1 The development of the organizational and conceptual basis of radiological protection[1]

Within a few weeks of Roentgen's discovery of X-rays in 1895, the potential of X-rays for diagnosing fractures became apparent. However, the occurrence of acute adverse effects such as erythema and skin burns within the next few years made persons applying X-rays in medicine and technique aware of the need to avoid overexposure. Similar undesirable effects were reported after the discovery of natural radioactivity by H. Becquerel in 1896, specifically of radium by M. Curie, and medical application.

The first organized coordinated effort for radiation protection came in 1921 when the British X-ray and Radium Protection Committee issued detailed recommendations and instructions. The American Roentgen Ray Society also proposed general recommendations in the early 1920s on the basis of avoiding acute effects.

At the Second International Congress of Radiology held in Stockholm in 1928 [28B1], the unit "roentgen" (R) was recognized as the unit for X-ray dose. It was at this congress that the "International X-ray and Radium Protection Commission" was founded, the forerunner of the later (from 1950 onwards) "International Commission on Radioligical Protection (ICRP)". The primary concern of the 1928 Commission was to elaborate recommendations designed to provide protection to members of the medical profession in their work with X-rays and gamma-rays from radium. In 1934 the Commission recommended 0.2 R per day as the "tolerance dose" [34I1].

Due to the great expansion in radiation protection work consequent upon nuclear energy developments in the period from 1940 to 1950, the International Congress of Radiology in 1950 [51I1] extended the scope of the Commission - now ICRP - and broadened its area of responsibility beyond the protection of the medical profession only.

It was in 1950 that the ICRP spelt out the first time the various effects which were to be considered in making its recommendations. These recommendations were to deal primarily with the basic principles of radiation protection and to leave to the various international and regional agencies such as IAEA, EURATOM and national regulatory bodies the responsibility of introducing detailed technical regulations, codes of pratice or laws suited to the needs of their member countries or specific countries.

The present Commission of ICRP is assisted by 4 Committees working in the following specialized fields [99I1]:

- Committee 1 (Radiation Effects) considers the risk of induction of cancer and heritable disease together with the underlying mechanisms of radiation action; also, the risks, severity, and mechanism of induction of tissue/organ damage and developmental defects.

- Committee 2 (Doses from Radiation Exposures) is concerned with the development of dose coefficients for the assessment of internal and external radiation exposure, development of reference biokinetic and dosimetric models, and reference data for workers and members of the public.

[1] A concise and consolidated summary is given by A. Nagaratnam [95N1] in his handbook on the salient features of the information given in ICRP Publications on the concept of radiological protection.

- Committee 3 (Protection in Medicine) is concerned with protection of persons and newborn children when ionizing radiation is used for medical diagnosis, therapy, or for biomedical research; also, assessment of the medical consequences of accidental exposures.

- Committee 4 (Application of the Commission's Recommendations) is concerned with providing advice on the application of the recommended system of protection in all its facets for occupational and public exposure; it also acts as the major point of contact with other international organizations and professional societies concerned with protection against ionizing radiation.

In its 1950 recommendations [51I1], ICRP replaced the 1934 concept of "tolerance dose" [34I1] by that of the "maximum permissible dose" with the recognition that there could be risk even at these levels: "Whilst the values proposed for maximum permissible exposure are such as to involve a risk which is small compared to other hazards of life, nevertheless, in view of the unsatisfactory nature of much of the evidence on which our judgement must be based, coupled with the knowledge that certain radiation effects are irreversible and cumulative, it is strongly recommended that every effort be made to reduce exposure to all types of radiation to the lowest possible levels ... and that any unnecessary exposure be avoided".

According to the 1958 recommendations [59I1] the basic permissible dose to gonads, bloodforming organs, and lenses of the eyes for persons occupationally exposed at any age over 18 years was 5 rem (50 mSv) per year or weekly 0.1 rem (1 mSv), used for purposes of planning and design. No recommendation was made for exposure of individual members of the public but it was suggested that the per capita dose should not exceed 5 rem (50 mSv) per generation excluding medical exposures and exposures to natural background radiation. A linear non-threshold response was assumed for genetic effects.

In 1962 it was recommended by the ICRP that the dose to individual members of the population at large should be limited to 0.5 rem (5 mSv) per year [64I1]. ICRP made it explicit that doses from natural background and from medical exposures were excluded from the maximum permissible doses. However, ICRP "recognizes especially the importance of the gonad doses resulting from medical exposure and the attendant genetic hazard to the population", and recommended that "the medical profession exercises 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".

In 1977 [77I1] ICRP published epoch-making recommendations giving a new philosophical and conceptual framework of radiological protection. It is characterized by

1. Statement of the aim of radiation protection as being to prevent detrimental non-stochastic effects and to limit the probability of stochastic effects to levels deemed to be acceptable.
2. Formulation of the basic tenets of the system of radiation protection as
   a: *Justification*: No practice shall be adopted unless its introduction produces a positive net benefit.
   b: *Optimization*: All (necessary) exposures shall be kept as low as reasonably achievable, economic and social factors being taken into account (ALARA principle).
   c: *Dose limitation*: The dose equivalents to individuals shall not exceed the limits recommended for the appropriate circumstances by the Commission (limitation of the effective dose equivalent for stochastic effects in workers to 50 mSv per year, for non-stochastic effects in specific organs to 500 mSv annually; limitation of the effective dose equivalent to control the risk from stochastic effects of individual members of the public (critical groups) to 5 mSv in a year, and to 50 mSv annually for non - stochastic effects).

Subsequent to the publication of the 1977 recommendations there have been clarifications and amendments, the most important ones at the 1985 meeting of the Commission [85I1]:
Considering the effective dose equivalent limits for members of the public, made in its 1977 recommendations, "the Commission's present view is that the principal (stochastic) limit is 1 mSv in a year. However, it is permissible to use a subsidiary dose limit of 5 mSv in a year for some years, provided that the average annual effective dose equivalent over a lifetime does not exceeed the principal limit of 1 mSv in a year".

Apart from changes in terminology and definitions:

- "non - stochastic effects" are now called "deterministic effects",
- "quality factor" is replaced by "radiation weighting factor",
- "dose equivalent" is replaced by "equivalent dose",
- "effective dose equivalent" is replaced by "effective dose"

the 1990 recommendations of the ICRP in its Publication 60 [91I1] have brought down significantly the dose limits for occupational exposure from 50 mSv for the annual effective dose to 100 mSv in 5 years corresponding to an average of 20 mSv annually. (Additionally the effective dose should not exceed 50 mSv in a single year).

The concept of justification, optimization and individual dose limits has been retained, however, a distinction is made between the systems of protection for *proposed* and *continuing practices*, and *intervention*:

While, as in the past, the system of protection in practices is following the general principles of justification of a practice, optimization of protection (the magnitude of individual doses, the number of people exposed, and the likelihood of incurring potential exposures should all be kept as low as reasonably achievable, economic and social factors being taken into account), and limitation of individual dose and risk, an additional system of protection in intervention has been introduced.

This is based on the following principles:

1. The proposed intervention should do more good than harm, i.e. the reduction in detriment resulting from the reduction in dose should be sufficient to justify the harm and the costs, including social costs, of the intervention.
2. The form, scale, and duration of the intervention should be optimized so that the net benefit of the reduction of dose and consequently of the detriment should be maximized.

Regarding hereditary effects, ICRP Publ.26 [77I1] added the hereditary risk to the first and second generation offspring to the stochastic risk to the exposed individual, the effects in later generations being considered as part of the consequences for society. ICRP Publ.60 [91I1] now attributes the whole hereditary detriment to the detriment suffered by the exposed individual, thus avoiding the need for a two - stage assessment.

Under the motto "Radiological Protection at the Start of the 21th Century" ICRP in 2002 has started an initiative which represents a genuine attempt to simplify the system of protection to one that is more coherent and easily explicable [02C1; 02C2].

Since classical cost-benefit analysis based on an utilitarian ethical policy answering the question "how much does it cost to reduce a dose and how many lives are saved?", is unable to consider the individual, the Commission already modified the principle of optimization by the introduction of the concept of a *constraint*. Constraint is an individual-related criterion, applied to a single source in order to ensure that the most exposed individuals are not subjected to excessive risk, and to limit the inequity introduced by cost-benefit analysis.

Although in the future the process of taking all reasonable action to reduce exposures is still likely to be called the Optimization of Protection, optimization is intended to be replaced by a different requirement. Namely, residual doses, after the application of *Constraints*, should be kept "as low as reasonably achievable" (ALARA). In this context the emphasis of constraints should provide a basic level of health protection for individuals exposed to a particular controllable source. Since there is likely to be some risk to health even at small doses introduction of a moral requirement is discussed for each controllable source to take all reasonable steps to restrict both the individual doses to levels below the action level and the number of exposed individuals. In this context it should be emphasized that these Constraints are not intended to be applied to justified medical exposures.

Under the aspect "common sense would be often more important than formal application of differential equations in optimization" stakeholder involvement is discussed to determine or negotiate for the best level of protection in the circumstances. This means that whilst the dose constraints thus represent a basic standard of individual health protection, stakeholder involvement determines how far

below the action level is “as low as reasonable practicable”, and will avoid the previous formal cost-benefit analyses. Consequently ALARA would represent the optimum level of protection from the source under control or for an uncontrolled source.

References

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