EVOLUTION AND TRENDS OF THE CONCEPT OF DOSE LIMITS

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INTRODUCTION

The purpose of this presentation is to review the evolution of an important concept of radiation protection, discussing the change of emphasis or even meaning involved in its use. The concept discussed is that of the limits and the extension of their use to situations not covered in the past. While the author is involved in the work of the ICRP, it should be noted that, except when they are straight quotations, the materials presented in this paper do not represent necessarily the formal position of the ICRP.

DOSE LIMITS

The dose limits are at present only one component of the radiation protection recommendations. However, they are usually judged to have great importance, and the fact that the ICRP recommended values have been widely accepted has resulted in a global uniformity that is very positive for radiation protection.

Limits in the past

The real meaning of the limits has changed basically with the improving knowledge of radiobiology. Radiation protection has evolved enormously since the early concepts of "tolerable" levels of radiation that were analogous to toxicological ideas of thresholds and safety factors. In the old days, protection was considered to be absolute, provided that the technical means used to control and restrict the radiation levels did not fail.

This approach was very reasonable when only what is now called "non-stochastic effects" of radiation were known. However, in spite of advances in radiobiological knowledge, this approach persisted, even if qualified by some statements. A far-reaching consequence of the threshold and safety factor concept was the tendency to interpret radiation protection solely as an "individual-related" activity, a tendency which persisted long after non-threshold effects were beginning to be taken into account. With this perspective, the relevant protection parameter was deemed to be the total dose to individuals, irrespective of the sources of origin.

Conceptual basis of present dose limitation

The identification and mainly the quantification of what is called now the "stochastic effects" of radiation caused a continuing change of attitude in radiation protection, which crystallized in the recommendation contained in ICRP Publication 26. It is not the purpose of this paper to describe in detail what is prescribed in the recommendation, but to stress the conceptual changes.

The role of the limit is to provide a minimum level of protection. The dose limits recommended by the ICRP are not intended, as they were in the past, to be design or planning values, but the lower boundary of a non-acceptable region of values. Values above the limits are specifically not permitted, but values below the limits are not automatically permitted. In this sense, the limits are basically constraints for the optimization procedures.

However, the use of limits as constraints for optimization presents some conceptual difficulties, especially in the case of exposures of members of the public. The limit is an individual-related requirement, while optimization is a source-related requirement. Because the limits apply to the combined exposure from many sources, they cannot be used to restrict a given single source even when optimization would allow it. In fact, exposures at the limit from one single source would leave no margin for other practices exposing the same critical group. The problem of overlap of exposures from different practices is not restricted to any given instant of time. Each year of operation of a continuing practice can cause exposures which would be delivered in the future and which would add to the contribution of other years of operation in the practice.

It is possible to control the combined future average effective dose equivalent from all practices by applying practical limits to the dose commitment per unit practice for each of the practices. This concept has been used in some countries to set constraints to the collective effective dose equivalente commitment per MW year of electrical energy produced by nuclear means.

Upper bounds

For the purpose of constraining optimization of the protection of specific practices or sources, it seems reasonable that national authorities select "dose upper bounds" which are only fractions of the dose limit, allowing for the exposure overlap from all practices, and even reserving some margin for unforseen but justified sources in the future, which otherwise could be precluded.

Upper bounds are the real basic constraints for the optimization of radiation protection of specific practices or sources. An upper bound of dose corresponds to an upper bound of the radiation risk due to a specific practice. It is therefore possible to select upper bounds for given practices by comparison with what is considered acceptable by society for other types of risks, either of similar practices or of practices giving similarly beneficial products.

The dose limits recommended for the case of occupational exposures are typical group upper bounds for a situation where many different exposing radiation sources can exist. In spite of their historical development, they really are at present source-related group upper bounds. This flavour is strongly reflected in the ICRP policy underlying the use of committed dose equivalent.

In a statement the Commission confirms that its policy is to limit the risk committed by each year of operation, no credit being taken for earlier years, if they have committed lower risks or for future years in the expectation of improved conditions of exposure.

It is also clear that the purpose is to limit the risk committed in a given period, and not the time distribution of the expression of the risk. The same is true when considering continuing practices, where the limitation applies to the dose commitment from a year of practice (and therefore to the maximum per caput annual dose in the future), thus limiting the risk committed by one year of practice.

Limits in the near future

It is likely that no revolutionary changes will occur with the limit concept. Limits will be presented as combined upper bounds, having the aim of restricting the risk committed during one year of work or practice. The ensuing risk expression will be distributed in time even in the case of pure external exposures, existing a double time distribution for the case of intakes of radionucleides and a triple time distribution in the case of releases into the environment.

It is also likely that there will be more emphasis on upper bounds and group upper bounds for specified limited groups of sources. The value of the limits will probably depend on radiological knowledge accumulated during the development of new recommendations, but the criterion of comparison of risks with safe industry and with hazards of everyday's life are likely to be maintained.

LIMITATION OF RISK IN THE CASE OF PROBABILISTIC EXPOSURES

The system of dose limitation recommended by the ICRP gives no guidance on design criteria for features reducing the probability of disruptive events leading to radiation exposures. However, the underlying philosophy of the system could be used for such purpose.

This possibility stems from the basic concept that the limits really restrict the risk due to a year of work or practice. With a random accidental event, the risk depends on the probability of the event and on the resulting dose in the individuals receiving the highest dose. Regarding radiation effects, one deals, therefore, with effects of second order stochasticity. For example, the probability of dying (risk) of a member of the public due to a given potential disruptive event can be expressed as $R = P_1 P_2$, where R is the "risk", P_1 is the probability of occurrence of the event which would result in a dose H to the member of the public under consideration, and P_2 is the conditional probability of death given dose H.

If several potential events are taken to be possible, the risk R defined in the previous paragraph becomes:

$$R = \sum_i P_{1i} P_{2i}$$

It should be realized that all P_2 are proportional to dose at the lower doses (where only stochastic effects are possible), but increase steeply with whole-body dose at values above 2 Gy due to acute non-stochastic effects. Probability values must be assigned to the disruptive events that are expected to cause significant exposures if they occur. Event-tree assessments will yield probability values P_{1i} due to the various potential events.

There is no inherent reason to limit the risk due to probabilistic events to the same level as that implied by the dose upper bound set for a particular source, specially if such an upper bound was established specifically for normal operations. Nevertheless, if it is assumed that the purpose is to restrict the risk to that order of magnitude, for members of the public it should correspond to annual values of 10^{-6} to 10^{-5}. For example, selecting an annual value of 10^{-6}, the design of safety features should be such that

$$\sum_i P_{1i} P_{2i} \leq 10^{-6}$$

Some countries use this type of probabilistic criterion for other applications, such as in nuclear safety assessments. The main use, however, is expected to be in the design of safety features involved in the use of large radiation sources.