	Fraction in organ of reference of that in total body f_2 Element	Fraction in organ of reference of that in total body f_2 Radio-nuclide	Fraction from blood to organ of reference f'_2	Fraction reaching organ of reference By ingestion f_w	Fraction reaching organ of reference By inhalation f_a
Z			Ch-1			eq. 44, 45	eq. 49			eq.41,42		eq. 47	eq. 46
	Eu		Bone 7×10^3 g 5 cm			1500 (Ha-55)			0.85 (Ha-33 Ha-36)		0.36 (Ha-33 Ha-36)	3.6×10^{-5}	0.09
	Eu^{152}				0.38		0.38			0.36			
	Eu^{152}				4.7×10^3		1137			0.73			
	Eu^{154}				5.8×10^3		1192			0.75			
	Eu^{155}				621		439			0.50			
	Eu		Kidneys 300 g 7 cm			1480			0.07 (Ha-33 Ha-36)		0.03 (Ha-33 Ha-36)	3×10^{-6}	7.5×10^{-3}
	Eu^{152}				0.38		0.38			0.03			
	Eu^{152}				4.7×10^3		1125			0.06			
	Eu^{154}				5.8×10^3		1180			0.06			
	Eu^{155}				621		438			0.04			
	Eu		Liver 1.7×10^3 g 10 cm			127			0.05 (Ha-33 Ha-36)		0.25 (Ha-33 Ha-36)	2.5×10^{-5}	0.06
	Eu^{152}				0.38		0.38			0.25			
	Eu^{152}				4.7×10^3		124			0.06			
	Eu^{154}				5.8×10^3		124			0.05			
	Eu^{155}				621		105			0.08			
64	Gd		Total body 7×10^4 g 30 cm			550		$< 10^{-4}$ (Ha-36 Ha-55)	1.0 (D)		1.0 (D)	10^{-4}	0.25
	Gd^{153}				236		165			1.0 (D)			
	Gd^{159}				0.75		0.75			1.0 (D)			
	Gd		Bone 7×10^3 g 5 cm			1000 (Ha-55)			0.8 (Ha-34 Ha-36)		0.45 (Ha-34 Ha-36)	4.5×10^{-5}	0.11

	^{153} 9			236 0.75		0.75			0.52 0.45			
	Gd Gd^{153} Gd^{159}	Liver 1.7×10^3 g 10 cm		236 0.75	460	156 0.75		0.1 (Ha-34 Ha-36)	0.11 0.12	0.12 (Ha-34 Ha-36)	1.2×10^{-5}	0.03
65	Tb Tb^{160}	Total body 7×10^4 g 30 cm		73	670	66	$<10^{-4}$ (Ha-36 Ha-55)	1.0 (D)	1.0 (D)	1.0 (D)	10^{-4}	0.25
	Tb Tb^{160}	Bone 7×10^3 g 5 cm		73	1000 (Ha-55)	68		0.9 (Ha-31 Ha-34 Ha-36)	0.62	0.6 (Ha-34 Ha-36)	6×10^{-5}	0.15
	Tb Tb^{160}	Kidneys 300 g 7 cm		73	700	66		0.03 (Ha-31 Ha-34 Ha-36)	0.03	0.03 (Ha-34 Ha-36)	3×10^{-6}	7.5×10^{-3}
66	Dy Dy^{165} Dy^{166}	Total body 7×10^4 g 30 cm		0.097 3.4	700	0.097 3.4	$<10^{-4}$ (Ha-36 Ha-55)	1.0 (D)	1.0 (D) 1.0 (D)	1.0 (D)	10^{-4}	0.25
	Dy Dy^{165} Dy^{166}	Bone 7×10^3 g 5 cm		0.097 3.4	1000 (Ha-55)	0.097 3.4		0.85 (Ha-33 Ha-36)	0.6 0.6	0.6 (Ha-33 Ha-36)	6×10^{-5}	0.15
	Dy Dy^{165} Dy^{166}	Liver 1.7×10^3 g 10 cm		0.097 3.4	500	0.097 3.4		0.04 (Ha-33 Ha-36)	0.06 0.06	0.06 (Ha-33 Ha-36)	6×10^{-6}	0.02

* Reference equations unless otherwise indicated.

Gen.* ref. Z	Element and radio-nuclides	Average daily ingestion I (g/day)	Organ of reference, mass (g) effective radius (cm)	Average concen-tration, C (g/g wet tissues)	Half-life (days) Physical T_r	Half-life (days) Bio-logical T_b	Half-life (days) Effective T	Fraction from GI tract to blood f_1	Fraction in organ of reference of that in total body f_2: Element	Fraction in organ of reference of that in total body f_2: Radio-nuclide	Fraction from blood to organ of reference f_2'	Fraction reaching organ of reference: By ingestion f_w	Fraction reaching organ of reference: By inhalation f_a
			Ch-1			eq. 44, 45	eq. 49			eq. 41, 42		eq. 47	eq. 46
67	Ho		Total body 7×10^4 g 30 cm			750		$<10^{-4}$ (Ha-36 Ha-55)	1.0 (D)		1.0 (D)	10^{-4}	0.25
	Ho^{166}				1.1		1.1			1.0 (D)			
	Ho		Bone 7×10^3 g 5 cm			1000 (Ha-55)			0.85 (Ha-33 Ha-36 Ha-86)		0.64 (Ha-33, Ha-36 Ha-48, Ha-86)	6.4×10^{-5}	0.16
	Ho^{166}				1.1		1.1			0.64			
	Ho		Kidneys 300 g 7 cm			800			0.02 (Ha-33 Ha-36 Ha-86)		0.02 (Ha-33, Ha-36 Ha-48, Ha-86)	2×10^{-6}	5×10^{-3}
	Ho^{166}				1.1		1.1			0.02			
	Ho		Liver 1.7×10^3 g 10 cm			875			0.07 (Ha-33 Ha-36 Ha-86)		0.06 (Ha-33, Ha-36 Ha-48, Ha-86)	6×10^{-6}	0.02
	Ho^{166}				1.1		1.1			0.06			
68	Er		Total body 7×10^4 g 30 cm			650		$<10^{-4}$ (Ha-36 Ha-55)	1.0 (D)		1.0 (D)	10^{-4}	0.25
	Er^{169}				9.4		9.3			1.0 (D)			
	Er^{171}				0.31		0.31			1.0 (D)			

	r	Bone 7×10^3 g 5 cm			1000 (Ha-55)			0.92 (Ha-36)		0.6 (Ha-34) Ha-36)	6×10^{-5}	0.15
	Er^{169} Er^{171}			9.4 0.31		9.3 0.31			0.60 0.60			
	Er	Kidneys 300 g 7 cm			650			0.02 (Ha-36)		0.02 (Ha-34 Ha-36)	2×10^{-3}	5×10^{-3}
	Er^{169} Er^{171}			9.4 0.31		9.3 0.31			0.02 0.02			
	Er	Liver 1.7×10^3 g 10 cm			433			0.02 (Ha-36)		0.03 (Ha-34) Ha-36)	3×10^{-6}	7.5×10^{-3}
	Er^{169} Er^{171}			9.4 0.31		9.2 0.31			0.02 0.02			
69	Tm	Total body 7×10^4 g 30 cm			675		$<10^{-4}$ (Ha-36 Ha-55)	1.0 (D)		1.0 (D)	10^{-4}	0.25
	Tm^{170}			127		107			1.0 (D)			
	Tm^{171}			694		342			1.0 (D)			
	Tm	Bone 7×10^3 g 5 cm			1000 (Ha-55)			0.95 (Ha-36)		0.65 (Ha-36 Ha-88)	6.5×10^{-5}	0.16
	Tm^{170} Tm^{171}			127 694		113 410			0.69 0.78			
	Tm	Kidneys 300 g 7 cm			335			0.01 (Ha-36)		0.02 (Ha-36 Ha-88)	2×10^{-6}	5×10^{-3}
	Tm^{170} Tm^{171}			127 694		92 226			0.02 0.01			
70	Yb	Total body 7×10^4 g 30 cm			685		$<10^{-4}$ (Ha-36 Ha-55)	1.0 (D)		1.0 (D)	10^{-4}	0.25
	Yb^{175}			4.1		4.1			1.0 (D)			

* Reference equations unless otherwise indicated.

Gen.* ref.	Element and radio-nuclides	Average daily ingestion I (g/day)	Organ of reference, mass (g) effective radius (cm)	Average concen-tration, C (g/g wet tissues)	Half-life (days) Physical T_r	Half-life (days) Bio-logical T_b	Half-life (days) Effective T	Fraction from GI tract to blood f_1	Fraction in organ of reference of that in total body f_2 Element	f_2 Radio-nuclide	Fraction from blood to organ of reference f_2'	Fraction reaching organ of reference By ingestion f_w	By inhalation f_a
Z			Ch-1			eq. 44, 45	eq. 49			eq. 41, 42		eq. 47	eq. 46
	Yb Yb^{175}		Bone 7×10^3 g 5 cm		4.1	1000 (Ha-55)	4.1		0.85 (Ha-33)	0.58	0.58 (Ha-33)	5.8×10^{-5}	0.15
	Yb Yb^{175}		Kidneys 300 g 7 cm		4.1	685	4.1		0.05 (Ha-33)	0.05	0.05 (Ha-33)	5×10^{-6}	0.013
71	Lu Lu^{177}		Total body 7×10^4 g 30 cm		6.8	750	6.7	$<10^{-4}$ (Ha-36 Ha-55)	1.0 (D)	1.0 (D)	1.0 (D)	10^{-4}	0.25
	Lu Lu^{177}		Bone 7×10^3 g 5 cm		6.8	1000 (Ha-55)	6.75		0.9 (Ha-36)	0.68	0.68 (Ha-36)	6.8×10^{-5}	0.17
	Lu Lu^{177}		Kidneys 300 g 7 cm		6.8	750	6.7		0.01 (Ha-36)	0.01	0.01 (Ha-36)	10^{-6}	2.5×10^{-3}
72	Hf Hf^{181}		Total body 7×10^4 g 30 cm		46	563 (Ki-1)	43	$<10^{-4}$ (com-pared to Zr)	1.0 (D)	1.0 (D)	1.0 (D)	10^{-4}	0.25
	Hf Hf^{181}		Liver 1.7×10^3 g 10 cm		46	625	43		0.5 (Ki-1)	0.45	0.45 (Ki-1)	4.5×10^{-5}	0.11

	Hf^{181}		Spleen 150 g 7 cm		46	350	41		0.08 (Ki-1)	0.12	0.13 (Ki-1)	1.3×10^{-5}	0.03
	Hf Hf^{181}		Kidneys 300 g 7 cm		46	563	43		0.02 (Ki-1)	0.02	0.02 (Ki-1)	2×10^{-6}	5×10^{-3}
	Hf Hf^{181}		Bone 7×10^3 g 5 cm		46	600	43		0.16 (Ki-1)	0.15	0.15 (Ki-1)	1.5×10^{-5}	0.04
73	Ta Ta^{182}		Total body 7×10^4 g 30 cm		112	240	76	$<10^{-4}$ (Ha-101 com- pared to Nb)	1.0 (D)	1.0 (D)	1.0 (D)	10^{-4}	0.25
	Ta Ta^{182}		Liver 1.7×10^3 g 10 cm		112	400 (Ha-38 Ha-87 Ha-88)	88		0.5 (Ha-38 Ha-87)	0.35	0.3 (Ha-38 Ha-87)	3×10^{-5}	0.08
	Ta Ta^{182}		Bone 7×10^3 g 5 cm		112	300	82		0.25 (Ha-38 Ha-87)	0.22	0.2 (Ha-38 Ha-87)	2×10^{-5}	0.05
	Ta Ta^{182}		Kidneys 300 g 7 cm		112	400	88		0.05 (Ha-38 Ha-87)	0.035	0.03 (Ha-38 Ha-87)	3×10^{-6}	7.5×10^{-3}
	Ta Ta^{182}		Spleen 150 g 7 cm		112	240	76		0.01 (Ha-38 Ha-)87	0.01	0.01 (Ha-38 Ha-87)	10^{-6}	2.5×10^{-3}

* Reference equations unless otherwise indicated.

Gen.* ref. Z	Element and radio-nuclides	Average daily ingestion I (g/day)	Organ of reference, mass (g) effective radius (cm)	Average concen-tration, C (g/g wet tissues)	Half-life (days) Physical T_r	Half-life (days) Bio-logical T_b	Half-life (days) Effective T	Fraction from GI tract to blood f_1	Fraction in organ of reference of that in total body f_2: Element	Fraction in organ of reference of that in total body f_2: Radio-nuclide	Fraction from blood to organ of reference f'_2	Fraction reaching organ of reference: By ingestion f_w	Fraction reaching organ of reference: By inhalation f_a
			Ch-1			eq. 44, 45	eq. 49			eq.41,42		eq. 47	eq. 46
74	W		Total body 7×10^4 g 30 cm			1 (Ha-34)		0.1 (Ha-34 Ha-101)	1.0 (D)		1.0 (D)	0.1	0.3
	W^{181}				140		1			1.0 (D)			
	W^{185}				74		1			1.0 (D)			
	W^{187}				1		0.5			1.0 (D)			
	W		Bone 7×10^3 g 5 cm			9 (Ha-34)			0.65 (Ha-34 Ha-101 Ws-2)		0.07 (Ha-34 Ha-101)	7×10^{-3}	0.02
	W^{181}				140		8.5			0.60			
	W^{185}				74		8			0.57			
	W^{187}				1		0.9			0.13			
	W		Liver 1.7×10^3 g 10 cm			4 (Ha-34)			0.24 (Ha-34 Ha-101 Ws-2)		0.06 (Ha-34 Ha-101)	6×10^{-3}	0.02
	W^{181}				140		3.9			0.24			
	W^{185}				74		3.8			0.23			
	W^{187}				1		0.8			0.1			
75	Re		Total body 7×10^4 g 30 cm			7 (Ha-89)		0.5 (com-pared to Tc)	1.0 (D)		1.0 (D)	0.5	0.5
	Re^{183}				73		6.4			1.0 (D)			
	Re^{186}				3.79		2.5			1.0 (D)			
	Re^{187}				1.8×10^{13}		7			1.0 (D)			
	Re^{188}				0.71		0.64			1.0 (D)			

	Re^{183} Re^{186} Re^{187} Re^{188}	Thyroid 20 g 3 cm		73 3.79 1.8×10^{13} 0.71	3	2.9 1.7 3 0.57		3×10^{-3} (Ha-89)	3×10^{-3} 5×10^{-3} 3×10^{-3} 6×10^{-3}	7×10^{-3} (Ha-89)	3.5×10^{-3}	3.5×10^{-3}
	Re Re^{183} Re^{186} Re^{187} Re^{188}	Skin 2×10^3 g 0.1 cm		73 3.79 1.8×10^{13} 0.71	25	19 3.3 25 0.69		0.9 (Ha-89)	0.74 0.34 0.89 0.27	0.25 (Ha-89)	0.13	0.13
	Re Re^{183} Re^{186} Re^{187} Re^{188}	Bone 7×10^3 g 5 cm		73 3.79 1.8×10^{13} 0.71	3.5	3.3 1.82 3.5 0.59		5×10^{-3} (Ha-89)	5×10^{-3} 7×10^{-3} 5×10^{-3} 9×10^{-3}	0.01 (Ha-89)	5×10^{-3}	5×10^{-3}
	Re Re^{183} Re^{186} Re^{187} Re^{188}	Liver 1.7×10^3 g 10 cm		73 3.79 1.8×10^{13} 0.71	14	11.7 2.98 14 0.68		0.02 (Ha-89)	0.02 0.01 0.02 0.01	0.01 (Ha-89)	5×10^{-3}	5×10^{-3}
76	Os Os^{185} Os^{191m} Os^{191} Os^{193}	Total body 7×10^4 g 30 cm		95 0.58 16 1.3	2 (Ha-101)	2 0.45 1.8 0.8	0.1 (Ha-85 Ha-101 compared to Pt and Ir)	1.0 (D)	1.0 (D) 1.0 (D) 1.0 (D) 1.0 (D)	1.0 (D)	0.1	0.3

Reference equations unless otherwise indicated.

Gen.* ref. / Z	Element and radio-nuclides	Average daily ingestion I (g/day)	Organ of reference, mass (g) effective radius (cm)	Average concentration, C (g/g wet tissues)	Half-life (days) Physical T_r	Half-life (days) Biological T_b	Half-life (days) Effective T	Fraction from GI tract to blood f_1	Fraction in organ of reference of that in total body f_2 Element	f_2 Radio-nuclide	Fraction from blood to organ of reference f_2'	Fraction reaching organ of reference By ingestion f_w	By inhalation f_a
			Ch-1			eq. 44, 45	eq. 49			eq.41,42		eq. 47	eq. 46
	Os		Kidneys 300 g 7 cm			5 (Ha-101)			0.13 (Ha-87)		0.05 (Ha-87) Ha-101)	5×10^{-3}	0.02
	Os^{185}				95		4.8			0.12			
	Os^{191m}				0.58		0.52			0.06			
	Os^{191}				16		3.8			0.11			
	Os^{193}				1.3		1			0.07			
	Os		Liver 1.7×10^3 g 10 cm			5.5			0.11 (Ha-87)		0.04 (Ha-87 Ha-101)	4×10^{-3}	0.01
	Os^{185}				95		5.2			0.11			
	Os^{191m}				0.58		0.52			0.05			
	Os^{191}				16		4.1			0.09			
	Os^{193}				1.3		1			0.05			
77	Ir		Total body 7×10^4 g 30 cm			20 (Ha-85)		0.1 (G, compared with Rh)	1.0 (D)		1.0 (D)	0.1	0.3
	Ir^{190}				12		7.5			1.0 (D)			
	Ir^{192}				74.5		15.8			1.0 (D)			
	Ir^{194}				0.79		0.76			1.0 (D)			
	Ir		Kidneys 300 g 7 cm			50			0.11 (Ha-85)		0.045 (Ha-85)	4.5×10^{-3}	0.014
	Ir^{190}				12		9.7			0.06			
	Ir^{192}				74.5		30			0.09			
	Ir^{194}				0.79		0.78			0.05			

	Ir		Spleen 150 g 7 cm			50			0.05 (Ha-85)		0.02 (Ha-85)	2×10^{-3}	6×10^{-3}
	Ir^{190}				12		9.7			0.03			
	Ir^{192}				74.5		30			0.04			
	Ir^{194}				0.79		0.78			0.02			
	Ir		Liver 1.7×10^3 g 10 cm			27			0.31 (Ha-85)		0.23 (Ha-85)	0.023	0.07
	Ir^{190}				12		8.3			0.25			
	Ir^{192}				74.5		20			0.29			
	Ir^{194}				0.79		0.77			0.23			
78	Pt		Total body 7×10^4 g 30 cm			24 (Ha-85)		0.1 (Ha-85 compared to Ir)	1.0 (D)		1.0 (D)	0.1	0.3
	Pt^{191}				3		2.7			1.0 (D)			
	Pt^{193m}				3.4		3.0			1.0 (D)			
	Pt^{193}				1.8×10^5		24			1.0 (D)			
	Pt^{197m}				0.056		0.056			1.0 (D)			
	Pt^{197}				0.75		0.73			1.0 (D)			
	Pt		Kidneys 300 g 7 cm			60 (Ha-85)			0.25 (Ha-85)		0.1 (Ha-85)	0.01	0.03
	Pt^{191}				3		2.9			0.11			
	Pt^{193m}				3.4		3.2			0.11			
	Pt^{193}				1.8×10^5		60			0.25			
	Pt^{197m}				0.056		0.056			0.1			
	Pt^{197}				0.75		0.74			0.1			
	Pt		Spleen 150 g 7 cm			60			0.02 (Ha-85)		8×10^{-3} (Ha-85)	8×10^{-4}	2.4×10^{-3}
	Pt^{191}				3		2.9			8.6×10^{-3}			

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Gen.* ref.	Element and radio-nuclides	Average daily ingestion I (g/day)	Organ of reference, mass (g) effective radius (cm)	Average concentration, C (g/g wet tissues)	Half-life (days) Physical T_r	Half-life (days) Biological T_b	Half-life (days) Effective T	Fraction from GI tract to blood f_1	Fraction in organ of reference of that in total body f_2 Element	Fraction in organ of reference of that in total body f_2 Radio-nuclide	Fraction from blood to organ of reference f_2'	Fraction reaching organ of reference By ingestion f_w	Fraction reaching organ of reference By inhalation f_a
Z			Ch-1			eq. 44, 45	eq. 49			eq. 41, 42		eq. 47	eq. 46
	Pt^{193m}				3.4		3.2			8.6×10^{-3}			
	Pt^{193}				1.8×10^{5}		60			0.02			
	Pt^{197m}				0.056		0.056			8×10^{-3}			
	Pt^{197}				0.75		0.74			8×10^{-3}			
	Pt		Liver 1.7×10^{3} g 10 cm			20 (Ha-85)			0.12 (Ha-85)		8×10^{-3} (Ha-85)	8×10^{-4}	2.4×10^{-3}
	Pt^{191}				3		2.6			0.14			
	Pt^{193m}				3.4		3.2			0.14			
	Pt^{193}				1.8×10^{5}		20			0.12			
	Pt^{197m}				0.056		0.056			0.14			
	Pt^{197}				0.75		0.72			0.14			
79	Au		Total body 7×10^{4} g 30 cm	$<1.4\times 10^{-8}$ (Ti-1 through Ti-7)		120		0.1 (El-1)	1.0 (D)		1.0 (D)	0.1	0.3
	Au^{196}				5.6		5.4			1.0 (D)			
	Au^{198}				2.7		2.6			1.0 (D)			
	Au^{199}				3.15		3.1			1.0 (D)			
	Au		Liver 1.7×10^{3} g 10 cm	$<10^{-7}$ (Ti-1 through Ti-7)		300 (El-1 Blo-3)			0.1 (Blo-3)		0.04	4×10^{-3} (El-1)	0.01
	Au^{196}				5.6		5.5			0.04			
	Au^{198}				2.7		2.7			0.04			
	Au^{199}				3.15		3.1			0.04			

	Au^{196} Au^{198} Au^{199}		Kidneys 300 g 7 cm	$<10^{-7}$ (Ti-1 through Ti-7)	5.6 2.7 3.15	280	5.5 2.7 3.1		0.07 (Bt-1 Blo-3)	0.03 0.03 0.03	0.03	3×10^{-3}	9×10^{-3}
	Au Au^{196} Au^{198} Au^{199}		Spleen 150 g 7 cm	$<10^{-7}$ (Ti-1 through Ti-7)	5.6 2.7 3.15	240	5.5 2.7 3.1		0.01 (Blo-3)	5×10^{-3} 5×10^{-3} 5×10^{-3}	5×10^{-3}	5×10^{-4}	1.5×10^{-3}
80	Hg Hg^{197m} Hg^{197} Hg^{203}	2×10^{-5} (Sl-1)	Total body 7×10^{4} g 30 cm		1 2.7 45.8	10 (Ha-85)	0.91 2.1 8.2	0.75 (Sl-1)	1.0 (D)	1.0 (D) 1.0 (D) 1.0 (D)	1.0 (D)	0.75	0.63
	Hg Hg^{197m} Hg^{197} Hg^{203}		Kidneys 300 g 7 cm	5×10^{-7} (Stk-1)	1 2.7 45.8	14.5	0.94 2.3 11.0		0.5 (Ha-85)	0.36 0.38 0.47	0.35 (Ha-85)	0.26	0.22
	Hg Hg^{197m} Hg^{197} Hg^{203}		Liver 1.7×10^{3} g 10 cm	2.6×10^{-7} (Stk-1)	1 2.7 45.8	13.5	0.93 2.3 10.4		0.2 (Ha-85)	0.15 0.16 0.19	0.15 (Ha-85)	0.11	0.09
	Hg Hg^{197m} Hg^{197} Hg^{203}		Spleen 150 g 7 cm	1.3×10^{-7} (Stk-1)	1 2.7 45.8	10 (Ha-85)	0.9 2.1 8.2		0.02 (Ha-85)	0.02 0.02 0.02	0.02 (Ha-85)	0.02	0.01

* Reference equations unless otherwise indicated.

Gen.* ref. Z	Element and radio-nuclides	Average daily ingestion I (g/day)	Organ of reference, mass (g) effective radius (cm)	Average concen-tration, C (g/g wet tissues)	Half-life (days) Physical T_r	Half-life (days) Bio-logical T_b	Half-life (days) Effective T	Fraction from GI tract to blood f_1	Fraction in organ of reference of that in total body f_2 Element	Fraction in organ of reference of that in total body f_2 Radio-nuclide	Fraction from blood to organ of reference f_2'	Fraction reaching organ of reference By ingestion f_w	Fraction reaching organ of reference By inhalation f_a
			Ch-1			eq. 44, 45	eq. 49			eq. 41, 42		eq. 47	eq. 46
81	Tl		Total body 7×10^4 g 30 cm	$<8.6 \times 10^{-8}$ (Ti-1 through Ti-7)		5 (Ha-34)		0.45 (Ha-101)	1.0 (D)		1.0 (D)	0.45	0.48
	Tl^{200}				1.13		0.92			1.0 (D)			
	Tl^{201}				3		1.9			1.0 (D)			
	Tl^{202}				12		3.5			1.0 (D)			
	Tl^{204}				1.1×10^3		5.0			1.0 (D)			
	Tl		Kidneys 300 g 7 cm	$<10^{-7}$ (Ti-1 through Ti-7)		7 (Ha-34)			0.07 (Ha-34 Ha-84)		0.05 (Ha-34 Ha-84)	0.023	0.024
	Tl^{200}				1.13		0.97			0.05			
	Tl^{201}				3		2.1			0.06			
	Tl^{202}				12		4.4			0.06			
	Tl^{204}				1.1×10^3		7			0.07			
	Tl		Lungs 10^3 g 10 cm	8×10^{-8} (Ti-1 through Ti-7)		6 (Ha-34)			7×10^{-3} (Ha-34 Ha-84)		6×10^{-3} (Ha-34 Ha-84)	2.7×10^{-3}	2.9×10^{-3}
	Tl^{200}				1.13		0.95			6×10^{-3}			
	Tl^{201}				3		2.0			6×10^{-3}			
	Tl^{202}				12		4.0			7×10^{-3}			
	Tl^{204}				1.1×10^3		6.0			7×10^{-3}			
	Tl		Muscle 3×10^4 g 30 cm	8×10^{-8} (Ti-1 through Ti-7)		5.5 (Ha-34)			0.6 (Ha-34 Ha-84)		0.54 (Ha-34 Ha-84)	0.24	0.26

	Tl^{200} Tl^{201} Tl^{202} Tl^{204}				1.13 3 12 1.1×10^{3}		93 1.9 3.8 5.5			0.55 0.55 0.58 0.59			
	Tl		Bone 7×10^{3} g 5 cm			7			0.08 (Ha-34 Ha-84)		0.055 (Ha-34 Ha-84)	0.025	0.026
	Tl^{200} Tl^{201} Tl^{202} Tl^{204}				1.13 3 12 1.1×10^{3}		0.97 2.1 4.4 7.0			0.06 0.06 0.07 0.08			
	Tl		Liver 1.7×10^{3} g 10 cm			5			0.04 (Ha-34)		0.04 (Ha-34)	0.02	0.02
	Tl^{200} Tl^{201} Tl^{202} Tl^{204}				1.13 3 12 1.1×10^{3}		0.92 1.9 3.5 5			0.04 0.04 0.04 0.04			
82	Pb	4×10^{-4} (Mow-1)	Total body 7×10^{4} g 30 cm	1.1×10^{-6} (Ti-1 through Ti-7)		1.46×10^{3}		0.08 (Gd-1)	1.0 (D)		1.0 (D)	0.08	0.29
	Pb^{203}				2.17		2.17			1.0 (D)			
	Pb^{210}				7.1×10^{3}		1.2×10^{3}			1.0 (D)			
	Pb^{212}				0.44		0.44			1.0 (D)			
	Pb		Bone 7×10^{3} g 5 cm	6.6×10^{-6} (Ti-1 through Ti-7)		3.65×10^{3} (eq. 48)			0.7 (Ha-89 Ti-1 through Ti-7)		0.28 (Ha-89)	0.02	0.08
	Pb^{203} Pb^{210} Pb^{212}				2.17 7.1×10^{3} 0.44		2.17 2.4×10^{3} 0.44			0.28 0.56 0.28			
	Pb		Liver 1.7×10^{3} g 10 cm	2×10^{-6} (Ti-1 through Ti-7)		1947			0.1 (Ha-89 Ti-1 through		0.08 (Ha-89)	6.4×10^{-3}	0.023

* Reference equations unless otherwise indicated.

Gen.* ref.	Element and radio-nuclides	Average daily ingestion I (g/day)	Organ of reference, mass (g) effective radius (cm)	Average concen-tration, C (g/g wet tissues)	Half-life (days) Physical T_r	Half-life (days) Bio-logical T_b	Half-life (days) Effective T	Fraction from GI tract to blood f_1	Fraction in organ of reference of that in total body f_2 Element	Fraction in organ of reference of that in total body f_2 Radio-nuclide	Fraction from blood to organ of reference f_2'	Fraction reaching organ of reference By ingestion f_w	Fraction reaching organ of reference By inhalation f_a
Z			Ch-1			eq. 44, 45	eq. 49			eq.41,42		eq. 47	eq. 46
	Pb^{203} Pb^{210} Pb^{212}				2.17 7.1×10^3 0.44		2.17 1.5×10^3 0.44		Ti-7)	0.08 0.1 0.08			
	Pb		Kidneys 300 g 7 cm	$<1.4\times 10^{-7}$ (Ti-1 through Ti-7)		531			0.05 (Ha-89) Ti-1 through Ti-7)		0.14 (Ha-89)	0.01	0.04
	Pb^{203} Pb^{210} Pb^{212}				2.17 7.1×10^3 0.44		2.16 494 0.44			0.14 0.06 0.14			
83	Bi		Total body 7×10^4 g 30 cm	$<4.3\times 10^{-9}$ (Ti-1 through Ti-7)		5 (Ha-85 Ha-88)		0.01 (poorly absor- bed, G)	1.0 (D)		1.0 (D)	0.01	0.26
	Bi^{206} Bi^{207} Bi^{210} Bi^{212}				6.4 2.9×10^3 5.0 0.042		2.8 5 2.5 0.042			1.0 (D) 1.0 (D) 1.0 (D) 1.0 (D)			
	Bi		Kidneys 300 g 7 cm	$<2\times 10^{-8}$ (Ti-1 through Ti-7)		6			0.36 (Ha-85 Ha-88)		0.3 (Ha-85 Ha-88)	3×10^{-3}	0.08
	Bi^{206} Bi^{207} Bi^{210} Bi^{212}				6.4 2.9×10^3 5.0 0.042		3.1 6 3 0.042			0.33 0.36 0.33 0.30			

			Liver 1.7×10^{3} g 10 cm	$<7\times10^{-8}$ (Ti-1 through Ti-7)		15			0.45 (Ha-85 Ha-88)		0.15 (Ha-85 Ha-88)	1.5×10^{-3}	0.04
	Bi^{206} Bi^{207} Bi^{210} Bi^{212}				6.4 2.9×10^{3} 5.0 0.042		4.5 14.9 3.8 0.042			0.24 0.45 0.22 0.15			
	Bi		Spleen 150 g 7 cm	$<5\times10^{-8}$ (Ti-1 through Ti-7)		10 (Ha-85 Ha-88)			0.02 (Ha-85 Ha-88)		0.01 Ha-85 Ha-88)	10^{-4}	2.6×10^{-3}
	Bi^{206} Bi^{207} Bi^{210} Bi^{212}				6.4 2.9×10^{3} 5.0 0.042		3.9 10 3 0.042			0.01 0.02 0.01 0.01			
	Bi		Bone 7×10^{3} g 5 cm			13.3 (Ha-85 Ha-88)			0.08 (Ha-85 Ha-88)		0.03 (Ha-85 Ha-88)	3×10^{-4}	7.7×10^{-3}
	Bi^{206} Bi^{207} Bi^{210} Bi^{212}				6.4 2.9×10^{3} 5.0 0.042		4.3 13.2 3.6 0.042			0.05 0.08 0.04 0.03			
84	Po		Total body 7×10^{4} g 30 cm			30 (At-9 At-6 Sa-8)		0.06 (At-3 At-9 Sa-8)	1.0 (D)		1.0 (D)	0.06	0.28
	Po^{210}				138.4		25			1.0 (D)			
	Po		Kidneys 300 g 7 cm			70 (At-3 At-9 Hu-4)			0.16 (Fi-2)		0.07 (Fi-2)	4×10^{-3} (At-3)	0.02
	Po^{210}				138.4		46			0.13			
	Po		Spleen 150 g 7 cm			60 (Br-3 Hu-4)			0.08 (Sa-2)		0.04 (Fi-2 Fi-3)	2×10^{-3}	0.01
	Po^{210}				138.4		42			0.07			

* Reference equations unless otherwise indicated.

Gen.* ref.	Element and radio-nuclides	Average daily ingestion I (g/day)	Organ of reference, mass (g) effective radius (cm)	Average concen-tration, C (g/g wet tissues)	Half-life (days) Physical T_r	Half-life (days) Bio-logical T_b	Half-life (days) Effective T	Fraction from GI tract to blood f_1	Fraction in organ of reference of that in total body f_2 Element	Fraction in organ of reference of that in total body f_2 Radio-nuclide	Fraction from blood to organ of reference f'_2	Fraction reaching organ of reference By ingestion f_w	Fraction reaching organ of reference By inhalation f_a
Z			Ch-1			eq. 44, 45	eq. 49			eq.41,42		eq. 47	eq. 46
	Po		Liver 1.7×10^3 g 10 cm			41			0.23 (Fi-2)		0.17 (Fi-2)	0.01	0.05
	Po^{210}				138.4		32			0.22			
	Po		Bone 7×10^3 g 5 cm			24			0.08 (Fi-2)		0.1	6×10^{-3}	0.03
	Po^{210}				138.4		20			0.08			
85	At		Total body 7×10^4 g 30 cm			27		1.0 (compared to I)	1.0 (D)		1.0 (D)	1.0	0.75
	At^{211}				0.3		0.3			1.0 (D)			
	At		Thyroid 20 g 3 cm			36			0.04 (Ha-46 Ha-88)		0.03 (Ha-46)	0.03	0.023
	At^{211}				0.3		0.3			0.03			
	At		Spleen 150 g 7 cm			27			0.03 (Ha-46 Ha-88)		0.03 (Ha-46)	0.03	0.02
	At^{211}				0.3		0.3			0.03			
	At		Ovaries 8 g 3 cm			13.5			10^{-3} (Ha-46)		2×10^{-3} (Ha-46)	2×10^{-3}	1.5×10^{-3}
	At^{211}				0.3		0.3			2×10^{-3}			
86	Rn		Lungs 10^3 g 10 cm										
	Rn^{220}				6×10^{-4}								
	Rn^{222}				3.83								

87	(		Total body 7×10^4 g 30 cm			70	(	1.0 (compared to Cs)	1.0 (D)		1.0 (D)	1.0	0.75 (
	Fr		Muscle 3×10^4 g 30 cm			140 (compared to Cs)			0.8 (compared to Cs)		0.4 (compared to Cs)	0.4	0.3
88	Ra	5.5×10^{-12} (Stc-4 Sy-1)	Total body 7×10^4 g 30 cm	1.4×10^{-15} (Hu-1 Kt-3)		8.1×10^3		0.3 (Pit-1)	1.0 (D)		1.0 (D)	0.3	0.4
	Ra^{223}				11.7	12 (Dur-3)	5.9			1.0 (D)			
	Ra^{224}				3.64	6 (Dur-3)	2.3			1.0 (D)			
	Ra^{226}				5.9×10^5	900 (Dur-3)	900			1.0 (D)			
	Ra^{228}				2.4×10^3	250 (Dur-3)	230			1.0 (D)			
	Ra		Bone 7×10^3 g 5 cm	1.7×10^{-14} (Hu-1 Kt-3)		1.64×10^4 (Fi-3 Ea-4)			0.99 (Ge-1)				
	Ra^{223}				11.7		11.7			0.95	0.5	0.15	0.2
	Ra^{224}				3.64		3.64			0.86	0.5	0.15	0.2
	Ra^{226}				5.9×10^5		1.6×10^4			0.99	0.1	0.03	0.04
	Ra^{228}				2.4×10^3		2.1×10^3			0.99	0.1	0.03	0.04
	Ra		Kidneys 300 g 7 cm			10			0.004 (Fi-2)		0.002 (Fi-2)	6×10^{-4}	8×10^{-4}
	Ra^{223}				11.7		5.4			0.002			
	Ra^{224}				3.64		2.7			0.002			
	Ra^{226}				5.9×10^5		10			2×10^{-5}			
	Ra^{228}				2.4×10^3		10			9×10^{-5}			

* Reference equations unless otherwise indicated.

Gen.* ref.	Element and radio-nuclides	Average daily ingestion I (g/day)	Organ of reference, mass (g) effective radius (cm)	Average concentration, C (g/g wet tissues)	Half-life (days) Physical T_r	Half-life (days) Biological T_b	Half-life (days) Effective T	Fraction from GI tract to blood f_1	Fraction in organ of reference of that in total body f_2 Element	Fraction in organ of reference of that in total body f_2 Radio-nuclide	Fraction from blood to organ of reference f_2'	Fraction reaching organ of reference By ingestion f_w	Fraction reaching organ of reference By inhalation f_a
Z			Ch-1			eq. 44, 45	eq. 49			eq. 41,42		eq. 47	eq. 46
	Ra		Liver 1.7×10^3 g 10 cm			10			0.0006 (Fi-2)		0.0004 (Fi-2)	1.2×10^{-4}	1.6×10^{-4}
	Ra^{223}				11.7		5.4			0.0004			
	Ra^{224}				3.64		2.7			0.0005			
	Ra^{226}				5.9×10^5		10			4×10^{-6}			
	Ra^{228}				2.4×10^3		10			2×10^{-5}			
89	Ac		Total body 7×10^4 g 30 cm			2.4×10^4		$<10^{-4}$ (At-13, very poorly absorbed compared to $4f$ rare earths)	1.0 (D)		1.0 (D)	10^{-4}	0.25
	Ac^{227}				8×10^3		6×10^3			1.0 (D)			
	Ac^{228}				0.26		0.26			1.0 (D)			
	Ac		Bone 7×10^3 g 5 cm			7.3×10^4 (At-15 compared to Pu)			0.9 (Ha-63)		0.3 (Ha-63)	3×10^{-5}	0.08
	Ac^{227}				8×10^3		7.2×10^3			0.36			
	Ac^{228}				0.26		0.26			0.3			
	Ac		Kidneys 300 g 7 cm			2.4×10^4			0.01 (Ha-32)		0.01 (Ha-32)	10^{-6}	3×10^{-3}
	Ac^{227}				8×10^3		6×10^3			0.01			
	Ac^{228}				0.26		0.26			0.01			

			Liver 1.7×10^3 g 10 cm			2.4×10^3			0.05 (Ha-63)		0.5 (Ha-63)	5×10^{-5}	0.13
	Ac^{227}				8×10^3		1.9×10^3			0.16			
	Ac^{228}				0.26		0.26			0.5			
90	Th		Total body 7×10^4 g 30 cm			5.7×10^4		$<10^{-4}$ (Ha-8 Dw-2)	1.0 (D)		1.0 (D)	10^{-4}	0.25
	Th^{227}				18.4		18.4			1.0 (D)			
	Th^{228}				700		691			1.0 (D)			
	Th^{230}				2.9×10^7		5.7×10^4			1.0 (D)			
	Th^{231}				1.07		1.07			1.0 (D)			
	Th^{232}				5.1×10^{12}		5.7×10^4			1.0 (D)			
	Th^{234}				24.1		24.1			1.0 (D)			
	Th		Bone 7×10^3 g 5 cm			7.3×10^4 (compared to Pu)			0.9 (Ha-8)		0.7 (Ha-8 Ha-29)	7×10^{-5}	0.18
	Th^{227}				18.4		18.4			0.7			
	Th^{228}				700		693			0.7			
	Th^{230}				2.9×10^7		7.3×10^4			0.9			
	Th^{231}				1.07		1.07			0.7			
	Th^{232}				5.1×10^{12}		7.3×10^4			0.9			
	Th^{234}				24.1		24.1			0.7			
	Th		Kidneys 300 g 7 cm			2.2×10^4			0.02 (Ha-8 Ha-29)		0.05 (Ha-8 Ha-29)	5×10^{-6}	0.01
	Th^{227}				18.4		18.4			0.05			
	Th^{228}				700		678			0.05			
	Th^{230}				2.9×10^7		2.2×10^4			0.02			
	Th^{231}				1.07		1.07			0.05			
	Th^{232}				5.1×10^{12}		2.2×10^4			0.02			
	Th^{234}				24.1		24.1			0.05			

* Reference equations unless otherwise indicated.

Gen.* ref. Z	Element and radio-nuclides	Average daily ingestion I (g/day)	Organ of reference, mass (g) effective radius (cm)	Average concentration, C (g/g wet tissues)	Half-life (days) Physical T_r	Half-life (days) Biological T_b	Half-life (days) Effective T	Fraction from GI tract to blood f_1	Fraction in organ of reference of that in total body f_2 Element	Fraction in organ of reference of that in total body f_2 Radio-nuclide	Fraction from blood to organ of reference f_2'	Fraction reaching organ of reference By ingestion f_w	Fraction reaching organ of reference By inhalation f_a
			Ch-1			eq. 44, 45	eq. 49			eq.41,42		eq. 47	eq. 46
	Th		Liver 1.7×10^3 g 10 cm			5.7×10^4			0.05 (Ha-8 Ha-29)		0.05 (Ha-8 Ha-29)	5×10^{-6}	0.01
	Th^{227}				18.4		18.4			0.05			
	Th^{228}				700		691			0.05			
	Th^{230}				2.9×10^7		5.7×10^4			0.05			
	Th^{231}				1.07		1.07			0.05			
	Th^{232}				5.1×10^{12}		5.7×10^4			0.05			
	Th^{234}				24.1		24.1			0.05			
91	Pa		Total body 7×10^4 g 30 cm			4.1×10^4		$<10^{-4}$ (Ha-8, compared to 4f rare earths)	1.0 (D)		1.0 (D)	10^{-4}	0.25
	Pa^{230}				17.7		17.7			1.0 (D)			
	Pa^{231}				1.3×10^7		4.1×10^4			1.0 (D)			
	Pa^{233}				27.4		27.4			1.0 (D)			
	Pa		Bone 7×10^3 g 5 cm			7.3×10^4 (compared to Pu)			0.8 (Ha-8)		0.45 (Ha-8)	4.5×10^{-5}	0.11
	Pa^{230}				17.7		17.7			0.45			
	Pa^{231}				1.3×10^7		7.3×10^4			0.8			
	Pa^{233}				27.4		27.4			0.45			
	Pa		Kidneys 300 g 7 cm			5.1×10^4			0.05 (Ha-8)		0.04 (Ha-8)	4×10^{-6}	0.01
	Pa^{230}				17.7		17.7			0.04			

	Pa^{231}				1.3×10^{7}		$\times10^{4}$			0.05			
	^{233}				27.4		.4			0.04			
	Pa		Liver 1.7×10^{3} g 10 cm			5.8×10^{4}			0.07 (Ha-8)		0.05 (Ha-8)	5×10^{-6}	0.013
	Pa^{230}				17.7		17.7			0.05			
	Pa^{231}				1.3×10^{7}		5.8×10^{4}			0.07			
	Pa^{233}				27.4		27.4			0.05			
92	U	2×10^{-6} (Da-1)	Total body 7×10^{4} g 30 cm	3×10^{-10}		100 (Ber-1 Ber-3)		$<10^{-4}$ (Ha-1)	1.0 (D)		1.0 (D)	10^{-4}	0.25
	U^{230}				20.8		17.2			1.0 (D)			
	U^{232}				2.7×10^{4}		100			1.0 (D)			
	U^{233}				5.9×10^{7}		100			1.0 (D)			
	U^{234}				9.1×10^{7}		100			1.0 (D)			
	U^{235}				2.6×10^{11}		100			1.0 (D)			
	U^{236}				8.7×10^{9}		100			1.0 (D)			
	U^{238}				1.7×10^{12}		100			1.0 (D)			
	U		Kidneys 300 g 7 cm	1.4 2×10^{-8} (Vo-1) 6 μg		15 (Vo-1 Sx-1 McL-1)			0.065 (Vo-1)		0.11 (Vo-1 Sx-1 McL-1)	1.1×10^{-5}	0.028
	U^{230}				20.8		8.7			0.065			
	U^{232}				2.7×10^{4}		15			0.065			
	U^{233}				5.9×10^{7}		15			0.065			
	U^{234}				9.1×10^{7}		15			0.065			
	U^{235}				2.6×10^{11}		15			0.065			
	U^{236}				8.7×10^{9}		15			0.065			
	U^{238}				1.6×10^{12}		15			0.065 (Vo-1 for all U f_2 values			

[a] Reference equations unless otherwise indicated.

Gen.* ref.	Element and radio-nuclides	Average daily ingestion I (g/day)	Organ of reference, mass (g) effective radius (cm)	Average concen-tration, C (g/g wet tissues)	Half-life (days) Physical T_r	Half-life (days) Bio-logical T_b	Half-life (days) Effective T	Fraction from GI tract to blood f_1	Fraction in organ of reference of that in total body f_2 Element	Fraction in organ of reference of that in total body f_2 Radio-nuclide	Fraction from blood to organ of reference f_2'	Fraction reaching organ of reference By ingestion f_w	Fraction reaching organ of reference By inhalation f_a
			Ch-1			eq. 44, 45	eq. 49			eq. 41, 42		eq. 47	eq. 46
	U		Bone 7×10^3 g 5 cm	10^{-9} (Ly-1) low closer to 1.3×10^{-9}		300 (Ber-1 Ber-3)			0.85 (Vo-1)		0.11 (Ber-1 Ber-3)	1.1×10^{-5}	0.028
	U^{230}				20.8		19.5			0.85			
	U^{232}				2.7×10^4		300			0.85			
	U^{233}				5.9×10^7		300			0.85			
	U^{234}				9.1×10^7		300			0.85			
	U^{235}				2.6×10^{11}		300			0.85			
	U^{236}				8.7×10^9		300			0.85			
	U^{238}				1.6×10^{12}		300			0.85			
93	Np		Total body 7×10^4 g 30 cm			3.9×10^4		$< 10^{-4}$ (Ha-1 Ha-10)	1.0 (D)		1.0 (D)	10^{-4}	0.25
	Np^{237}				8×10^8		3.9×10^4			1.0 (D)			
	Np^{239}				2.33		2.33			1.0 (D)			
	Np		Bone 7×10^3 g 5 cm			7.3×10^4 (com-pared to Pu)			0.85 (Ha-8)		0.45 (Ha-8)	4.5×10^{-5}	0.11
	Np^{237}				8×10^8		7.3×10^4			0.85			
	Np^{239}				2.33		2.33			0.45			
	Np		Kidneys 300 g 7 cm			6.4×10^4			0.05 (Ha-8)		0.03 (Ha-8)	3×10^{-6}	7.5×10^{-3}
	Np^{237}				8×10^8		6.4×10^4			0.05			
	Np^{239}				2.33		2.33			0.03			

			Liver 1.7×10^3 g 10 cm			5.4×10^4			0.07 (Ha-8)		0.05 (Ha-8)	5×10^{-6}	0.013
	Np^{237} Np^{239}				8×10^8 2.33		5.4×10^4 2.33			0.07. 0.05			
94	Pu		Total body 7×10^4 g 30 cm			6.5×10^4		3×10^{-5} (Ln-5 Bal-1 Bs-4 Kt-6)	1.0 (D)		1.0 (D)	3×10^{-5}	0.25
	Pu^{238}				~~3.3~~ 3.16 $\times 10^4$		2.2×10^4			1.0 (D)			
	Pu^{239}				8.9×10^6		6.4×10^4			1.0 (D)			
	Pu^{240}				2.4×10^6		6.3×10^4			1.0 (D)			
	Pu^{241}				4.8×10^3		4.5×10^3			1.0 (D)			
	Pu^{242}				1.4×10^8		6.5×10^4			1.0 (D)			
	Pu		Bone 7×10^3 g 5 cm			7.3×10^4 (Ln-5 Ln-12)			0.9 (Ln-5 Kt-2)		0.8 (Ln-5 Ha-93)	2.4×10^{-5} (Ph-1 Ph-2 Kt-6)	0.2
	Pu^{238}				3.3×10^4		2.3×10^4			0.83			
	Pu^{239}				8.9×10^6		7.2×10^4			0.9			
	Pu^{240}				2.4×10^6		7.1×10^4			0.9			
	Pu^{241}				4.8×10^3		4.5×10^3			0.81			
	Pu^{242}				1.4×10^8		7.3×10^4			0.9			
	Pu		Liver 1.7×10^3 g 10 cm			3×10^4			0.07 (Ln-4 Ha-26)		0.15 (Ln-4 Ha-26)	4.5×10^{-6}	0.038
	Pu^{238}				3.3×10^4		~~1.6~~ 1.54 $\times 10^4$			0.11			
	Pu^{239}				8.9×10^6		3×10^4			0.07			
	Pu^{240}				2.4×10^6		3×10^4			0.07			
	Pu^{241}				4.8×10^3		4.1×10^3			0.14			
	Pu^{242}				1.4×10^8		3.0×10^4			0.07			
	Pu		Kidneys 300 g 7 cm			3.2×10^4			0.01 (Ln-4 Ha-26)		0.02 (Ln-4 Ha-26)	6×10^{-7}	5×10^{-3}

* Reference equations unless otherwise indicated.

Gen.* ref.	Element and radio-nuclides	Average daily ingestion I (g/day)	Organ of reference, mass (g) effective radius (cm)	Average concen-tration, C (g/g wet tissues)	Half-life (days) Physical T_r	Bio-logical T_b	Effective T	Fraction from GI tract to blood f_1	Fraction in organ of reference of that in total body f_2 Element	Radio-nuclide	Fraction from blood to organ of reference f_2'	Fraction reaching organ of reference By ingestion f_w	By inhalation f_a
2			Ch-1			eq. 44, 45	eq. 49			eq. 41, 42		eq. 47	eq. 46
	Pu^{238}				3.3×10^4		1.6×10^4			0.015			
	Pu^{239}				8.9×10^6		3.2×10^4			0.01			
	Pu^{240}				2.4×10^6		3.2×10^4			0.01			
	Pu^{241}				4.8×10^3		4.2×10^3			0.02			
	Pu^{242}				1.4×10^8		3.2×10^4			0.01			
95	Am		Total body 7×10^4 g 30 cm			2×10^4		$< 10^{-4}$ (Ha-13 Ha-62 com-pared to 4f rare earths)	1.0 (D)		1.0 (D)	10^{-4}	0.25
	Am^{241}				1.7×10^5		1.8×10^4			1.0 (D)			
	Am^{243}				2.9×10^6		2×10^4			1.0 (D)			
	Am		Bone 7×10^3 g 5 cm			7.3×10^4 (com-pared to Pu)			0.9 (Ha-1 Ha-13)		0.25 (Ha-13)	2.5×10^{-5}	0.063
	Am^{241}				1.7×10^5		5.1×10^4			0.71			
	Am^{243}				2.9×10^6		7.1×10^4			0.88			
	Am		Liver 1.7×10^3 g 10 cm			3.48×10^3			0.06 (Ha-13)		0.35 (Ha-13)	3.5×10^{-5}	0.088
	Am^{241}				1.7×10^5		3.4×10^3			0.07			
	Am^{243}				2.9×10^6		3.5×10^3			0.06			
	Am		Kidneys 300 g 7 cm			2.7×10^4			0.04 (Ha-13)		0.03 (Ha-13)	3×10^{-6}	7.5×10^{-3}
	Am^{241}				1.7×10^5		2.3×10^4			0.04			
	Am^{243}				2.9×10^6		2.7×10^4			0.04			

Cm	Total body 7×10^{4} g 30 cm			2.4×10^{4}		$<10^{-4}$ (Ha-12 compared to 4*f* rare earths)	1.0 (D)		1.0 (D)	10^{-4}	0.25
Cm^{242}			162.5		161.4			1.0 (D)			
Cm^{243}			1.3×10^{4}		8.4×10^{3}			1.0 (D)			
Cm^{244}			6.7×10^{3}		5.2×10^{3}			1.0 (D)			
Cm^{245}			7.3×10^{6}		2.4×10^{4}			1.0 (D)			
Cm^{246}			2.4×10^{6}		2.4×10^{4}			1.0 (D)			
Cm	Bone 7×10^{3} g 5 cm			7.3×10^{4} (compared to Pu)			0.9 (Ha-12)		0.3 (Ha-12)	3×10^{-5}	0.075
Cm^{242}			162.5		162.1			0.3			
Cm^{243}			1.3×10^{4}		1.1×10^{4}			0.39			
Cm^{244}			6.7×10^{3}		6.1×10^{3}			0.35			
Cm^{245}			7.3×10^{6}		7.2×10^{4}			0.9			
Cm^{246}			2.4×10^{6}		7.1×10^{4}			0.9			
Cm	Kidneys 300 g 7 cm			2.4×10^{4}			0.02 (Ha-12)		0.02 (Ha-12)	2×10^{-6}	5×10^{-3}
Cm^{242}			162.5		161.4			0.02			
Cm^{243}			1.3×10^{4}		8.4×10^{3}			0.02			
Cm^{244}			6.7×10^{3}		5.2×10^{3}			0.02			
Cm^{245}			7.3×10^{6}		2.4×10^{4}			0.02			
Cm^{246}			2.4×10^{6}		2.4×10^{4}			0.02			
Cm	Liver 1.7×10^{3} g 10 cm			3×10^{3}			0.05 (Ha-12)		0.4 (Ha-12)	4×10^{-5}	0.1
Cm^{242}			162.5		154.3			0.38			
Cm^{243}			1.3×10^{4}		2.5×10^{3}			0.12			
Cm^{244}			6.7×10^{3}		2.1×10^{3}			0.16			
Cm^{245}			7.3×10^{6}		3×10^{3}			0.05			
Cm^{246}			2.4×10^{6}		3×10^{3}			0.05			

* Reference equations unless otherwise indicated.

Gen.* ref. Z	Element and radio-nuclides	Average daily ingestion I (g/day)	Organ of reference, mass (g) effective radius (cm)	Average concen-tration, C (g/g wet tissues)	Half-life (days) Physical T_r	Half-life (days) Bio-logical T_b	Half-life (days) Effective T	Fraction from GI tract to blood f_1	Fraction in organ of reference of that in total body f_2 Element	Fraction in organ of reference of that in total body f_2 Radio-nuclide	Fraction from blood to organ of reference f_2'	Fraction reaching organ of reference By ingestion f_w	Fraction reaching organ of reference By inhalation f_a
			Ch-1			eq. 44, 45	eq. 49			eq. 41, 42		eq. 47	eq. 46
97	Bk		Total body 7×10^4 g 30 cm			6.5×10^4		$3 \times 10^{-}$[illegible] (compared to Pu)	1.0 (D)		1.0 (D)	3×10^{-5}	0.25
	Bk^{249}				290		289			1.0 (D)			
	Bk		Bone 7×10^3 g 5 cm			7.3×10^4 (compared to Pu)			0.9 (compared to Pu)		0.8 (compared to Pu)	2.4×10^{-5}	0.2
	Bk^{249}				290		289			0.8			
98	Cf		Total body 7×10^4 g 30 cm			6.5×10^4		3×10^{-5} (compared to Pu)	1.0 (D)		1.0 (D)	3×10^{-5}	0.25
	Cf^{249}				1.7×10^5		4.7×10^4			1.0 (D)			
	Cf^{250}				3.7×10^3		3.5×10^3			1.0 (D)			
	Cf^{252}				803		793			1.0 (D)			
	Cf		Bone 7×10^3 g 5 cm			7.3×10^4 (compared to Pu)			0.9 (compared to Pu)		0.8 (compared to Pu)	2.4×10^{-5}	0.2
	Cf^{249}				1.7×10^5		5.1×10^4			0.9			
	Cf^{250}				3.7×10^3		3.5×10^3			0.8			
	Cf^{252}				803		794			0.8			

* Reference equations unless otherwise indicated.

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