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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The International Commission on Radiological Protection
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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	J. B. HURSH
A. M. BRUES	L. D. MARINELLI
P. W. DURBIN	W. S. SNYDER
J. W. HEALY	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	M. K. NAKAIDZUMI
W. BINKS	G. J. NEARY
A. M. BRUES	M. N. POBEDINSKI
W. H. LANGHAM	E. E. POCHIN
L. D. MARINELLI	C. G. STEWART
W. G. MARLEY	

[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 the 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)
R. G. JAEGER (Germany)
W. V. MAYNEORD (Great Britain)
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R. S. STONE (U.S.A.)
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

G. FAILLA, Chairman (U.S.A.)
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D. G. CATCHESIDE (Australia)
J. C. JACOBSEN (Denmark)
J. F. LOUTIT (Great Britain)
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C. GARRETT (Canada)
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P. RØNNE (Denmark)
W. J. OOSTERKAMP (Netherlands)
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P. RØNNE (Denmark)
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Committee V (*Handling of radioactive isotopes and disposal of radioactive waste*)

1953–1956

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1956–

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F. D. SOWBY (Canada)
F. W. WESTERN (U.S.A.)
Technical Secretary: G. G. ROBECK (U.S.A.)

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

exposed 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

attention 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 the 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*