Internal monitoring of intakes of radioactive materials: New approaches of the ICRP

A review of ICRP publications in this area

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The International Commission on Radiological Protection (ICRP) has formulated recommendations concerning the philosophy of radiation protection. This philosophy has been used by the IAEA, World Health Organization (WHO), International Labour Organisation (ILO), and the Nuclear Energy Agency of the Organisation for Economic Co-operation and Development (NEA/OECD) for preparation in 1982 of the revised *Basic safety standards for radiation protection*. It provides a worldwide basis for harmonized and up-to-date radiation protection standards.* These revised standards were a new substantial step in the continuing efforts of the Agency towards reducing the risk resulting from the use of radioactive materials and other sources of ionizing radiation. The main idea of this ICRP philosophy is the control of individual risks through special dose limits, optimization of radiation protection, and justification of all practices involving exposure to radiation.

To authorities and persons who are responsible for the protection of workers against ionizing radiation and to those concerned with the planning and management of occupational radiation protection, the general principles have been set out by the ICRP in *General principles of monitoring for radiation protection of workers* and lately by the IAEA in its *Basic principles for occupational radiation monitoring.*** The main objectives of radiation monitoring of workers are to ensure that exposures are kept as low as reasonably achievable and that the authorized limits are not exceeded.

The type and extent of radiation monitoring required depends on the radiological conditions in the area of work concerned and the radiation conditions associated with the work. Such a programme requires comprehensive internal radiation monitoring among other monitoring methods (i.e., individual dosimetry for external dose, contamination of skin and clothes, workplace monitoring, including determination of radiation levels, airborne contamination, and surface contamination). This can be achieved by using special apparatus designed to measure radiation emitted from the body (whole-body counters or monitors, or partial-body counters such as a thyroid counter) and/or by bioassay procedures (analysis of urine and faeces).

Until recently, there has been a lack of information in the chain of the dose limitation system, the annual limits on intake of radionuclides, principles of internal monitoring, and interpretation of the results of measurements. In accordance with the ICRP's general principles for quantitative assessment of internal exposures, monitoring programmes using these methods must be designed and implemented in such a manner that the results can be used either to assess primary quantities (committed effective dose equivalent or committed dose equivalent) for comparison with primary limits or to assess the secondary quantity (intake of radionuclides) for comparison with the annual limit on intake (ALI). But the last link of this chain — data used to convert the results of measurements in everyday practice to dose or to intake of radioactive material — has been practically missing. Attempts made in the 1960s to develop this part of the monitoring programme were lacking in technical basis and, therefore, were not fully successful.*

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* *Basic safety standards for radiation protection*, Safety Series No. 9, IAEA, Vienna (1982).

** *General principles of monitoring for radiation protection of workers*, Report of the ICRP Committee 4, ICRP Publication 35. *Annals of the ICRP*, Vol. 9, No. 4, Pergamon Press, Oxford (1982); and *Basic principles for occupational radiation monitoring*, IAEA Safety Series No. 84, IAEA, Vienna (1987).

* See *Evaluation of radiation doses to body tissues from internal contamination due to occupational exposure*, a report of the ICRP Committee 4, ICRP Publication 10, Pergamon Press, Oxford (1968); and *The assessment of internal contamination resulting from recurrent or prolonged uptakes*, a report of ICRP Committee 4, ICRP Publication 10a, Pergamon Press, Oxford (1971).

Dose limitation system

The ICRP system of dose limitation is based on the principle of controlling the risk associated with 1 year of work practice. To translate this principle into a dose-limitation system, ICRP has introduced the concept of the committed dose and has derived values of ALIs on the basis of limits on the committed dose equal to the annual dose limits.

In radiation exposure control of workers, it is a requirement that in any one year, the *sum* of the dose equivalent from external irradiation and of the committed effective dose equivalent from intakes of radionuclides should be below the appropriate annual dose limit. For each year it will be necessary to derive committed effective dose equivalents resulting from intakes of radionuclides in that year.

While the application of this method of dose control presents few problems with intakes of short- and medium-lived radionuclides, questions arise in the case of radionuclides which are retained in the body for a longer time and that call for further consideration. In such cases, the doses actually received during any year following the intake are small compared to the annual dose limits. The integration of such doses for 50 years, implicit in the definition of the committed dose, amounts to controlling the associated risk to well above the expected human lifespan.

An alternative procedure of calculating annual effective dose equivalents has not been recommended; this procedure would permit workers to receive in 1 year an intake of a radionuclide of sufficient magnitude that subsequent employment in future years could be limited. This would raise additional problems in recordkeeping, especially when a worker changes employment.

Committed dose equivalent

The concept of committed dose equivalent triggers a number of problems related to exposure data recordkeeping.

A worker may sustain radiation exposure either from radiation sources external to the body or from intakes to the body of radioactive materials. The ICRP requires that doses from all sources be considered additively and be subject to the overriding requirement of the dose equivalent limits for non-stochastic and stochastic radiation effects. For such intake of radioactive materials, it will therefore be necessary to estimate the dose equivalent by every tissue in the body which is irradiated to a significant extent. The ALIs are derived from the concept of "committed dose equivalent" (over 50 years). Specific values cannot be estimated without further knowledge of the metabolism of the radionuclides. This implies the availability of *complete* information about the physical properties of radionuclides incorporated and their metabolism (uptake, retention, and distribution of a radionuclide and its daughter products in all the tissues of the body). The physical properties (i.e., essentially the nature and the energy of the radiation emitted) have been known with very satisfactory precision for a long time.* As for the modelling of the metabolism, this has progressed a great deal during the last 20 years, as is shown by the development of knowledge between issuance of two other ICRP publications, specifically numbers 2 and 30.**

ICRP Publication 30 specifies ALIs by ingestion and inhalation for a large number of radionuclides which will ensure that the dose limits to different tissues do not exceed those prescribed by the ICRP. It aims to give complete information about the fate of a radionuclide after it enters the body (i.e., the retention function is given for each organ and tissue concerned).

Strictly speaking, individual monitoring programmes for internal exposure usually cannot be based on the model and data characterizing specific features of metabolism of the individual worker concerned. They are not known to a sufficient extent beforehand. If established later, their use (leading to different programmes for different persons) would not be warranted for situations characterized by low levels of exposure. General models are used for such situations.

Publication 30 also describes general models of human adult metabolism and models for individual chemical elements. They are used for establishing the secondary basic limits for internal exposure of workers. The annual limits of intake are used for protection planning; they are the result of a choice of conservative rather than average or realistic parameters and assumptions. They also do not always describe adequately the excretion and the early phase of metabolism, which are of no or small importance for establishing the ALI, but might be important in monitoring.

However, the simplicity of the ICRP system, independent of the age and sex of the worker, is an attractive feature which may outweigh the inequity which it introduces.

The results from these monitoring practices will give no meaningful information without further interpretation even in exceptional circumstances (e.g., the direct monitoring of radioiodine in the thyroid gland or the estimation of tritiated water in urine after equilibrium following intake). To obviate difficulties in the interpretation of the results of measurements in the field of internal contamination, ICRP Committee 4 prepared the new publication *Individual monitoring for intakes of radionuclides by workers: Design and interpretation.****

* *Radionuclide transformations: Energy and intensity of emission*, ICRP Publication 38, *Annals of the ICRP*, Vols. 11-13, Pergamon Press, Oxford (1983).

** *Recommendations: ICRP report of Committee 2 on permissible dose for internal radiation, 1959*, ICRP Publication 2, Pergamon Press, Oxford (1960); and *Limits for intake of radionuclides by workers*, ICRP Publication 30 Part 1, *Annals of the ICRP*, Vol 2, No. 3/4, Pergamon Press, Oxford (1979).

*** *Individual monitoring for intakes of radionuclides by workers: Design and interpretation*, a report of the ICRP Committee 4, ICRP Publication 54, *Annals of the ICRP*, Vol. 9, No. 4, Pergamon Press, Oxford (1988).

This document has been adopted by the main commission of the ICRP.

After a review of the principles of individual monitoring and the use of derived reference levels in this operation, this publication provides a description of the metabolic models which have been used to establish the functions of the retention and excretion of radionuclides. Following this, an extensive treatment is given of the methods for monitoring, on one hand by direct measurement on the individual, and on the other by radiotoxicological analysis of the excreta. A special survey is devoted to the difficult problem of the follow-up of exposure to actinides. The last part of the general section of the document deals with monitoring programmes, based on the synthesis of the recommendations of ICRP publications 26, 30, and 35, taking into account at the same time the practical problems confronting those responsible for the follow-up of persons exposed. On one hand, these programmes concern so-called routine monitoring, relative to the individual follow-up of persons permanently engaged in work that exposes them to the risk of internal exposure. On the other hand, they concern special monitoring carried out after an accident, or when exceptional work presents a significant risk of exposure.

The interpretation of the results of measurements (i.e., the conversion of the body burden, or of the excretion to intake or dose, forms the fundamental element of monitoring) and the decisions relevant to protection from irradiation can depend as much on the individual surveyed as on the place of work. It is advisable, however, to clearly distinguish interpretation of the results of measurements. In routine monitoring, it will be sufficient to consider standard metabolism and dosimetry models, using in particular the biological parameters defined for an average individual. This would appear to be justified under normal working conditions. On the contrary, if an increase in exposure is shown, or if an incident occurs whose significance is confirmed by the initial results of special monitoring, it is desirable, in so far as possible, to use modelling more specific to the case studied.

Practical limitations

The individual monitoring programmes proposed in Publication 54 respond moreover to various practical limitations. In particular, it should be possible to correctly interpret the results of measurements if the person exposed has worked a short or a long time, if the person is assigned to a fixed place of work or engaged in highly mobile work, and finally if the exposure conditions (e.g., the intake times) are well known or quite uncertain. An original approach to this problem is presented in Publication 54 concerning the choice of the interval between two routine monitoring tests. They aim to limit the error in the interpretation of the results, whatever the times (generally unknown) of the contamination periods. This choice also has been dictated by the necessity of improving the management of examination scheduling, which can quickly become very complicated in the case of installations with a large number of workers. Another concern has been to establish rules of interpretation and decision that are simple to understand and use. Very often individual contamination monitoring is only one part of the work of those responsible for initiating and carrying it out. In this regard, the derived reference levels, along with some simple rules for decision-making in case the levels are exceeded, form the essential basis for individual follow-up. The direct comparison of the measurement results with these levels allows one to know immediately the amount of the contamination, as well as the course of action to take.

The appendix of Publication 54 is extensive. It provides indispensable data for individual monitoring of internal exposure to radionuclides normally encountered in the nuclear industry, in research, and in medical and pharmaceutical applications of radioisotopes. Only exposure by inhalation is envisaged. The other modes of intake arise from incidents where an investigation and special actions are carried out depending on the particulars of each case.

A description of the metabolism and the effect of possible therapy aimed at reducing the body burden is given for each of the elements included. The various isotopes relative to each element are subsequently considered. First, a reminder of the main emissions useful for their detection is given, then an account of the measurement techniques with their limits of detection, and finally a summary of the dose factors (sievert per becquerel inhaled), the ALIs, and the derived air concentrations (DACs).

Detailed information is given both for routine and special monitoring. For routine monitoring a list of intervals between examinations which allow the interpretation of measurement results without excessive errors is proposed for each isotope. The data relevant to special monitoring are given for the first 7 days after the incident. For each of the appropriate measurements, Publication 54 contains a tabulation of the activity measured as a fraction of the intake and the derived investigation levels. Information is given on the equilibrium retention and excretion values after chronic daily intake of an activity equal to ALI/365. Finally, for each isotope, the retention and excretion as a fraction of the body burden are given in the form of curves for 10 000 days after inhalation for three particle sizes.

Publication 54 forms, above all, a technical document for radiation protection personnel concerned with applying the recommendations published by the ICRP in other connections to the individual monitoring of internal contamination.