Monitoring Concept as Laid Down in the German Guidelines

K. Henrichs[a] and A. Dalheimer[b]

[a)] *Siemens AG, 82739 München, Germany*
[b)] *Federal Office for Radiation Protection, 85762 Oberschleißheim, Germany*

Abstract

The ALARA-principle in radiation protection also means, that there is a reasonable balance between resources used to monitor exposures and the benefit of such programs. In Germany, the procedure for the monitoring and the assessment of exposures due to incorporated radionuclides is laid down in three guidelines adopted by the Federal Ministry for the Environment, Nature Conservation and Reactor Safety (BMU). These guidelines define general rules for the monitoring of activity intakes, regulate the assessment of exposures and set the requirements measuring laboratories have to fulfil.

The purpose of the approach was to establish a consistent system, that ensures that dose assessments are as reliable as necessary and as simple as possible, and that guarantees the necessary quality standards.

The implementation of the Euratom-Directive within German law requires that these guidelines be adapted. Within this process, the experience gained during the practical application of these regulations will be taken into account as well as more recent dosimetric information.

Introduction

Monitoring potentially incorporated radionuclides at workplaces is generally performed

- to check whether the protection of workers is adequate,
- to convince the worker that he is well protected,
- to ensure that all information is available, which might be needed in compensation claims,
- and to help the employer to document that he did not cause harm to his workforce.

Additionally, in few cases the results of monitoring are needed for decisions concerning countermeasures.

The incorporation monitoring requires considerable resources in manpower, expertise and money. A reasonable balance between these costs and the benefit requires a clear definition of the requested reliability of monitoring results. The basis for the definition of this requested reliability must be the radiological importance of the potential or actual incorporation.

In Germany the monitoring of incorporations is regulated on the basis of Radiation Protection Ordinance [1] by three guidelines, which together define the standard for the monitoring of workers occupationally handling radioactive materials. The titles of these guidelines are:

1. ”Guideline for Physical Radiation Protection Surveillance” [2],
2. ”Guideline for Assessment of Exposures by Incorporated Radiation Emitters” [3], and
3. ”Guideline for Requirements for Measuring Laboratories” [4].

The German government adopted these three guidelines to establish a consistent system in incorporation monitoring [5], to

- define clear criteria for the necessity and use of routine and special monitoring programmes,
- ensure that dose assessments are as reliable as necessary but also as simple as possible,
- standardize as far as possible the procedures of dose assessments, and
- guarantee the necessary quality standards.

The scientific basis of this regulatory system is formed by the publications 30, 48 and 54 of the International Commission on Radiological Protection (ICRP). Recent or future revisions of these models and data can easily be taken into account by just revising the data annexes without changing the structure or general rules.

The implementation of the Euratom Directive [6] within federal German law, necessitates the amendment of the three above-mentioned guidelines. Within the scope of these amendments, experience gained in the application of the guidelines up until now is to be taken into account as well as more recent scientific knowledge about

internal dosimetry. Proposals of different working groups of the German-Swiss Radiation Protection Association (FS) were published [7].

Physical radiation protection surveillance

Necessity of monitoring programmes

According to the guideline, monitoring at a certain workplace (routine or special monitoring) is required in general, if an incorporation possibly exceeding 10 % of the nuclide specific annual limit of intake (ALI) cannot be ruled out. This percentage corresponds to the dose level defining the occupationally exposed worker in Germany. For the handling of nuclide mixtures the contribution of each single contribution is to be taken into account. The difference between routine and special monitoring concerns the knowledge about the temporal course of an incorporation. Routine measurements are required when nothing about the dates of possible incorporations is known. In contrast, if the date or time interval of possible incorporations is sufficiently well known, special monitoring is to be performed.

The Guideline for "Physical Radiation Protection Surveillance" [2] gives practical help to check the criterion for the necessity of a monitoring program. The simplest case is that of manipulating unsealed activity on a laboratory desk. For this case, it gives numbers quantifying the fraction of material possibly inhaled without any notice. Another method proposed to check the criterion makes use of the results of air activity measurements. To check the criterion for the necessity of a monitoring program, it is also possible to make use of local long-term experience with earlier monitoring measurements.

Action levels

One objective was to avoid unjustified work at activity levels which are irrelevant for the health of the occupationally exposed persons or under legal aspects. Therefore, two action levels define the necessity of additional measures.

The first and lower one is the so-called interpretation level, corresponding to an annual intake of 0.03 ALI. This level roughly corresponds to the detection limit characterizing the external dosimetry. It is only applicable in the case of routine monitoring and it takes into account the uncertainties arising from the lacking knowledge concerning the date of incorporation. To check this criterion, the results of routine measurements only have to be compared with nuclide specific values W tabulated in the appendix of the "Guideline for Physical Radiation Protection Surveillance" [2]. W corresponds to the measurement result expected following an intake of 0.03 ALI at the beginning of the monitoring interval:

$$\text{interpretation level} = W / n = 0.03\ \text{ALI}\ \ R(\Delta t) / n$$

with $R(\Delta t)$ = retention or excretion rate,
Δt = length of the monitoring interval,
n = number of intervals per year.

The division by n takes into account that such an intake could happen repeatedly during each interval. There is a common misinterpretation that due to this division longer monitoring intervals allow lower requirements (i.e. higher detection limits). However, this does not recognize that the reference value decreases approximately exponentially with the increasing length of the monitoring intervals.

Table 1. Extract of the table for routine monitoring in guideline [2], defining monitoring procedure, monitoring interval and reference value (**WBC** = whole body counter, **LC** = lung counter, **AM** = air activity measurement, **U** = urine analysis, **F** = fecal analysis)

Nuclide	Compound, Inhalation class	ALI (Bq)	Monitoring Procedure	Monitoring Interval (d)	Reference Value (Bq, Bq/d, Bq/m^3)	Standard Value (Bq, Bq/d per incorp. Bq)	Interpretation Level (Bq, Bq/d per incorp. Bq)
1	2	3	4	5	6	7	-
Co-60	W	$4\ 10^6$	WBC	180	$3\ 10^3$	$6.4\ 10^{-2}$	$1.5\ 10^3$
	Y	$4\ 10^5$	WBC	180	$1\ 10^3$	$1.4\ 10^{-1}$	$5\ 10^2$
…							
I-131	D	$1\ 10^6$	Thyroid U	14 14	$2\ 10^3$ 10	$1.0\ 10^{-1}$ $6.4\ 10^{-4}$	$8\ 10^1$ $4\ 10^{-1}$
…							
Cs-137	D	$6\ 10^6$	WBC	180	$3\ 10^4$	$3.3\ 10^{-1}$	$1.5\ 10^4$
…							
Th-232	W	$3\ 10^1$	AM + U + F (LC)	-	$4\ 10^{-4}$ -	- -	$4\ 10^{-4}$ -
	Y	$6\ 10^1$	AM + U + F (LC)	-	$8\ 10^{-4}$ -	- -	$8\ 10^{-4}$ -
…							
U-233 234 235 238	D	$3\ 10^4$	U	30	2	$4.8\ 10^{-3}$	$2\ 10^{-1}$
	W	$9\ 10^3$	U	180	$3\ 10^{-2}$	$2.8\ 10^{-4}$	$1.5\ 10^{-2}$
	Y	$5\ 10^2$	AM + U + F (LC)	-	$6\ 10^{-3}$ -	- -	$6\ 10^{-3}$ -

If the measured activity or activity concentration does not exceed the interpretation level there is no need for any further action, calculation of intake and doses is not necessary; only the result of the measurement is recorded to document that the measurement was performed. If the measured value is above the interpretation level, intake and doses must be assessed by means of a very simple and standardized method, the so-called reference procedure. The assumptions and models used for this reference procedure ensure that on the average the potential exposure is overestimated.

The second action level is called investigation level, at 0.3 ALI. As long as the intake for the calendar year expected on the basis of the available measurements in combination with the reference procedure is below 0.3 ALI, there is no need for further assessments and measurements. As soon as the investigation level is exceeded, additional measurements and investigations are required until they ensure a sufficiently reliable dose assessment, later described as individual assessment.

Requirements for the monitoring procedure

If any monitoring procedure is necessary, it must ensure the detection of an annual intake of at least 0.03 ALI. Three factors influence the methods and frequencies applied for this procedure:

- the physical characteristics of the radionuclide,
- the biokinetics of the incorporated compound, and
- the sensitivity of the equipment available (e. g. detection limit).

An additional requirement concerns the potential under-/overestimation of intakes resulting from unknown intake-times. The corresponding factor must not exceed a value of 3. The ”Guideline for Radiation Protection Surveillance” [2] defines for about 90 radioisotopes and its various compounds the method(s) to be applied and the lengths of the appropriate monitoring intervals. Table 1 shows an extract of the corresponding appendix of this guideline [2].

Assessment of exposure by incorporated radiation emitters

As already stated above, one of the main objectives was the standardization of monitoring procedures, including the dose assessment. This means, that for all results (intakes and doses) below the investigation level, there is a strictly defined method for the interpretation of the measured values, the so-called reference procedure. Only for the small fraction of cases above the investigation level it seems justified to deviate from this procedure and to introduce as much individual information as necessary or as available. Figure 1 shows this simple scheme, which describes how to proceed beginning with the reference procedure and possibly ending with an individual assessment (see ”Guideline for Assessments of Exposure by Incorporated Radiation Emitters” [3]).

Reference procedure

As described above, below the interpretation level there is no interpretation at all. Above this interpretation level, a very simple method is to be applied to calculate intakes and doses. This means, the measured activity or activity concentration has to be divided by a tabulated value. These above mentioned values are retention functions or excretion rates resulting from the biokinetic models of the ICRP publication 30, 48 and 54. These values are listed in the appendix of the ”Guideline for Assessments of Exposure by Incorporated Radiation Emitters” [3]. The next step is the comparison of the thus estimated intake with the investigation level. As long as this level is not exceeded, only intake and resulting doses have to be recorded together with the measured data.

Individual assessment

As soon as the investigation level is exceeded, the first step is to check, whether reliable information is available about the possible dates of the incorporation, the chemical compound and the AMAD (activity median aerodynamic diameter). By means of this information, a new intake and the resulting doses have to be estimated. This new intake has to be compared with the investigation level again.

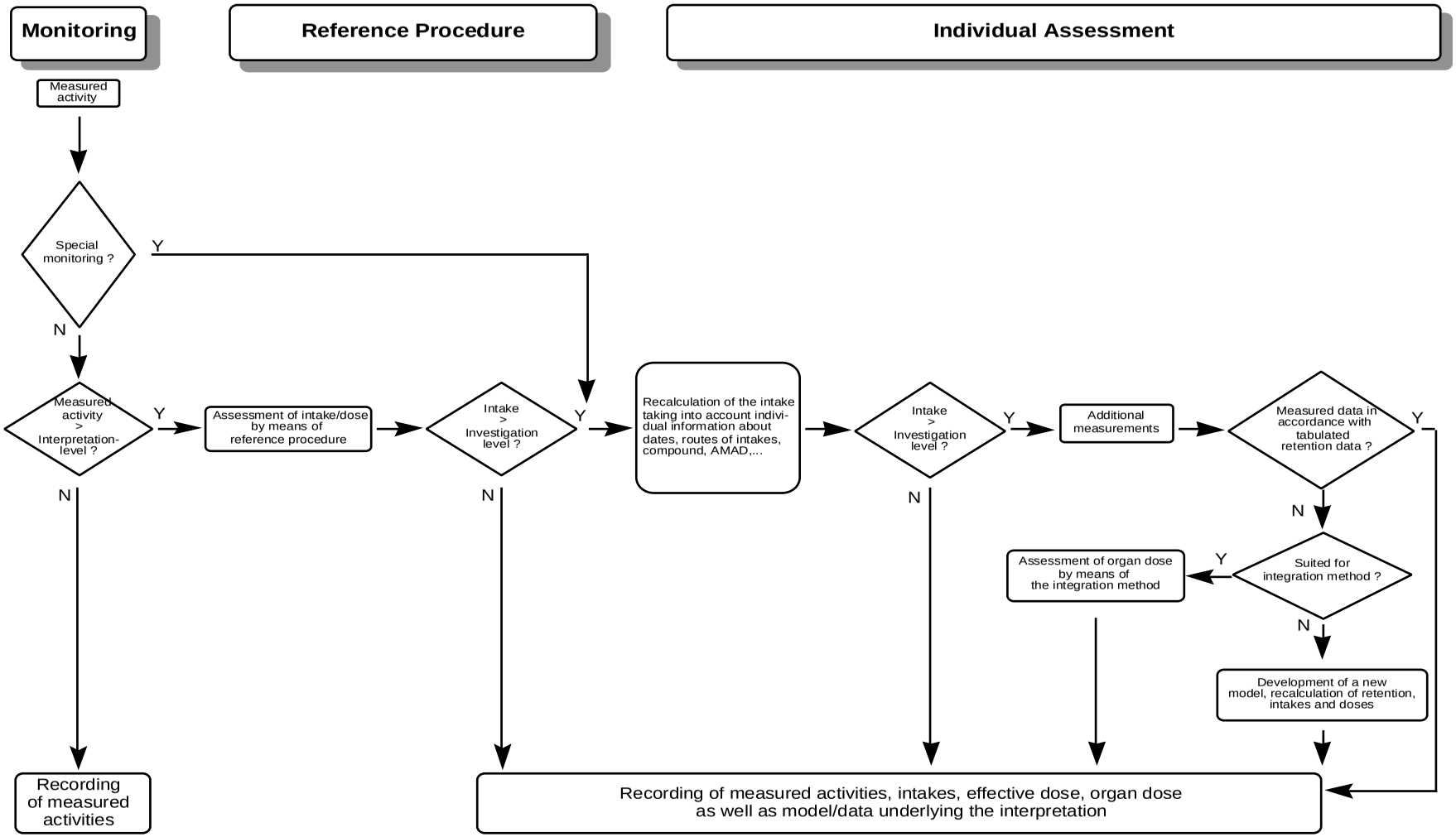

Figure 1: Scheme for the assessment of intake and dose

If the investigation level still is exceeded, measurements of the individual retention characteristics are to be performed enabling a comparison with the ICRP retention models. If there are no substantial discrepancies between measurements and model, the previously calculated intakes and doses are recorded. If there are considerable differences, the individual retention must be measured and modelled as far as possible. A new dose calculation must be based on these measurements including the calculation of new dose conversion factors.

One possible step to derive individual dose assessments makes use of the so-called integration method:

1. calculation of the number of disintegrations U(S) in the source organ, and
2. calculation of the dose by multiplying of the above mentioned value U(S) with the specific effective energy SEE, that means the dose per disintegration, tabulated in [3].

This method may be applied, if the total activity is located in the region seen by the measurements, decay products do not contribute significantly and the dose calculation is restricted to the time interval of measurements.

Requirements for measuring laboratories

Laboratories performing measurements and being responsible for the assessment of intakes and doses must fulfil certain requirements. These requirements are defined in the third guideline "Requirements for Measuring Laboratories" [4]. Among others these requirements concern:

- equipment,
- scientific know how necessary for the dose assessment, and
- participation in quality assurance procedures (intercomparison programmes).

Of central importance are requirements concerning the minimum detectable amount (MDA) prescribed for all important radionuclides, the bias and the precision which are well defined by appropriate test-statistics, organized by the *Coordinating Office on Incorporation Monitoring of the BfS* (Federal Office of Radiation Protection).

Consequences of the implementation of the Euratom Directive [9]

Dose limits

The lowered dose limits imposed by the European Commission (CEC), have consequences both in terms of monitoring programmes, and of the requirements affecting measuring methods and measuring institutions. At present, the monitoring programme must ensure that 3 % of the annual limit on intake (ALI) is detected for each individual. For some (and most important) radionuclides the corresponding detection limits (MDA) for the measuring laboratories are unrealistic. Therefore, it will be necessary, to question this 3 %-level. For some radionuclides, the influence of the lower dose limits is, however, partly compensated for, by newer biokinetic data.

The Euratom Directive now limits exclusively the effective dose, and no longer organ doses. With the introduction of this regulation in Germany, the necessity of limiting intakes (ALI; Annual Limits on Intake), no longer applies. The ALI values are no longer necessary within the scope of the ordinance, should, however, be included in the guidelines as derived supplementary values.

The Guideline on Physical Radiation Protection [2] can then, with respect to the determination of external exposure, be formulated in a more homogeneous way. The reference values for internal and external exposure, which, with good reason, differ greatly in their definition, can in this way be laid down on the basis of a common concept.

Requirements for a data exchange at the European level

The requirements for the exchange of data also across European borders, as it is laid down by the CEC, forces action to achieve the harmonization of the objectives of monitoring (i.e. establishing criteria for the requirements, level of reliability, etc.), and of monitoring methods. In addition, this also requires a common basis of models and data for the interpretation of monitoring results.

Dose coefficients

Through the inclusion of dose coefficients in the Euratom Directive, these values become binding. A disadvantage here is the consequent loss in flexibility with regard to more recent biokinetic data. To be welcomed is, however, from the point of view of the practical application of radiation protection, the degree of legal certainty, which is thus attained. The introduction of updated biokinetic models and data, does not actually always lead to improvements in practical radiation protection.

The influence of the amended dose coefficients on the monitoring programme is, for certain nuclides, partly compensated for by modified biokinetic data (excretion rates).

Time-related attribution of doses

The definition of the dose limit by Euratom as an average, 5-year value, offers the opportunity of arriving at better regulations for radionuclides with longer retention within the human body, for the purposes of defining a more realistic, time-related 'distribution' of the committed dose.

Conclusion

With the three guidelines, a consistent system of regulations was established to monitor occupationally exposed persons in Germany for intakes of radioactivity. It contributes to an adequate protection of the persons, ensures the comparability of dosimetric information from different institutions and it balances resources requested and protection aspects.

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