Recommendations of the International Commission on Radiological Protection. (As Amended 1959 & Revised 1962) (ICRP Publication 6)

RADIATION PROTECTION

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(*As Amended* 1959 *and Revised* 1962)

ICRP PUBLICATION 6

PUBLISHED FOR
The International Commission on Radiological Protection
BY
PERGAMON PRESS
OXFORD · LONDON · EDINBURGH · NEW YORK
PARIS · FRANKFURT
1964

1. PREFACE

PREVIOUS recommendations of the Commission have been given in Recommendations of the International Commission on Radiological Protection—adopted 1958 (ICRP Publication 1), and in the " Report on decisions at the 1959 meeting of the ICRP ", published in 1959 and reprinted in a number of scientific journals. In addition, both of the above publications have been reprinted with the Report of Committee II on Permissible Dose for Internal Radiation (ICRP Publication 2), 1959, and with the Report of Committee III on Protection Against X-rays up to Energies of 3 MeV and Beta- and Gamma-Rays from Sealed Sources (ICRP Publication 3), 1960.

Subject to the amendments and comments given in Part 3 of this report, all recommendations made in the above publications are still valid. Although the 1958 Recommendations have been amended both in 1959 and 1962, the Commission has decided not to publish at this time a new revised version of its general recommendations. This is partly because there has as yet been no change in the basic philosophy calling for radical revision of the old text, and partly because it is felt that it would be confusing to have two separate texts with essentially the same content but with somewhat different wordings.

For the reader's convenience, however, the revised text of Chapter C on Maximum Permissible Doses (paragraphs 45–70 of the 1958 Recommendations), as amended in 1959 and 1962, has been included in Part 4 of this report. Chapters A, B, and D of the 1958 Recommendations are also reproduced in Part 4, showing the relevant amendments. Part 4 thus contains all of the Commission's general recommendations, as amended to 1962.

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2. ORGANIZATION

THE International Commission on Radiological Protection originated in the Second International Congress of Radiology in 1928. Since then the Commission has had a close relationship with succeeding Congresses, and it has also been looked to as the appropriate body to give general guidance on the more widespread use of radiation sources caused by the rapid developments in the field of nuclear energy. The Commission wishes to maintain fully its traditional contact with medical radiology, and to fulfil its responsibilities to the medical profession. In addition, the Commission recognizes its responsibility to other professional groups and its obligation to provide guidance within the field of radiation protection as a whole.

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

The Commission has kept its recommendations 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.

Since the Ninth International Congress of Radiology in Munich the Commission has published two reports, entitled "Permissible Dose for Internal Radiation" (ICRP Publication 2), and "Protection Against X-rays up to Energies of 3 MeV and Beta- and Gamma-rays from Sealed Sources" (ICRP Publication 3). The latter report is essentially a code of practice for medical radiologists.

In 1959 the International Commission on Radiological Protection and the International Commission on Radiological Units and Measurements were jointly asked by the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) to prepare a report dealing with somatic effects of medical radiation exposures. A study group was appointed at the Munich meeting; it met in 1960, and prepared a report entitled "Exposure of Man to Ionizing Radiation Arising from Medical Procedures, with Special Reference to Radiation-Induced Diseases". The report was submitted to the UNSCEAR at the end of 1960, and in 1961 it was published in *Physics in Medicine and Biology* 6, No. 2 (Taylor and Francis Ltd., London).

Committee reports have also been prepared on:

(*a*) Protection Against Electromagnetic Radiation above 3 MeV and Electrons, Neutrons and Protons;

(*b*) Handling and Disposal of Radioactive Materials in Hospitals and Small Establishments;

(*c*) RBE (Relative Biological Effectiveness).*

It is expected that these reports will be published during 1964.

The Commission has maintained close contact with the World Health Organization (WHO) and with the International Atomic Energy Agency (IAEA), with both of which the Commission has an official relationship. The Commission has been represented by observers at a number of meetings organized by the WHO and the IAEA. Co-operation has also been maintained with the International Labour Office (ILO), the Food and Agriculture Organization, and the UNSCEAR, all of which have been invited to send observers to technical meetings of the Commission and its committees. The Commission has been represented at all meetings of the UNSCEAR during the period 1960–1962.

During the period between the two last Congresses, the ILO has prepared an international instrument consisting of a Radiation Protection Convention (No. 115) supplemented by a Recommendation (No. 114). The Commission realizes that the reference to its work, in paragraphs 3,

* Published in *Health Physics* 9, No. 4 (1963).

4 and 5 of the Recommendation, increases its responsibility and adds to the importance of keeping its recommendations continually under review.

Grants of money have been made to the Commission by a number of organizations. The Ford Foundation has allocated $250,000, to be paid over a period of 5 years. The World Health Organization contributed $9,000 in the years 1960 and 1961, and $10,000 in 1962 and 1963. The International Society of Radiology gave $3,000 for the period between the 1959 and 1962 Congresses and $3,000 for 1963. A sum of $10,000 was received from the UNSCEAR in connection with the work of the Joint Study Group described above. The International Atomic Energy Agency has contributed $6,000 for 1963. The Commission wishes to express its sincere appreciation to all these organizations.

A meeting of the Commission and its committees was held in Stockholm in May 1962. The Commission also met in Ottawa in executive sessions immediately before the Tenth International Congress of Radiology; at these meetings the Commission prepared the present report incorporating its latest recommendations as well as amendments to previous recommendations.

Since the meeting in Munich the Commission has suffered the death of two of its most distinguished members; its Chairman Emeritus, Sir Ernest Rock Carling, and its Vice-Chairman Emeritus, Professor G. Failla. The Commission owes a great debt of gratitude to them for their invaluable work during the most significant years in the history of radiation protection.

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

1959–1962

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)—Deceased 1960
G. Failla, *Vice-Chairman Emeritus* (U.S.A.)—Deceased 1961

B. Lindell, *Secretary* (Sweden)

1962

E. E. Pochin, *Chairman* (Great Britain)
L. Bugnard, *Vice-Chairman* (France)
W. Binks (Great Britain)
O. Hug (Germany)
H. Jammet (France)
B. Lindell (Sweden)
J. F. Loutit (Great Britain)
K. Z. Morgan (U.S.A.)
H. J. Muller (U.S.A.)
R. M. Sievert (Sweden)
C. G. Stewart (Canada)
R. S. Stone (U.S.A.)
L. S. Taylor (U.S.A.)

F. D. Sowby, *Scientific Secretary* (Canada)

During the Stockholm meeting in May, 1962, the Commission decided to reorganize the structure of its committees. The previous committees were dissolved at the time of the Tenth International Congress of Radiology and four new committees were established to review various topics of interest to the Commission:

1. Radiation Effects
2. Internal Exposure
3. External Exposure
4. Application of Recommendations.

The following have accepted invitations to serve as members of these committees:

Committee 1

J. F. LOUTIT, *Chairman* (Great Britain)
F. DEVIK (Norway)
A. R. GOPAL-AYENGAR (India)
O. HUG (Germany)
L. F. LAMERTON (Great Britain)
J. LEJEUNE (France)
H. B. NEWCOMBE (Canada)
R. SCOTT RUSSELL (Great Britain)
A. C. UPTON (U.S.A.)

Committee 2

K. Z. MORGAN, *Chairman* (U.S.A.)
W. BINKS (Great Britain)
A. M. BRUES (U.S.A.)
B. CHR. CHRISTENSEN (Denmark)
M. IZAWA (Japan)
M. LAFUMA (France)
L. D. MARINELLI (U.S.A.)
W. G. MARLEY (Great Britain)
E. E. POCHIN (Great Britain)
V. SHAMOV (U.S.S.R.)
W. S. SNYDER (U.S.A.)
C. G. STEWART (Canada)

Committee 3

E. E. SMITH, *Chairman* (Great Britain)
J. DUTREIX (France)
R. G. JAEGER (Austria)
L.-E. LARSSON (Sweden)
A. PERUSSIA (Italy)
E. DALE TROUT (U.S.A.)
B. M. WHEATLEY (Great Britain)
H. O. WYCKOFF (U.S.A.)

Committee 4

H. JAMMET, *Chairman* (France)
D. J. BENISON (Argentina)
G. C. BUTLER (Canada)
H. DAW (U.A.R.)
H. J. DUNSTER (Great Britain)
B. LINDELL (Sweden)
D. MECHALI (France)
C. POLVANI (Italy)
P. RECHT (Belgium)
C. P. STRAUB (U.S.A.)
E. G. STRUXNESS (U.S.A.)
F. WESTERN (U.S.A.)

This reorganization does not change, in essence, the scope of program of the previous Committees I and II, but the old Committees III, IV and V and the ICRP/ICRU Committee on RBE are not included as such under the new structure. All problems relating to external exposure, both for quantum and for particulate radiation at any energy, will now be considered within the new Committee 3. Special *ad hoc* task groups will be set up from time to time to deal with specific problems.

The Committees I–V and the *ad hoc* Committee on RBE had the following composition during the period 1959–1962.

Committee I (Advisory Committee on Biology)

J. F. LOUTIT, *Chairman* (Great Britain)
A. A. BUZZATI-TRAVERSO (Italy)
J. A. COHEN (The Netherlands)
F. DEVIK (Norway)
A. R. GOPAL-AYENGAR (India)
L. F. LAMERTON (Great Britain)
J. LEJEUNE (France)
H. B. NEWCOMBE (Canada)
J. NIELSEN (Denmark)
R. SCOTT RUSSELL (Great Britain)
A. C. STEVENSON (Great Britain)
A. C. UPTON (U.S.A.)
S. WARREN (U.S.A.)

Committee II (Protection against radiation from internal radioactive substances)

K. Z. MORGAN, *Chairman* (U.S.A.)
W. BINKS (Great Britain)
A. M. BRUES (U.S.A.)
B. CHR. CHRISTENSEN (Denmark)
M. IZAWA (Japan)
W. H. LANGHAM (U.S.A.)
L. D. MARINELLI (U.S.A.)
W. G. MARLEY (Great Britain)
M. POBEDINSKI (U.S.S.R.)
E. E. POCHIN (Great Britain)
W. S. SNYDER (U.S.A.)
C. G. STEWART (Canada)

Committee III (Protection against X-rays and electrons up to energies of 3 MeV and beta- and gamma-rays from sealed sources)

R. G. JAEGER, *Chairman* (Germany)
E. E. SMITH, *Vice-Chairman* (Great Britain)
C. B. BRAESTRUP (U.S.A.)
E. D. TROUT (U.S.A.)
C. GARRETT (Canada)
F. GAUWERKY (Germany)
H. HOLTHUSEN (Germany)
L. LORENTZON (Sweden)
S. B. OSBORN (Great Britain)
C. POLVANI (Italy)
D. J. STEVENS (Australia)
H. O. WYCKOFF (U.S.A.)
J. ZAKOVSKY (Austria)
A. ZUPPINGER (Switzerland)

Committee IV (Protection against electrons and electromagnetic radiation above 3 MeV, neutrons and radiation from heavy particle accelerators)

G. J. NEARY, *Chairman* (Great Britain)
J. W. BOAG (Great Britain)
F. HERČÍK (Czechslovakia)
G. S. HURST (U.S.A.)
H. E. JOHNS (Canada)
G. JOYET (Switzerland)
W. H. KOCH (U.S.A.)
J. S. LAUGHLIN (U.S.A.)
C. A. TOBIAS (U.S.A.)
M. TUBIANA (France)
B. M. WHEATLEY (Great Britain)
K. G. ZIMMER (Germany)

Committee V (Handling of radioactive isotopes and disposal of radioactive waste)

C. P. STRAUB, *Chairman* (U.S.A.)
L. R. DONALDSON (U.S.A.)
H. J. DUNSTER (Great Britain)
H. JAMMET (France)
A. W. KENNY (Great Britain)
C. A. MAWSON (Canada)
A. A. PERUSSIA (Italy)
E. H. QUIMBY (U.S.A.)
F. D. SOWBY (Canada)
E. G. STRUXNESS (U.S.A.)
F. WESTERN (U.S.A.)

ICRP/ICRU Committee on RBE (Relative biological effectiveness)

L. F. LAMERTON, *Chairman* (Great Britain)
J. F. LOUTIT (Great Britain)
H. H. ROSSI (U.S.A.)
W. S. SNYDER (U.S.A.)
G. J. NEARY (Great Britain)
O. HUG (Germany)
H. I. KOHN (U.S.A.)
H. QUASTLER (U.S.A.)
M. TUBIANA (France)
A. C. UPTON (U.S.A.)

RULES GOVERNING THE SELECTION AND WORK OF THE INTERNATIONAL COMMISSION ON RADIOLOGICAL PROTECTION

1. (a) The International Commission on Radiological Protection (ICRP) shall be composed of a Chairman and not more than twelve other members. The selection of the members shall be made by the ICRP from nominations submitted to it by the National Delegations to the International Congress of Radiology and by the ICRP itself. The selections shall be subject to approval by the International Executive Committee (IEC) of the Congress. Members of the ICRP shall be chosen on the basis of their recognized activity in the fields of medical radiology, radiation protection, physics, health physics, biology, genetics, biochemistry and biophysics, with regard to an appropriate balance of expertise rather than to nationality.

(b) The membership of the ICRP shall be approved during each International Congress for service until the end of the succeeding Congress, or until new members are appointed. Not less than two but not more than four members shall be changed at any one Congress. In the intervening period vacancies may be filled by 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 shall not have voting privileges unless specifically authorized by the ICRP.

(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 their opinions may be recorded in the minutes.

2. The Chairman shall be elected by the ICRP from among its members to serve until the end of the succeeding Congress, or until his successor is elected. The choice shall not be limited to the country in which it is proposed to hold the succeeding Congress. The Chairman shall be responsible for reporting the proceedings and recommendations of the ICRP at the next Congress.

3. The ICRP shall elect from among its members a Vice-Chairman who will serve in the capacity of Chairman in the event that the Chairman is unable to perform his duties.

4. Minutes of meetings and records of the ICRP shall be made by a Scientific Secretary selected by the Chairman of the ICRP, subject to the approval of its members. The Scientific Secretary need not be a member of the ICRP. The records of the ICRP shall be passed on to the succeeding Scientific Secretary.

5. The Chairman, in consultation with the Vice-Chairman and the Scientific Secretary, shall prepare a program to be submitted to the Commission for discussion at its meetings. Proposals to be considered shall be submitted to the Chairman for circulation to all members of the ICRP and other specially qualified individuals at least two months before any meeting of the ICRP.

6. Decisions of the ICRP shall be made by a majority vote of the members. A minority opinion may be appended to the minutes of a meeting if so desired by any member, upon his submission of the same in writing to the Scientific Secretary.

7. The ICRP may establish such committees as it deems necessary to perform its functions.

3. THE 1962 EXPLANATORY STATEMENTS AND AMENDMENTS TO THE 1958 RECOMMENDATIONS* AND TO THE 1959 ADDENDUM

RBE AND QF

ALL doses specified in the Commission's recommendations are expressed in rems,† which implies that the absorbed dose (expressed in rads) should be multiplied by an appropriate weighting factor. Previously the weighting factor was termed the " RBE ". The use of this term both in radiobiology and for protection purposes presents certain problems, which are discussed in detail in the Report of the ICRP/ICRU Committee on RBE (*Health Physics* **9**, No. 4 (1963)).

The Commission now endorses the following statement, taken from Report 10a‡ of the International Commission on Radiological Units and Measurements (ICRU):

> The term " RBE dose " has in past publications of the Commission not been included in the list of definitions but was merely presented as a " recognized symbol ". In its 1959 report the Commission also expressed misgivings over the utilization of the same term, " RBE ", in both radiobiology and radiation protection. It now recommends that the term RBE be used in radiobiology only and that another name be used for the linear-energy-transfer-dependent factor by which absorbed doses are to be multiplied to obtain for purposes of radiation protection a quantity that expresses on a common scale for all ionizing radiations the irradiation incurred by exposed persons. The name recommended for this factor is the *quality factor* (*QF*). Provision for other factors are also made. Thus a *distribution factor* (*DF*) may be used to express the modification of biological effect due to non-uniform distribution of internally deposited isotopes. The product of absorbed dose and modifying factors is termed the *dose equivalent* (*DE*). As a result of discussions between ICRU and ICRP the following formulation has been agreed upon:
>
> *The Dose Equivalent*
>
> 1. For protection purposes it is useful to define a quantity which will be termed the " dose equivalent " (*DE*).
> 2. (*DE*) is defined as the product of absorbed dose, *D*, quality factor (*QF*), dose distribution factor (*DF*), and other necessary modifying factors.
>
> $$(DE) = D(QF)(DF) \ldots$$
>
> 3. The unit of dose equivalent is the " rem ". The dose equivalent is numerically equal to the dose in rads multiplied by the appropriate modifying factors.

With regard to the actual values of *QF* that should be used for radiation protection calculations, the Commission endorses the " RBE " values which it published in 1955 (*Brit. J. Radiol.*, Supplement 6). These values are related to the LET of the radiation independdently of other exposure factors. It is recommended that with regard to specification of radiation quality the basic parameter be LET_∞ (the " Stopping Power "), defined as the energy loss per unit distance of the charged particles originally set in motion by electromagnetic radiation or neutrons, or of the charged particles which originate in radiation sources (alpha-rays, beta-rays, etc.), i.e. the delta-rays are not counted as separate tracks. The *DE* (expressed in rems) is obtained by summation of the products of doses delivered at any LET and the appropriate *QF*-factors, as well as any other factors recommended by the Commission, for example the " *n* " factor (see discussion below). Simplifications of this procedure are allowed provided they do not result in an underestimate of the true *DE*. An example of such a simplification is the use of a single value of *QF* for all fast neutrons.§

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* ICRP Publication 1.

† The term " dose ", when used in this context, is now to be understood as " dose equivalent " (see discussion below).

‡ United States National Bureau of Standards Handbook 84.

§ Note the special case of the lens of the eye (*q.v.*).

The relationship between QF and LET recommended for radiation protection calculations is the following:

TABLE I. LET–QF RELATIONSHIP

LET_∞ (keV per micron in water)	QF
3.5 or less	1
3.5–7.0	1–2
7.0–23	2–5
23–53	5–10
53–175	10–20

In practice the QF for X- and gamma-rays is taken as unity, and for electrons it is only greater than unity at very low energies.

Most practical DE problems consist in the evaluation of the hazard due to a mixture of neutrons and gamma-radiation. The QF of neutrons as a function of neutron energy has been evaluated for neutron energies up to 10 MeV (United States National Bureau of Standards Handbook 63). If the neutron energy distribution is known, the absorbed dose due to neutrons may then be multiplied by an appropriate QF to obtain the DE. If the precise neutron energy is unknown the absorbed doses due to neutrons and gamma-rays should be evaluated separately. The sum of the neutron doses multiplied by 10* and the gamma-ray doses multiplied by 1 may be considered an upper limit of the DE. Finally, the simplest approach is merely to measure the total absorbed dose and to multiply it by a QF of 10. While being the simplest, this method may result in an overestimate by a factor that can approach 10. (A detailed discussion of the measurement of neutron flux and neutron dose is to be found in United States National Bureau of Standards Handbook 72).

* Note the special case of the lens of the eye (*q.v.*).

For heavy recoil nuclei the LET may be greater than 175 keV/μ. There is however experimental evidence that even in this case the QF probably does not exceed 20. This value is therefore considered to be appropriate for heavy recoil nuclei.

For internal exposure QF should be taken as 1 for β^-, $\beta+$, gamma- and X-radiation and conversion electrons (except in the case of β^-, $\beta+$ and e^- radiations with maximum energy, E_m, $\leq$ 0.03 MeV, for which the QF is taken to be 1.7), 10 for alpha-particles and 20 for fission fragments and for nuclei recoiling during alpha-emission.

There are certain radiation exposure conditions in protection work where the QF concept as outlined above is either inapplicable or can only be applied with major qualifications. Important examples are those where gross non-uniformity of dose distribution occurs, as with the bone-seeking radioactive nuclides or with radioactive particles in the lung. For the bone-seekers special methods have been developed for the determination of maximum permissible body-burdens, involving the use of an additional factor "n", the "relative damage factor" (see Report of Committee II, ICRP Publication 2). The concept of DE for the bone-seekers, in relation to its use with external radiation, presents a number of problems, on which further work is required.

In the case of the lung, an estimate of the DE to the critical tissue determined merely by the product of QF and mean dose may be greatly in error, but further experimental advance is needed before a better estimate can be made.

THE LENS OF THE EYE AS A CRITICAL ORGAN

In the 1958 Recommendations the blood-forming organs, the gonads and the lenses of the eyes were regarded as the most radiosensitive tissues. There is evidence indicating that the lens may be specially radiosensitive only to particulate radiation of high LET (e.g. neutrons having an energy of about 1 MeV). On the evidence available at present the lens seems not to assume a greater importance than

other tissues when X-, gamma- and beta-radiations only are concerned. The Commission therefore recommends that the lenses of the eyes no longer be considered as tissues to which the formula applies, but that the maximum permissible dose shall be 4 rems/13 weeks, corresponding to a maximum permissible annual dose of 15 rems. However, in the case of particulate radiation of high LET a special *QF* of 30 shall be used, instead of the usual value of 10.

The *QF* values to be used for irradiation of the lens by radiations other than those mentioned above are still under consideration by the Commission.

SIGNIFICANT AREAS AND VOLUMES

The Commission's 1955 recommendations (*Brit. J. Radiology*, Supplement 6) included a reference to the volume or area over which the dose should be averaged in the computation of maximum permissible tissue doses. This reference has not been republished in subsequent recommendations and it is recommended that the following principles should apply.

Within permissible dose ranges specified for occupational exposure, when the object of control is to reduce to a very low order of magnitude the risk of late effects (such as malignant change from an accumulated dose of radiation) it is justifiable to consider the average dose to the whole organ or tissue. This has practical advantages in that the significant volume can be taken as that of the organ or tissue under consideration. In fact, this principle has necessarily been used already in calculating permissible concentrations of radioactive nuclides in tissues.

When skin is contaminated with radioactive material, it is considered that the previous recommendation of a significant area of 1 cm^2 might be too restrictive. It is therefore recommended that the significant area in such cases be taken to be of the order of 30 cm^2. This is a practicable recommendation from the standpoint of procedures used to determine the degree of contamination of the skin.

In other cases of external exposure, especially when the distance to the source is very short or when the exposed area is very small, it would not be appropriate to recommend the dose to be assessed as the average over 30 cm^2; for these cases it is recommended that the previous practice of referring to 1 cm^2 be maintained.

"PERMISSIBLE DOSE" AND "MAXIMUM PERMISSIBLE DOSE"

In the chapter on "Basic Concepts" (paragraphs 29–32 of the 1958 Recommendations) the Commission defined what it considers to be a *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)."

On the basis of the above criteria, the Commission has given recommendations with regard to the *maximum* dose which, still fulfilling the above requirements, should be permitted under various circumstances. The Commission has balanced as far as possible the risk of the exposure against the benefit of the practice, and has also considered the possible danger involved in remedial actions once the exposure has occurred. This dose has been called the *maximum permissible dose.*

The basis of the Commission's recommendations is that any exposure to radiation may carry some risk. The assumption has been made that, down to the lowest levels of dose, the risk of inducing disease or disability in an individual increases with the dose accumulated by the individual, but is small even at the maximum permissible levels recommended for occupational exposure. This assumption is supported by the limited statistics available which indicate that for radiation workers of the last generation, exposed, subject to the maximum permissible levels of that time, the risks of somatic effects are comparable with or less than those of the majority of other trades and professions, and would therefore be considered as not unacceptable. The Commission similarly considered the risk of somatic effects in individuals within certain population groups, and recommended maximum permissible levels for these individuals.

With regard to genetic effects, the Commission assumed that the genetic burden to a population will be proportional to the genetic dose received by that population (see paragraph 63 of the 1958 Recommendations). The Commission therefore recommended a maximum permissible genetic dose of 5 rems,* on the basis that the resulting burden to society would be " tolerable and justifiable in view of the benefits that may be expected to accrue from the expansion of the practical application of ' atomic energy ' ".

The implication of a maximum permissible dose is that it must be capable of being controlled. It is therefore clear that the Commission's recommended maximum permissible doses are appropriate for those conditions in which the levels can be controlled. However, in the case of accidents and of environmental contamination when exposures may not be subject to control, the concept of a fixed maximum permissible dose ceases to be meaningful. Instead, other considerations arise, such as the need to balance the risk from radiation against the risks of particular countermeasures. The principles upon which these risks might be assessed and balanced are still under consideration.

* From all sources additional to natural background plus the lowest practicable contribution from medical exposure.

DOSE-RATE EFFECTS

(*a*) Somatic Effects

It has long been recognized that the effects of radiation may be dependent not only on the accumulated dose received but also on the way in which this total is fractionated and on the dose-rate at which each fraction is given. This applies particularly to radiation of low LET such as X-rays, gamma-rays and beta-radiation which are by far the commonest radiations encountered in occupational practice at the present time. It appears possible on some theoretical and experimental grounds that when either the total dose or the dose-rate is very low any effects will be directly proportional to the total dose and independent of dose-rate. This assumption is implicit in past recommendations on permissible levels and although confirmatory proof is lacking it is believed to be a reasonable basis for assessment.

(*b*) Genetic Effects

A linear dose-effect relationship unaffected by dose-rate has been generally accepted in the past for gene-mutations. Recent experimental work has shown, however, that at intermediate and higher levels of dose-rate the number of mutations produced in test-subjects may not be independent of dose-rate. Because of the importance of the genetic effect the Commission has made a special survey of recent work. This survey indicates that evidence for dependence of mutation frequency on dose-rate comes at present almost entirely from a study of seven gene-loci in spermatogonial cells and oocytes of the mouse. For insects there is not yet clear evidence of a difference in effectiveness of acute

and chronic doses that cannot be ascribed to selection. No general relationship appears therefore to hold for all species, and the Commission does not at present modify its recommendations to allow for dose-rate effects in man.

CATEGORIES OF EXPOSURE

In paragraph 36 of the 1958 Recommendations the Commission referred to certain categories of exposed *individuals*, essentially within three groups:

A: Occupationally exposed individuals

B: Special groups

C: The population at large.

Group B was subdivided into three subgroups, namely:

"B(*a*): Adults who work in the vicinity of controlled areas, but who are not themselves employed on work causing exposure to radiation,

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

"B(*c*): Members of the public living in the neighborhood of controlled areas."

In the 1958 Recommendations the Commission made certain recommendations regarding the exposure of individuals in groups A and B. No recommendation was given in the 1958 Recommendations with regard to the dose to individuals in the population at large, but in an additional paragraph in the 1959 Addendum it was recommended that the maximum dose to these individuals should be equal to the maximum recommended for individuals within group B(c).

The Commission recognizes that the above description of the categories of exposure of *individuals* may have been open to misunderstanding, and in particular that the term "exposure of special groups" may have been taken to imply that maximum permissible doses for individuals in this category of exposure refer to a dose averaged over the group. To avoid this misunderstanding the above categories of exposure have been slightly revised to conform with current practice and the present recommendations relate to exposure of three categories of individuals.*

The first category consists of individuals who are occupationally exposed to radiation.†

The second category comprises adults who work in the vicinity of controlled areas or who enter controlled areas occasionally in the course of their duties, but who are not themselves employed on work involving exposure to radiation.

The third category consists of individual members of the population at large (including persons living in the neighborhood of controlled areas). The reader is referred to paragraphs 45–57a in Section 4(c) of this report for the maximum permissible doses applicable to individuals in these categories.

In addition to recommending maximum permissible doses for individuals, the Commission also gives separate recommendations about the average exposure to the population as a whole, determined by exposures of the individuals within the above categories (see paragraphs 58–70c of Section 4(c) of this report).

EXPOSURE OF WOMEN OF REPRODUCTIVE AGE

Occupational Exposure

The Commission has reviewed the questions involved in the occupational exposure of pregnant women, and the associated possibilities of somatic damage to foetal tissues which were referred to in the 1959 Addendum to ICRP Publication 1 (1958 Recommendations). In this connection, consideration must be given to exposure during a period of up to 2 months before a pregnancy is recognized, and to exposure during the remainder of the pregnancy.

* It should be noted that exposures within the first two categories as defined here correspond to the two classes of exposure used in the International Labour Office's Radiation Protection Convention, namely (1) Workers directly engaged in radiation work, and (2) Workers not directly engaged in radiation work.

† The term "occupational exposure" refers to exposure within controlled areas, i.e. where workers could receive doses in excess of 1.5 rems/year (paragraphs 37 and 71 of Section 4 of this report).

During the first of these periods, many of the processes of embryogenesis and organogenesis are occurring; this is a stage when the embryo is particularly sensitive to radiation. It is also evident that any recommendations for this period must in practice apply to all women of reproductive age.

In the 1959 Addendum to ICRP Publication 1, the Commission made the following recommendation with regard to the receipt of quarterly doses of 3 rems, referred to in paragraph 49 of ICRP Publication 1:

> 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, especially in the case of women of reproductive age.

The Commission is now of the opinion that the recommendation given in paragraph 49 of ICRP Publication 1, for dose accumulation at rates up to 3 rems per quarter, should not apply in circumstances involving abdominal exposure of women of reproductive age. The Commission now recommends that women of reproductive age should be occupationally employed only under conditions where the exposure of the abdomen is limited to 1.3 rems in a 13-week period, corresponding to 5 rems per year delivered at an even rate. Under these conditions the dose to an embryo during the first two months of pregnancy would normally be less than 1 rem, a dose which the Commission considers to be acceptable.

After two months it is likely that a pregnancy would be recognized by the woman herself or by her physician. While many of the critical stages of embryogenesis are now past, more recent evidence indicates that even at this stage the fetus is still particularly radiosensitive. For instance, investigation has shown that exposure of fetuses to doses of a few rads of X-rays can give rise to detectable somatic mutations, resulting in the condition of pigment mosaicism, although this condition does not appear to be detrimental. Furthermore, the possible induction of leukaemia and other malignant conditions has to be considered. Surveys of such conditions in children have in the past led to conflicting conclusions. Recent studies, however, do indicate that exposure of the fetus *in utero* to doses of a few rads of X-rays might somewhat increase the incidence of malignant disease within the subsequent decade.

For occupational exposure, therefore, it is now recommended that when a pregnancy has been diagnosed, arrangements be made to ensure that the exposure of the woman be such that the average dose to her fetus during the remaining period of the pregnancy does not exceed 1 rem. Under conditions in which the foetal dose may approximate to that received by the woman, for example when the abdomen is exposed to penetrating radiation, this recommendation will normally be met if the woman is not exposed at rates greater than those applicable to members of groups B(a) and B(b) as specified in ICRP Publication 1, since such workers may not be exposed at rates greater than 1.5 rems per year (see paragraph 54).

Under conditions in which the fetal dose will be considerably less than that received by the woman, as for example when working with diagnostic X-ray equipment of 150 kv or less, or where the abdomen is protected from or not exposed to the radiation, the recommendation may be satisfied by continuing occupational exposure of the woman at a rate not exceeding 1.3 rems per 13 weeks.

Exposure of Individuals in Special Groups

With regard to pregnant women exposed under the conditions which relate to the former groups B(a) and B(b), it is considered that no special precautions need to be taken.

Radiological Examinations of Women of Reproductive Age

The Commission wishes to call attention to reports of embryonic and fetal sensitivity to ionizing radiation and to emphasize that the possibility of pregnancy must be taken into account by the attending physician when deciding on radiological examinations that involve the lower abdomen and pelvis of women of reproductive age. The Commission also wishes to point out that the ten-day interval following the onset of menstruation is the only

time when it is virtually certain that women of such age are not pregnant. Therefore, it is recommended that all radiological examinations of the lower abdomen and pelvis of women of reproductive age, that are not of importance in connection with the immediate illness of the patient, be limited in time to this period when pregnancy is improbable. The examinations that should be delayed to await the onset of the next menstruation are those that could without detriment be delayed till the conclusion of a pregnancy or at least until its latter half.

REWORDING AND EXTENSION OF PARAGRAPH 52e AND 52g OF THE 1959 ADDENDUM TO ICRP PUBLICATION 1, CONCERNING SHORT-TERM EXPOSURES AND EMERGENCY WORK

The recommendations on short-term exposure to radioactive materials given in the above-mentioned paragraphs have been useful in establishing general principles of interpretation for such exposure. However, experience has indicated that the restriction on exposure as given in the last paragraph of 52g might be dealt with more effectively, in the case of long-lived bone-seeking nuclides, by using the method described in paragraph 86a (*q.v.*). Also the wording of paragraphs 52e and 52g has been slightly altered to make it entirely clear that short-term intakes are being compared with intakes at the MPC levels and not with the resulting body-burden, and that hazards not due to radiation may require a separate assessment. Therefore, paragraph 52e is replaced by the following statement:

> (52e) One or more short-term exposures to radioactive materials within a period of 13 consecutive weeks are considered acceptable if the total *intake* of radioactive material during this period does not exceed the cumulative intake allowed when exposure occurs for 13 weeks at the maximum levels (MPC values) for occupational exposure given in the Report of Committee II (ICRP Publication 2). If significant exposure to external sources occurs concurrently, the quarterly intake referred to above should be estimated to make allowance for the dose equivalent delivered by external sources (ICRP Publication 2, page 24). The 50-year integrated dose to the critical organ from such an intake will not exceed 1.3 rems for the whole body, blood-forming organs or gonads, 8 rems for skin, thyroid and bone,* and 4 rems for other organs.

Because of the chemical toxicity of natural uranium, U^{238}, U^{236}, or U^{235} in soluble form in amounts permitted according to the above on the basis of radiological protection, the inhalation of uranium of any isotopic composition should not exceed 2.5 milligrams of soluble uranium in one day, or the ingestion averaged over 2 days should not exceed 150 milligrams of soluble uranium.† For insoluble forms of uranium, maximum intake shall be limited by the same rule that applies to other radioactive materials set forth above.

Because of the low specific activity of certain other radioactive materials with very long radioactive half-lives (e.g. Rb^{87}, In^{115}, Nd^{144}, Sm^{147}, Re^{187}, etc.), the mass or chemical toxicity will in general determine maximum rates of intake. Similar considerations will apply also to the values given in Table 1 of ICRP Publication 2. Paragraph 52g is replaced by the following statement:

> Emergency work involving exposure to radioactive materials at levels above the normal maximum permissible concentrations shall be planned on the basis that the total intake of radioactive material during the emergency period should not exceed the cumulative intake that would result from exposure for 1 year at the maximum levels (MPC values) for occupational exposure to such radioactive materials given in the Report of Committee II (ICRP Publication 2). If significant exposure to external sources might be expected to occur concurrently, the annual intake referred to above should be estimated to make allowance for the dose equivalent delivered by the external sources (ICRP Publication 2, page 24). The 50-year integrated dose to the critical organ from such an intake

* The dose to bone is based on a body-burden of 0.1 μc of Ra^{226} (see Report of Committee II, ICRP Publication 2).

† This restriction on the ingestion of soluble form of uranium revises the maximum permissible concentration recommended in Table 1 of ICRP Publication 2 for the continuous ingestion of drinking water. The new values of MPC for uranium that result from taking into account the chemical toxicity of uranium are given in Part 5 of the present report (ICRP Publication 6).