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Radiation protection — Monitoring of workers occupationally exposed to a risk of internal contamination with radioactive material

Radioprotection — Surveillance professionnelle des travailleurs exposés à un risque de contamination interne par des substances radioactives

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Foreword

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This document was prepared by Technical Committee ISO/TC 85, *Nuclear energy, nuclear technologies, and radiological protection*, Subcommittee SC 2, *Radiological protection,* in collaboration with the European Committee for Standardization (CEN) Technical Committee CEN/TC 430, *Nuclear energy, nuclear technologies, and radiological protection,* in accordance with the Agreement on technical cooperation between ISO and CEN (Vienna Agreement).

This second edition cancels and replaces the first edition (ISO 20553:2006), which has been technically revised.

The main changes are as follows:

— the reference to the recent publication of ICRP Occupational Intakes of Radionuclides (OIR) series, instead of ICRP publications 66 and 78, to calculate the maximum time intervals for routine monitoring programmes.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

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Introduction

In the course of employment, individuals may work with radioactive materials that could be taken into the body. Minimising the risks to workers from incorporated radionuclides requires the monitoring of potential or actual intakes. The requirements for such a monitoring programme and the selection of methods and frequencies of monitoring depend upon the applicable legislation or regulatory body, the purpose of the radiation protection programme, the probability of potential intakes, and the characteristics of the materials handled.

This document offers guidance for making a decision whether a monitoring programme is required, in the absence of any value set by regulations, and proposes the methodology for setting up a monitoring program, as well as its design. Its intention is to optimise the efforts for such a monitoring programme consistent with legal requirements and with the purpose of the radiation protection programme. Recommendations of international expert bodies and international experience with the practical application of these recommendations in radiation protection programmes have been considered in the development of this document. Its application facilitates the exchanges of information between authorities, supervisory institutions and employers. This document is not a substitute for legal requirements.

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Radiation protection — Monitoring of workers occupationally exposed to a risk of internal contamination with radioactive material

1 Scope

This document specifies the minimum requirements for the design of programmes to monitor workers exposed to the risk of internal contamination by radioactive material and establishes principles for the development of compatible goals and requirements for monitoring programmes.

This document specifies the

a) purposes of monitoring and monitoring programmes,

b) description of the different categories of monitoring programmes,

c) quantitative criteria for conducting monitoring programmes,

d) suitable monitoring methods and criteria for their selection,

e) information that has to be collected for the design of a monitoring programme,

f) general requirements for monitoring programmes (e.g. detection limits, tolerated uncertainties),

g) frequencies of measurements calculated using the ICRP Occupational Intakes of Radionuclides (OIR) series,

h) individual monitoring in specific cases (intake of actinides, intake via a wound and intake through the intact skin),

i) quality assurance, and

j) documentation, reporting and record-keeping.

This document does not apply to

— the monitoring of exposure to radon and its radioactive decay products,

— detailed descriptions of measuring methods and techniques,

— detailed procedures for in vivo measurements and in vitro analysis,

— interpretation of measurements results in terms of dose,

— biokinetic data and mathematical models for converting measured activities into absorbed dose, equivalent dose and effective dose,

— the investigation of the causes or implications of an exposure or intake.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 15189, *Medical laboratories — Requirements for quality and competence*

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ISO 17025, *General requirements for the competence of testing and calibration laboratories*

ISO 23588, *Radiological protection — General requirements for proficiency tests for in vivo radiobioassay*

ISO 28218, *Radiation protection — Performance criteria for radiobioassay*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org/

3.1
absorption type
type of material, classified according to its rate of absorption from the respiratory tract into blood

3.1.1
absorption type V
type V
deposited materials that, for dosimetric purposes, are assumed to be instantaneously absorbed into blood from the respiratory tract (only certain gases and vapours; very fast absorption)

[SOURCE: ICRP publication 130]

3.1.2
absorption type F
type F
deposited materials that are readily absorbed into blood from the respiratory tract (fast absorption)

[SOURCE: ICRP publication 130]

3.1.3
absorption type M
type M
deposited materials that have intermediate rates of absorption into blood from the respiratory tract (moderate absorption)

[SOURCE: ICRP publication 130]

3.1.4
absorption type S
type S
deposited materials that are relatively insoluble in the respiratory tract (slow absorption)

[SOURCE: ICRP publication 130]

3.2
activity
quotient of $-dN$ by dt, where dN is the change in the number of radioactive nuclei, at a particular energy state and at a given time, due to spontaneous nuclear transformations in the time interval dt

Note 1 to entry: It is expressed as $A = -dN/dt$. Activity can be calculated as $A = \lambda N$, where λ is the decay constant and N is the number of present radioactive nuclei.

Note 2 to entry: The special name for the unit of activity in the International System of Units is becquerel (Bq), One Bq equals one transformation per second ($1\ Bq = 1\ s^{-1}$). The use of the former unit curie ($1\ Ci = 3{,}7 \times 10^{10}\ Bq$), is also accepted in many countries and by the Bureau International des Poids et Mesures.

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[SOURCE: ISO 12749-1:2020, 3.1.2, modified – By removing the capital letter from the word "Curie" and adding “One Bq equals one transformation per second”]

3.3
activity median aerodynamic diameter
AMAD
value of aerodynamic diameter such that 50 % of the airborne *activity* (3.2) in a specified aerosol is associated with particles smaller than the AMAD, and 50 % of the *activity* (3.2) is associated with particles larger than the AMAD

Note 1 to entry: The aerodynamic diameter of an airborne particle is the diameter of a unit density sphere that has the same terminal settling velocity in air as the particle of interest.

3.4
clearance
net effect of the biological processes by which radionuclides are removed from the body or from a tissue, organ or region of the body

Note 1 to entry: The clearance rate is the rate at which this occurs.

3.5
radioactive contamination
contamination
radioactive substances on surfaces, or within solids, liquids or gases, including the human body, where their presence is unintended or undesirable, or the process giving rise to their presence in such places

[SOURCE: ISO 12749-2:2022, 3.1.5]

3.6
committed effective dose
quantity $E(\tau)$, defined as:

$$E(\tau)=\sum_{T} w_T \cdot H_T(\tau)$$

where $H_{\mathrm{T}}(\tau)$ is the committed equivalent dose to tissue or organ T over the integration time τ elapsed after an *intake* (3.12) of radioactive substances and w_{T} is the tissue weighting factor for tissue or organ T.

Note 1 to entry: The committed equivalent dose to an organ or tissue is the time integral of the equivalent dose rate to that organ or tissue after an *intake* (3.12) of radioactive substances.

Note 2 to entry: Where τ is not specified, it is taken to be 50 years for adults and the time to the age of 70 years for *intakes* (3.12) by children. For workers, the integration time to calculate committed equivalent doses is 50 years.

[SOURCE: ISO 12749-2:2022, 3.1.19, modified by adding Note 1 and “For workers, the integration time to calculate committed equivalent doses is 50 years” in Note 2]

3.7
annual committed dose
committed effective dose (3.6) from *intakes* (3.12) of radionuclides in one year

3.8
dose coefficient
committed effective dose (3.6) per unit *intake* (3.13), e(50), where 50 is the dose-commitment period in years over which the dose is calculated

3.9
retention function
function $m(t)$ representing the activity of a radionuclide in the whole body or in an organ, at a time t after a unit acute *intake* (3.12) as predicted by a reference biokinetic model

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3.10
excretion function
function $m(t)$ representing the activity of a radionuclide in a 24 h excreta sample, at a time t after a unit acute *intake* (3.12) as predicted by a reference biokinetic model

3.11
event
any unintended occurrence, including operating error, equipment failure or other mishap, and deliberate action on the part of others, the consequences or potential consequences of which are not negligible from the point of view of protection and safety

[SOURCE: ISO 12749-2:2022, 3.3.25]

3.12
intake
<process> act or process of taking radionuclides into the body by inhalation or ingestion or through the skin

Note 1 to entry: Other exposure pathways by intake are injection (e.g. in nuclear medicine) and intake via a wound, as distinguished from intake through (intact) skin.

[SOURCE: IAEA Nuclear Safety and Security Glossary: 2022 (Interim) Edition]

3.13
intake
<quantity> *activity* (3.2) of a radionuclide taken into the body in a given time period or as a result of a given *event* (3.11)

[SOURCE: IAEA Nuclear Safety and Security Glossary: 2022 (Interim) Edition]

3.14
in vitro analysis
analysis including measurements of radioactivity present in biological samples taken from an individual

Note 1 to entry: These include urine, faeces and nasal samples. In special monitoring programmes, samples of other materials such as blood and hair may be taken.

Note 2 to entry: These analyses are sometimes referred to as indirect measurements.

Note 3 to entry: In the case of urine or faeces analysis, the time of the measurement is the end day of sample collection.

3.15
in vivo measurement
direct measurements
measurement to determine the presence of or to estimate the amount of radioactive material in a living organism

Note 1 to entry: Normally, the measurement devices are whole-body or partial-body (e.g. lung, thyroid) counters.

[SOURCE: ISO 12749-2:2022, 3.4.8]

3.16
investigation level
value of a quantity such as effective dose, *intake* (3.13) or *contamination* (3.5) per unit area or volume at or above which an investigation would be conducted

[SOURCE: IAEA Nuclear Safety and Security Glossary: 2022 (Interim) Edition]

3.17
detection limit
smallest true value of the measurand which ensures a specified probability of being detectable by the measurement procedure

[SOURCE: ISO 12749-1:2020, 3.4.11]

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3.18
monitoring
measurement of dose, dose rate or activity for reasons relating to the assessment or control of exposure to radiation or exposure due to radioactive material, and the interpretation of the results

3.18.1
individual monitoring
monitoring using measurements by equipment worn by individuals, or measurements of the quantities of radioactive substances in or on, or taken into, the bodies of individuals, or measurements of quantities of radioactive substances excreted from the body by individuals

[SOURCE: IAEA Nuclear Safety and Security Glossary: 2022 (Interim) Edition]

3.18.2
workplace monitoring
monitoring using measurements made in the working environment

3.19
monitoring programme
pre-planned set of personal or workplace measurements used to determine personal exposure to radioactive materials

Note 1 to entry: This document distinguishes four different categories of monitoring programme, namely *routine monitoring programme* (3.19.1), *special monitoring programme* (3.19.2), *confirmatory monitoring programme* (3.19.3), and *task-related monitoring programme* (3.19.4).

3.19.1
routine monitoring programme
monitoring programme associated with continuing operations and intended to demonstrate that working conditions, including the levels of individual dose, remain satisfactory, and to meet regulatory requirements

3.19.2
special monitoring programme
monitoring programme performed to quantify *intakes* (3.13) following actual or suspected *events* (3.11)

3.19.3
confirmatory monitoring programme
monitoring programme carried out to confirm assumptions about working conditions, for example that significant *intakes* (3.13) do not occur

3.19.4
task-related monitoring programme
monitoring programme related to a specific operation, to provide information on a specific operation of limited duration, or following major modifications applied to the installations or operating procedures, or to confirm that the routine monitoring programme is suitable

3.19.5
monitoring interval
period between two times of measurement of the same type and category

3.20
quality assurance
QA
part of quality management focused on providing confidence that quality requirements will be fulfilled

[SOURCE: ISO 9000:2015, 3.3.6]

3.21
quality control
part of quality management focused on fulfilling quality requirements

[SOURCE: ISO 9000:2015, 3.3.7]

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3.22
quality management
management with regard to quality

Note 1 to entry: Quality management can include establishing quality policies and quality objectives, and processes to achieve these quality objectives through quality planning, quality assurance, quality control, and quality improvement

[SOURCE: ISO 9000:2015, 3.3.4]

3.23
recording level
level of dose, exposure or *intake* (3.13) specified by the regulatory body at or above which values of dose, exposure or *intake* (3.13) received by workers are to be entered in their individual exposure records

[SOURCE: ISO 12749-2:2022, 3.6.10]

4 Symbols and abbreviated terms

AMAD	Activity median aerodynamic diameter
$A^{\#}$	Detection limit
$e(50)$	Dose coefficient: committed effective dose accumulated within 50 years following a unit intake
$m(t)$	Value of the retention or the excretion function at time, t, (in days) after a unit intake
IAEA	International Atomic Energy Agency
ICRP	International Commission on Radiological Protection
PAS	Personal air sampling
QA	Quality assurance
SAS	Static air sampling
ΔT	Time interval (in days) between two measurements in a routine monitoring programme

5 Purpose and need for monitoring programmes

5.1 General aspects

5.1.1 The purpose of monitoring, in general, is to verify and document that the worker is protected adequately against risks from intakes and that the protection complies with regulatory requirements. Therefore, it forms part of the overall radiation protection programme, starting with an assessment to identify work situations in which there is a risk of radionuclide intake by workers and to quantify the likely intake of radioactive material and the received committed effective dose. Decisions about the need for monitoring and the design of the monitoring programme should be made in the light of such a risk assessment. It is always necessary, in the first instance, to put in place radiation protection measures in order to reduce the risk of intakes to as low as reasonably practicable.

5.1.2 Factors determining the need for a monitoring programme are

— the magnitude of likely intakes;

— the need to detect intakes events when they occur;

— the need to assess the effectiveness of protective equipment such as respiratory protective equipment;

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— the need to assess the effectiveness of workplace controls.

5.1.3 The purpose of the monitoring programme, e.g. for dose assessment purposes or to show that intakes are as low as reasonably practicable or to confirm that routine monitoring is not required, shall be clearly defined.

5.1.4 The way the monitoring programme is to be organized shall be documented according to Clause 12 including the basis for interpreting the results. The monitoring programme shall be reviewed after any major modifications have been made to the installation, to operations, or to the regulatory requirements.

5.2 Types of monitoring

5.2.1 Workplace monitoring

5.2.1.1 Workplace monitoring includes measurements of airborne activity and surface contamination in the workplace. The primary aim is to determine the possible presence of contamination by radioactive material on the surfaces or in the air in order to assess the risk of intake by workers who may be present there. The results of the measurements can be used to make decisions on the need for, and design of, an individual monitoring programme or as reassurance that such a programme is not required.

5.2.1.2 Surface contamination is not directly related to individual exposure but can indicate the pre-existence of uncontrolled spread of radioactive material and the potential for an intake due to inhalation, ingestion, or intake via a wound or through (intact) skin.

5.2.1.3 Continuous monitoring of airborne radionuclides is important, because inhalation is generally the main exposure pathway for workers. The main objectives of airborne activity monitoring are to:

— help to assess the intakes of workers through inhalation;

— support individual dose assessments, e.g. air monitoring can provide information on the time of an intake;

— rapidly detect abnormal or deteriorating conditions, thereby making it possible to take the appropriate protective action, for example, the use of respiratory protective equipment;

— provide information for setting up individual monitoring programmes for workers.

It can also be needed in those cases where individual monitoring is not sufficiently sensitive.

In the absence of a value set by regulations, workplace monitoring is required in workplaces where individual annual committed doses are likely to exceed 1 mSv and recommended where there is a potential for contamination.

5.2.2 Individual monitoring

Individual monitoring provides the information needed to assess the exposure of a single worker by measuring the person's whole body, organ or excreta activity. Individual monitoring can be used to show that the worker has not been contaminated by radioactive material at the workplace, or if this is not the case, provides data on which to calculate the dose due to the intake.

5.3 Categories of monitoring programmes

5.3.1 Routine monitoring programme

Routine monitoring programmes are performed to quantify doses where there is the possibility either of undetected accidental intakes or of chronic intakes. They can also be used to demonstrate that the work environment and work procedures are under satisfactory control[9].

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In the absence of a value set by regulations, workers shall be routinely individually monitored, and the results used to assess dose, when they could potentially receive an intake of radionuclides resulting in a committed effective dose of more than 5 mSv per year.

Workers should be routinely individually monitored, and the results used to assess dose, when they could potentially receive an intake of radionuclides resulting in a committed effective dose between 1 and 5 mSv per year.

These values take into account only exposures by incorporated radionuclides. In cases where external exposure is likely to be significant, the value of the potential external exposure shall be subtracted.

The likely magnitude of intakes should initially be assessed taking into account the possibility of chronic intakes due to insufficient personal protective measures or accidental intakes due to failure of these measures. If available, this assessment can be done on the basis of results of earlier monitoring programmes (individual or workplace monitoring).

If a worker is exposed to more than one radionuclide, the design of a monitoring programme may disregard radionuclides whose contribution to the likely annual committed dose is not significant. In the case of mixtures where the radionuclide composition is well known, it is possible to use the measurement of a single or a few radionuclides to infer the activities of the others.

5.3.2 Special monitoring programme

Special monitoring programmes are performed to quantify significant intakes following actual or suspected abnormal events. Therefore, the time of intake is usually known and additional information can be available, which helps to reduce the uncertainty of dose assessment. The purposes of dose assessment in such cases include assisting in decisions about countermeasures (e.g. decorporation therapy), compliance with legal regulations, and aiding decisions for the improvement of conditions at the workplace. In most cases, special monitoring programmes includes individual monitoring. In cases where there is reason to suspect that regulatory dose limits for occupational exposure could be exceeded, it can be appropriate to extend the measurements in order to derive individual retention and excretion functions and biokinetic model parameters and improve the dose assessment.

5.3.3 Task-related monitoring programme

Task-related monitoring programmes apply to a specific operation (construction work, site, etc…) having a fixed duration. Where work is of a short duration, it may be appropriate to have task-related monitoring rather than routine monitoring. The purpose and the dose criteria for carrying out task-related monitoring programmes are identical to those for routine monitoring programmes and may include workplace and individual monitoring.

5.3.4 Confirmatory monitoring programme

Confirmatory monitoring programmes can be required to check the assumptions about exposure conditions underlying the procedures selected (e.g. the effectiveness of protection measures). Even if there is no requirement for individual monitoring for dose assessment purposes, the appropriateness of confirmatory monitoring should be considered. It may consist of workplace or individual monitoring (e.g. by occasional measurements to investigate the potential accumulation of activity in the body or by in vivo measurements or in vitro analysis performed for selected workers representing groups of workers with identical or similar risks of intake).

6 Designing a routine monitoring programme

6.1 General requirements

Routine monitoring programmes shall be established including suitable individual monitoring and workplace monitoring according to the requirements specified in Clause 5 and Clause 6.

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The basis for routine monitoring programmes is the assumption that working conditions, and thus risks of intake, remain reasonably constant. The design of such a programme of regular measurements strongly depends on the level of the annual committed dose which is to be detected. This level shall be well below regulatory dose limits for occupational exposure; its definition should take into account uncertainties to a reasonable extent, for example in activity measurement and dose assessment. If this level is too high, intakes representing considerable fractions of regulatory dose limits for occupational exposure could be overlooked, while a low value can cause the expenditure of unnecessary efforts at low exposures.

When specifying a routine monitoring programme the detection of all intakes whose sum can lead to an annual committed dose exceeding 1 mSv shall be ensured. For some radionuclides, this requirement can only be achieved by workplace monitoring.

6.2 Routine individual monitoring

6.2.1 General

Individual monitoring can be made by in vivo measurements or by in vitro analyses. The selection depends on a number of factors, such as the following:

— radiation emitted by the radionuclide and its progeny;

— decay constant of the radionuclide;

— retention in the body or the excretion rate from the body of the contaminant as a function of the time between intake and measurement;

— biokinetics, organ deposition and excretion pathway of the contaminant;

— technical feasibility of measurement.

In the case of material with very short effective half-lives, i.e. <0,5 d, routine individual monitoring is in most cases not necessary, as the effective dose is dominated by the external exposure. However, there should be a considerable degree of confidence in the workplace monitoring system and some confirmatory monitoring may be undertaken (see Clause 9).

6.2.2 Methods

In vivo measurements can be performed on the whole body or on specific organs such as thyroid or lungs.

In vitro analyses are performed on excreta, generally urine or faeces. Urine excretion analysis usually requires a 24 h sample collected in a manner that avoids external contamination. Faecal excretion analysis is strongly recommended to be performed over three consecutive days[10].

For certain elements for which equilibrium is quickly reached between the blood and the urinary concentrations, it is also possible to take samples over shorter periods (“spot samples”). If the collection is not performed over a 24 h period, there should be a method for normalizing to 24 h excretion by volume, excreted creatinine or by the length of sampling interval[9].

6.2.3 Determining the frequency of monitoring

In vivo measurements or in vitro analyses in a routine monitoring programme are made at pre-determined times and are not related to any known intake events. Decisions therefore have to be made in advance concerning monitoring methods, frequencies, and the underlying biokinetic models. For the evaluation of intakes using measured values, it is also necessary to make assumptions concerning the time interval between intake and measurement.

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To determine the methods and the frequency of measurements, the following requirements shall be observed in addition to the general requirement specified in 6.1:

— the consequences resulting from an unknown time interval between intake and measurement shall be limited so that on average, over several monitoring intervals, doses are not underestimated, and the maximum underestimate of the dose resulting from a single intake does not exceed a factor of three;

— at least one measurement shall be performed annually. If the programme is established with a monitoring interval of 365 days, at least one measurement shall be performed each calendar year during which the worker is exposed.

In nearly all cases, the maximum overestimation is greater than the maximum underestimation. The constraint on the maximum underestimation of a single intake does not exclude a considerable overestimation.

The three requirements, together with the assumptions about the pattern of intake and the sensitivity of the selected methods of measurement determine the frequency of the routine measurements.

The first requirement, as specified in 6.1, is that the detection of all intakes whose sum can lead to an annual committed dose exceeding 1 mSv shall be ensured. This requirement depends on the retention and excretion of the radionuclide and on the sensitivity of the available measurement techniques, as given in Formula (1).

$$e(50)\cdot\frac{A^{\#}}{m(\Delta\mathrm{T})}\cdot\frac{365\mathrm{d}}{\Delta T}\leq 1\,\mathrm{mSv} \tag{1}$$

where

$e(50)$ is the dose coefficient: committed effective dose accumulated within 50 years following a unit intake

$A^{\#}$ is the detection limit

ΔT is the time interval (in days) between two measurements

$m(\Delta T)$ is the value of the retention function (for in vivo measurements) or of the excretion function (for in vitro analyses) at time ΔT after a unit intake

If exposure to more than one radionuclide cannot be ruled out, this requirement shall be adjusted accordingly so that a total annual committed dose of 1 mSv can reliably be detected and assessed. Small contributions may be ignored; see Clause 5.

The maximum potential underestimation shall not exceed a factor of three; assuming that a single intake occurred in the middle of the monitoring interval this requirement means, as given in Formula (2):

$$\frac{m\left(\frac{\Delta T}{2}\right)}{m(\Delta T)}\leq 3 \tag{2}$$

where

ΔT is the time interval (in days) between two measurements

$m(\Delta T/2)$ is the value of the retention function (for in vivo measurements) or of the excretion function (for in vitro analyses) at time $\Delta T/2$ after a unit intake

$m(\Delta T)$ is the value of the retention function (for in vivo measurements) or of the excretion function (for in vitro analyses) at time ΔT after a unit intake

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6.2.4 Methods and time intervals for commonly encountered radionuclides

The methods and time intervals summarized in this subclause were derived from the principles specified above and calculated using the following references and assumptions:

— acute intake by inhalation at the mid-point of the monitoring interval. This is a reasonable assumption for chronic intakes and, on average, it prevents the underestimation of intakes;

— inhalation of aerosol with a 5 µm default AMAD for occupational exposure or of gases or vapours by a reference worker at light work;

— total body, lung or thyroid contents, and daily urinary or faecal excretion following a unit intake (Bq per Bq) from ICRP OIR Data Viewer[11];

— committed effective dose per intake (Sv per Bq intake) provided by the ICRP Occupational Intakes of Radionuclides (OIR) series (ICRP publications 134, 137, 141 and 151)[12][13][14][15];

— typical detection limit for in vitro bioassay or in vivo measurements provided by the ICRP Occupational Intakes of Radionuclides (OIR) series (ICRP publications 134, 137, 141 and 151) as presented in Annex A. Detection limits for urine bioassay are given in units of Bq/l in the ICRP publications. A standard value for the urine excretion of 1,6 l/d is assumed to convert Bq/l into Bq/d.

The methods and maximum time intervals for routine monitoring programmes are summarized in Table 1 for commonly used radionuclides, Table 2 for iodine, Table 3 for radium and uranium compounds and Table 4 for actinides except uranium.

When the requirement to detect an annual committed dose of 1 mSv is not achievable, the time interval that gives the lowest detectable dose calculated using Formula (1) is indicated and the value of this detectable dose is specified in brackets. No values are given when the monitoring technique is not appropriate to detect the radionuclide or when the detectable committed effective dose is above 20 mSv. It should be noted that using Formula (1) may in some circumstances produce an overly pessimistic estimate of the detectable annual committed dose for a particular monitoring interval and measurement technique. The reason is that the Formula does not take into account residual retention or excretion from intakes in earlier monitoring periods. If it is taken into account, the magnitudes of intakes in later periods required to cause $m(t)$ to reach the detection limit may be reduced, resulting in a lower detectable annual committed dose[10]. The detectable annual committed dose may be calculated taking into account the carry-over of the activity due to the intake during the previous interval[10].

Methods and time intervals in Tables 1, 2, 3 and 4 are calculated for commonly encountered compounds and for compounds unspecified or not assigned to an absorption type. A 5 µm default activity median aerodynamic diameter is considered for aerosols. For radionuclides and compounds not specified in Tables 1, 2, 3 and 4, and for aerosols with a different AMAD, the methods and the time intervals of measurements shall be selected by observing the requirements laid down in 6.1 and this subclause.

For practical purposes it is recommended to assign radionuclides to a maximum monitoring interval of 7, 14, 30, 60, 90, 120, 180 or 365 days.

Techniques of in vitro bioassay and in vivo measurements selected to calculate maximum time intervals, together with their typical detection limits provided by the ICRP OIR series, are presented in Annex A. Other monitoring techniques may be used and in this case time intervals should be calculated using the appropriate detection limit.

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Table 1 — Methods and maximum time intervals (days) for routine monitoring programmes

Radionuclide	Compounds	Time interval [detectable dose (mSv)]	
		In vitro analyses Urine	In vivo measurements Whole body
^{3}H	Aerosols Biogenic organic compounds	90	—
^{3}H	Aerosols Type M, all unspecified compounds, glass fragments, luminous paint, titanium tritide, zirconium tritide	30	—
^{3}H	Aerosols Type S, carbon tritide, hafnium tritide	14 [9,9]	—
^{3}H	All other types	30	—
^{14}C	Gas or vapour Type V, carbon dioxide	60 [1,6]	—
^{14}C	Gas or vapour Type V, methane	120 [8,8]	—
^{14}C	Gas or vapour Type F, unspecified organic	7	—
^{14}C	Aerosols barium carbonate	60 [2,3]	—
^{14}C	Aerosols Type M, all unspecified forms	180 [2,7]	—
^{32}P	Aerosols Type F, sodium phosphate	30	—
^{32}P	Aerosols Type M, yttrium, stannic and zinc phosphates, all unspecified forms	7 [1,1]	—
^{33}P	Aerosols Type F, sodium phosphate	30	—
^{33}P	Aerosols Type M, yttrium, stannic and zinc phosphates, all unspecified forms	60	—
^{35}S	Sulphur dioxide, carbon disulphide, hydrogen sulphide, carbonyl sulphide, and other unspecified inorganic gases and vapours	14	—
^{35}S	Gas or vapour Type F, other organic	120	—
^{35}S	Aerosols Type F, caesium, nickel, strontium, and thorium sulphates	14	—
^{35}S	Aerosols Type M, barium sulphates; all unspecified forms	120	—
^{36}Cl	Inhaled gases or vapours, unspecified	30	—
^{36}Cl	Aerosols, Type F (default)	30	—
^{51}Cr	Aerosols, Type M (default)	60	60
^{54}Mn	Aerosols, Type M (default)	120 [3,5]	180
^{59}Fe	Aerosols Type M (ferric chloride; ferric oxide; all unspecified forms) or Type S (corrosion product)	—	120
^{57}Co	Aerosols Type F, cobalt nitrate, chloride,	180	365[a]
^{57}Co	Aerosol Type M, all unspecified forms	180	180[a]
^{57}Co	Aerosols Type S, cobalt oxide, FAP, PSL	365 [1,1]	365[a]
^{58}Co	Aerosols Type F, cobalt nitrate, chloride	—	120[b]
^{58}Co	Aerosols Type M, all unspecified forms	120	120[a]
^{58}Co	Aerosols Type S cobalt oxide, FAP, PSL	7 [1,8]	180[a]
^{60}Co	Aerosols Type F, cobalt nitrate, chloride or Type M, all unspecified forms	365	365[a]
^{60}Co	Aerosols Type S cobalt oxide, FAP, PSL	365 [9,9]	365[a]
^{63}Ni	Inhaled gases or vapours nickel carbonyl	365	—

[a] Or lung measurements.

[b] Or 180 days for lung measurements.

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Table 1 *(continued)*

Radionuclide	Compounds	Time interval [detectable dose (mSv)]	
		In vitro analyses Urine	In vivo measurements Whole body
^{63}Ni	Aerosols Type F, nickel chloride, sulphate, monosulphide, subsulphide	365	—
^{63}Ni	Aerosols Type M, nickel metal (default)	365	—
^{63}Ni	Aerosols Type S, nickel oxide	—	—
^{75}Se	Aerosols Type F, selenium dioxide, selenious acid, elemental selenium	120	180
^{75}Se	Aerosols, Type M (default)	180	180
^{89}Sr	Aerosols Type F, strontium chloride, sulphate and carbonate	14	—
^{89}Sr	Aerosols Type M, fuel fragments, all unspecified forms	60	—
^{89}Sr	Aerosols Type S, FAP, PSL, strontium titanate	7 [5,7]	—
^{90}Sr	Aerosols Type F (strontium chloride, sulphate and carbonate) or Type M (fuel fragments, unspecified forms)	365	—
^{90}Sr	Aerosols Type S, FAP, PSL, strontium titanate	—	—
^{110m}Ag	Aerosols Type F, silver nitrate	60 [2,8]	120
^{110m}Ag	Aerosols Type M, silver iodide, all unspecified forms	120 [8,9]	180
^{137}Cs	Aerosols Type F (caesium chloride, nitrate, sulphate) or Type M (irradiated fuel fragments; all unspecified forms)	180	180

[a] Or lung measurements.

[b] Or 180 days for lung measurements.

Table 2 — Methods and maximum time intervals (days) for routine monitoring programmes for iodine

Radionuclide	Compounds	Time interval [detectable dose (mSv)]	
		In vitro analyses Urine	In vivo measurements Thyroid
^{125}I	Elemental iodine and unspecified gases or vapours forms, methyl iodide, CH_3I; ethyl iodide, C_2H_5I, Aerosols Type F, (sodium iodide, caesium chloride vector, silver iodide, unspecified forms)	120	120
^{131}I	Elemental iodine and unspecified gases or vapours forms	14 [5,1]	14
^{131}I	Methyl iodide, CH_3I; ethyl iodide, C_2H_5I	14 [5,5]	14
^{131}I	Aerosols Type F, sodium iodide, caesium chloride vector, silver iodide, all unspecified forms	14 [5,6]	14

Where more than one method is indicated,

— the in vivo measurement, if available, should be the preferred method;

— urinary excretion analysis and in vivo measurements should be used for long-term, chronic exposure or if accumulations of small intakes cannot be ruled out;

Time intervals provided in Table 3 only take into account the radiological toxicity of uranium. For soluble uranium compounds with a ^{235}U enrichment by mass no greater than 3 %, the chemical toxicity of uranium is more limiting than the radiological hazard. In this case maximum time intervals may be shorter than those

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presented in Table 3. In this case, the maximum time intervals provided by ISO 16638-1[5] should be used. The maximum time intervals for routine monitoring programmes after inhalation of soluble compounds (uranium hexafluoride, uranium peroxide, uranium nitrate and ammonium diuranate) of natural or depleted uranium, as given in ISO 16638-1, is 30 days (in vitro urine analysis).

For uranium compounds or for mixture of radionuclides (e.g. plutonium/americium), the most conservative monitoring interval should be used depending on the radionuclide responsible for the major part of the dose. In this case, the calculation of the detectable dose should take into account the composition of the compound or of the mixture.

Table 3 — Methods and maximum time intervals (days) for routine monitoring programmes for radium and uranium compounds

Radionuclide	Compounds	Time interval [detectable dose (mSv)]			
		In vitro analyses		In vivo measurements	
		Urine	Faeces	Lungs	Whole body
^{226}Ra	Aerosols Type F, nitrate	60 [1,6]	120	—	—
^{226}Ra	Aerosols Type M, all unspecified forms	120 [9,4]	180	—	—
^{234}U	Aerosols Intermediate Type F/M: uranyl nitrate, uranium peroxide hydrate, ammonium diuranate, uranium trioxide	180	120	—	—
^{234}U	Aerosols Intermediate Type M/S: uranium octoxide, uranium dioxide	365	365	—	—
^{234}U	Aerosols uranium aluminide	365	365	—	—
^{234}U	Aerosols Type F, uranium hexafluoride, uranyl tributyl-phosphate	30	30 [1,9]	—	—
^{234}U	Aerosols Type M: uranyl acetylacetonate; depleted uranium aerosols from use of kinetic energy penetrators; vaporised uranium metal; all unspecified forms	180	180	—	—
^{235}U	Aerosols Intermediate Type F/M: uranyl nitrate, uranium peroxide hydrate, ammonium diuranate, uranium trioxide	180	120	90 [3,3]	365 [6,9]
^{235}U	Aerosols Intermediate Type M/S: uranium octoxide, uranium dioxide	365	365	365 [1,7]	365 [12,2]
^{235}U	Aerosols uranium aluminide	365	365	365 [1,3]	365 [9,3]
^{235}U	Aerosols Type F: uranium hexafluoride, uranyl tributyl-phosphate	30	30 [1,8]	—	365 [2,4]
^{235}U	Aerosols Type M: uranyl acetylacetonate; depleted uranium aerosols from use of kinetic energy penetrators; vaporised uranium metal; all unspecified forms	180	180	180 [1,6]	180 [9,9]
^{238}U	Aerosols Intermediate Type F/M: uranyl nitrate, uranium peroxide hydrate, ammonium diuranate, uranium trioxide	180	120	—	—
^{238}U	Aerosols Intermediate Type M/S: uranium octoxide, uranium dioxide	365	365	365 [10,0]	—
^{238}U	Aerosols uranium aluminide	365	365	365 [7,7]	—
^{238}U	Aerosols Type F: uranium hexafluoride, uranyl tributyl-phosphate	30	30 [3,4]	—	—
^{238}U	Aerosols Type M: uranyl acetylacetonate; depleted uranium aerosols from use of kinetic energy penetrators; vaporised uranium metal; all unspecified forms	180	180	180 [9,4]	—

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Table 4 — Methods and maximum time intervals (days) for routine monitoring programmes of compounds of actinides (except uranium)

Radionuclide	Compound	Time interval [detectable dose (mSv)]		
		In vitro analyses (alpha spectrometry)		In vivo measurements
		Urine	Faeces	Lungs
^{228}Th	Aerosols water soluble forms	180 [5,2]	120 [1,9]	120 [18,6]
^{228}Th	Aerosols Type M, thorium hydroxide	120 [4,9]	120 [1,8]	120 [17,1]
^{228}Th	Aerosols Type S, oxide, all unspecified forms	—	180 [1,8]	365 [12,8]
^{232}Th	Aerosols water soluble forms	180 [1,3]	120 [1,7]	
^{232}Th	Aerosols Type M, thorium hydroxide	180 [1,1]	120 [1,4]	—
^{232}Th	Aerosols Type S, oxide, all unspecified forms	—	365 [3,1]	—
^{237}Np	Aerosols neptunium nitrate	365	180 [2,0]	—
^{237}Np	Type M, neptunium citrate, oxalate, unspecified forms	365	180	180 [16,8]
^{237}Np	Type S, neptunium dioxide	365 [11,2]	365	365 [12,5]
^{238}Pu	Plutonium nitrate, $Pu(NO_3)_4$	365[2,2]	180 [1,3]	—
^{238}Pu	^{238}Pu dioxide, $^{238}PuO_2$; plutonium in mixed oxide [(UO_2+PuO_2) or (U, Pu)O_2]	—	365 [1,3]	—
^{238}Pu	^{238}Pu dioxide, $^{238}PuO_2$ ceramic	365 [12,6]	365	—
^{238}Pu	^{238}Pu dioxide, $^{238}PuO_2$ non-ceramic	365 [2,0]	180	—
^{238}Pu	Plutonium dioxide 1-nm nanoparticles, 1-nm PuO_2	365 [2,5]	180 [6,5]	—
^{238}Pu[a]	Type M, plutonium citrate; plutonium tri-butyl-phosphate (Pu-TBP); plutonium chloride ($PuCl_3$); unspecified form	365 [2,0]	120 [2,0]	—
^{239}Pu[a]	Plutonium nitrate, $Pu(NO_3)_4$	365 [2,7]	180 [1,4]	—
^{239}Pu[a]	^{239}Pu dioxide, $^{239}PuO_2$; plutonium in mixed oxide [(UO_2+PuO_2) or (U,Pu)O_2]	—	365 [1,4]	—
^{239}Pu[a]	Plutonium dioxide 1-nm nanoparticles, 1-nm PuO_2	365 [2,6]	120 [6,9]	—
^{239}Pu[a]	Type M, plutonium citrate; plutonium tri-butyl-phosphate (Pu-TBP); plutonium chloride ($PuCl_3$); unspecified form	365 [2,3]	120 [2,3]	—
^{241}Am	Aerosols americium nitrate	365	180 [3,0]	—
^{241}Am	Aerosols Type F, citrate	365	365 [14,7]	—
^{241}Am	Aerosols Type M, oxide, chloride	365	120 [1,3]	180 [10,0]
^{241}Am	Aerosols Type S, americium associated with plutonium oxide	365 [18,1]	365	365 [4,9]
^{243}Am	Aerosols americium nitrate	365	180	180 [12,2]
^{243}Am	Aerosols Type F, citrate	365	365 [1,5]	—
^{243}Am	Aerosols Type M, oxide, chloride	365	180	180 [4,9]
^{243}Am	Aerosols Type S, americium associated with plutonium oxide	365 [11,4]	365	365 [2,3]
^{242}Cm	Curium oxide, nitrate, and chloride	180	120	—
^{242}Cm	Aerosols Type F, citrate	365	365	—
^{242}Cm	Aerosol Type M, unspecified form	180	180	—

a ^{239}Pu is determined as total activity of ^{239}Pu and ^{240}Pu.

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Table 4 *(continued)*

Radionuclide	Compound	Time interval [detectable dose (mSv)]		
		In vitro analyses (alpha spectrometry)		In vivo measurements
		Urine	Faeces	Lungs
^{244}Cm	Curium oxide, nitrate, and chloride	365	90 [2,2]	—
^{244}Cm	Aerosols Type F, citrate	365	365 [9,3]	—
^{244}Cm	Aerosol Type M, unspecified form	365	180	—
a ^{239}Pu is determined as total activity of ^{239}Pu and ^{240}Pu.				

6.2.5 Tolerances for monitoring intervals

Tolerances for monitoring intervals based on practical considerations are given in Table 5. For sample not provided within the tolerance given in Table 5, the interpretation should follow the guidance given in ISO 27048[7] and the employer should considerer the appropriateness of administrative action regarding the worker.

Table 5 — Tolerances for a range of different monitoring intervals

Monitoring Interval Days	Tolerance days
7	±1
14	±2
30	±4
60	±7
90	±14
120	±14
180	±30
365	±30

6.3 Routine workplace monitoring

The results of air monitoring can be used to estimate the intake of a radioactive material by workers provided they meet two criteria. First, they reliably shall not underestimate the intakes. Second, they shall be confirmed by a confirmatory monitoring programme involving the use of individual measurements.

The establishment of a continuous monitoring system of airborne radioactive material in order to detect and assess collective or individual exposure requires knowledge of the work conditions, the materials handled and the type of occupation of the workers. The design of the system is expected to be tailored to the risk of intake. The measurements should be performed in the worker's breathing zone.

Two workplace monitoring methods may be used for monitoring individual exposures: personal air sampling (PAS) and static air sampling (SAS)[9].

Reliance on measurement of airborne activities by SAS can lead to errors especially when sources of air contamination are localized or change position over time, often because of worker action or movement. There can be significant differences between the level of airborne contamination in the worker's breathing area and the level measured at a fixed spot close by, with contamination in the breathing area usually being higher. The requirement to avoid underestimation may be achieved by applying correction factors taking into account spatial and temporal variability of radionuclide concentrations in the worker's breathing zone.

If the dosimetry for actinides is based on the continuous monitoring of air samples, either static air samplers or, where likely intakes are higher, personal air samplers, should be used. These measurements shall be supplemented by other methods, such as repeated nasal samples to detect intakes requiring a special

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monitoring programme, and by faecal or urine analysis or lung counting measurements to demonstrate that the air monitoring does not underestimate the actual intakes.

7 Designing a special monitoring programme

7.1 Special individual monitoring

7.1.1 General

The goal of special individual monitoring is to ensure that any intake is detected at an early stage and that the associated committed doses are evaluated. Special monitoring programmes are investigative; they are usually based on a suitable combination of in vivo measurements and in vitro analysis in association with the appropriate biokinetic model.

7.1.2 In vivo measurements and in vitro analyses

Table B.1 summarizes recommended in vivo and in vitro methods for special individual monitoring; it does not take into account the effects of treatment that can be undertaken to reduce the committed effective dose.

The radionuclide content of the body can be measured in vivo with appropriate external detectors. The result is rapidly available after the measurement. However, in vivo measurements may not be able to discriminate between external and internal contamination. Showering and changing of clothes is important as it can mostly eliminate external contamination interferences.

The choice between urine and faecal in vitro analysis depends on the biokinetics of the materials incorporated and on the route of intake. Large fluctuations in the faecal excretion of radionuclides from one day to the next give rise to uncertainty when interpreting the results. Consequently, faecal samples should preferably be collected over a period of three consecutive days to reduce this uncertainty. Faecal samples collected soon after intake include non-systemic activity from lung clearance to the GI tract or directly from ingestion. While amounts can fluctuate greatly, the fraction of intake in those samples is relatively large and there is a greater chance of detection of low-level intakes of actinides and other radionuclides. Faecal analysis is appropriate in the case of a suspected intake of compounds of absorption types M or S. In these cases, faecal excretion analysis may be used for assessing transfer to the gut from the lungs and hence estimating intake. For materials with long retention in the lung, repeated analysis throughout the year should be performed to confirm the results, since interpretation based on a single isolated result can be unreliable. Usually, a reliable dose assessment on the basis of urinary analysis requires a 24 h sample; but in the case of special monitoring programmes, it can be helpful to collect “spot samples” at early times post-intake with which to calculate early estimates of intake.

7.1.3 Other techniques

In the case of special monitoring, additional specific techniques may be performed:

— Nasal swabs: The measurement of nasal sample activity can be used to indicate the inhalation of α-emitting particles[16]; a positive result from such a measurement may be used as a prompt for further individual investigations for all the workers in the group. Such a measurement can also be useful for reducing the uncertainty in the time of an intake for dose assessment. The analysis of nasal swabs (nasal smears or nose-blowing into cellulose tissues) can supplement a special monitoring programme in order to give a rapid rough indication of the severity of an event and valuable information on the nature of the inhaled contaminant. However, activity of these samples represents activity that has been removed from the body before entering the lungs or the digestive tract.

— Exhalation monitoring: ^{220}Rn exhalation measurement allows the individual determination of ^{228}Th body burdens without chemical preparation. The detection limit of this method is comparable to that of urinary excretion analysis. Conclusions concerning ^{232}Th quantification require additional information about the nuclide spectrum.

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7.2 Special workplace monitoring

Special monitoring programmes refer to measurements made when an intake is suspected following an event.

The circumstances of each event are particular, for example, in the level of activity and duration of exposure, so it is difficult to standardize special workplace monitoring. The distribution of radioactive contamination should be assessed using air monitoring and surface contamination monitoring. Air monitoring devices fitted with alarms and which operate continuously should be used whenever operations or upset condition is likely to produce significant releases of radioactive material in the workplace. Air monitoring shall meet the general requirements defined in 6.2. Devices should also be located where they can reliably detect the release of radioactive material; this is not necessarily at points that are representative of the workers' breathing area.

8 Designing a task-related monitoring programme

Task-related monitoring programmes are required in the case of changes in working conditions and operations of limited duration, i.e. the duration is shorter than the intervals defined for routine monitoring programmes in Clause 6, Tables 1, 2, 3 and 4, to provide data for dose assessment and for the radiation protection optimisation process. The general requirements set out in 6.1 for routine monitoring programmes shall be applied to task-related monitoring programmes.

When an operation is planned, an appropriate monitoring programme shall be devised. Individual task-related monitoring programme may not be necessary with respect to internal exposure provided suitable individual protection is used during the tasks. Nonetheless, a special monitoring programme should be made available in case there is evidence that the protective measures have failed. Task-related monitoring is also required after major modifications have been applied to the installations or operating procedures.

Task-related workplace monitoring is based on the same principles as for routine workplace monitoring and the same requirements shall be fulfilled (see 6.3).

In contrast to routine monitoring programmes, more information can be available about the circumstances of an intake event, especially relating to the time between measurement and the intake.

The objectives of a task-related monitoring programme and the way it is organized, including the basis for interpreting the results, shall be documented according to Clause 12.

9 Designing a confirmatory monitoring programme

Confirmatory monitoring programmes serve to confirm the adequacy of protective measures and of assumptions made regarding the levels of exposure. Periodic measurements can be made to ensure that working conditions are satisfactory. For example, an analysis of faecal matter over the last three days of worksite operation can be appropriate. In association with radiation protection departments, the results of workplace monitoring (swipe tests and air sample measurements) and contamination measurements made on individuals can be compared and the radiation protection system modified if need be.

10 Individual monitoring in specific cases

10.1 Monitoring of nuclear medicine and radiopharmacy staff exposed to short-lived radionuclides

Individual routine monitoring may not be feasible for radionuclides with a half-life shorter than that of ^{131}I, i.e. 8 days. In this case, when the likely annual committed dose is above 1 mSv, implementation of triage monitoring in the nuclear medicine department, as presented in ISO 16637, is one option[4]. Triage monitoring programmes rely on frequent individual screening measurements performed in the workplace by local staff using standard laboratory instrumentation to detect whether potential intakes have occurred. In contrast to in vivo measurements or in vitro analysis performed within a routine monitoring programme, screening measurements do not allow determination of doses but they are adequate to verify that a given threshold is not exceeded. If the screening threshold is exceeded, in vivo or in vitro measurements should

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be performed in order to confirm internal contamination and to quantify the intake for the subsequent dose assessment.

10.2 Intakes of actinides

The detection limits associated with particular analytical techniques and the uncertainty of measurement and interpretation make it difficult to evaluate intakes rapidly. All of the above also lead to uncertainty in the assessment of the internal dose received by each worker. Individual monitoring takes the form of lung counting and monitoring of urinary and faecal excretion or exhalation.

In vivo detection of the intake of actinides using lung counting is based on the detection of x-ray and gamma ray photons with characteristic energy levels. However, this method offers a poor level of sensitivity due both to the low intensity of the photons emitted and attenuation by the tissues and to the high background due to other radionuclides present. Thus, for many radionuclides, the detection limits are above regulatory limits for occupational exposure. Lung counting is, therefore, not sufficient as a means of routinely monitoring small intakes and is used to supplement other methods. Air monitoring may be the preferred method particularly where particle size and solubility are well known.

10.3 Intake via a wound

ISO 20031 offers guidance for the design of a special monitoring programme and for dose assessment in the case of wound contamination with radionuclides[6].

A wound count shall be performed immediately, to determine whether decorporation therapy is advisable. This should be started as early as possible, if indicated. A smear measured by liquid scintillation can reveal contamination, with better detection levels than in vivo measurements, allowing additional analysis to be performed in the frame of the special monitoring programme. The activity of radioactive material at the site of the wound has to be measured, taking account of attenuation of the radiation by foreign matter and tissues in order to assess the dose to local tissues. Depending on the radionuclides and the quantity of material, and on the result of the medical examination, the decision may be taken to attempt to remove the material from the wound. In this case, the activity removed and the activity remaining around the wound have to be measured to obtain an activity balance.

Wounds act as routes by which radionuclides can enter the systematic circulation[12]. Even minor wounds, such as cuts and grazes on the skin and puncture wounds may allow radioactive material to penetrate the subcutaneous tissue and then infiltrate into the rest of the body. Therefore, a series of measurements has to be made to determine the activity transferred from the wound to the rest of the body. In the interest of reliable dose assessment, all methods applicable for the incorporated radionuclides, in vivo measurements and in vitro analyses, shall be applied. If in vivo measurements are made, the activity remaining around the wound may have to be shielded to avoid interference, unless the purpose of the monitoring is to determine the level of activity remaining in the wound. To assess the committed effective dose, allowance should be made for the effect of any treatment administered to accelerate the excretion of systemic activity.

10.4 Intake through the intact skin

Contamination on the skin can result in an intake of the radionuclide into the body. This especially shall be taken into account for tritium, iodine, caesium, some organic compounds and radionuclides in solution facilitating penetration through the skin. Therefore, for radionuclides for which contamination is directly measurable, a level for skin contamination shall be defined above which a special monitoring programme for intakes is required. For other radionuclides not directly measurable, a routine monitoring programme of intake shall be performed.

11 Investigation levels

In the context of internal contamination with radioactive material, investigation levels are levels of dose, intake or contamination at or above which investigations should be conducted to confirm the dose and to reduce the uncertainty associated with the dose assessment.

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These investigations may include:

— gathering more information about the time pattern of the contamination and the characteristics of the contaminant;

— additional workplace and/or individual monitoring.

Investigation levels shall be set at values corresponding to an annual committed dose no higher than 5 mSv.

In a routine monitoring programme, when there is a potential of more than one intake occurring within a year and when the probability of intake through the year is considered to be uniform, investigations levels should take into account the number of monitoring intervals.

12 Recording, documentation and reporting

12.1 Recording and documentation

12.1.1 General

The strategy and objectives for monitoring workers occupationally exposed to radioactive material shall be documented. For some radioactive materials, a single method of measurement is sufficient. In such a case, it is enough to lay down the frequency of sampling/measurement and the assumptions used in calculating the dose received from the results of the measurements. In other cases, a range of measurement methods can be necessary, including air-sampling, urine or faecal sampling, and part or whole-body monitoring. In these cases, the strategy shall set out the purpose and frequency of each type of measurement and the way the results are used in assessment of the dose received.

Sufficient records shall be kept of details of all measurements including the results, instruments used, calibrations, environmental conditions, correction factors, background measurements, etc. This should be such that the exact conditions of measurement may be reproduced in the future.

All reports and records shall be authenticated by the competent person responsible.

Account shall be taken of the national requirements in respect of record-keeping.

12.1.2 Samples

The procedure for taking samples (e.g. urine, faeces, nasal samples) shall be documented as part of the QA procedures. The procedure shall be designed to ensure that the sample is properly packaged and labelled and is not contaminated.

Each sample shall bear a unique identification. This identification shall be used to denote the identity of the worker, the date and time that the sample was taken, the duration of sampling and all subsequent measurements made on that sample. Depending on the requirements of national or state authorities, identification of the sample donor may be withheld from the sample identification number. Also, chain-of-custody requirements may exist and, if so, shall be adhered to.

12.1.3 Measurements

The procedure for making measurements shall be documented as part of the QA procedures. The procedure shall be designed to ensure that the equipment used is operating correctly and is properly calibrated.

Each measurement shall be given a unique identification. In the case of measurements on samples, this identification shall be used to denote the identity of the sample measured and the date and time of the measurement. In the case of direct measurements on individual workers, the identification shall denote the identity of the worker and the date and time of the measurement.

For each measurement, the nature of the measurement shall be recorded (e.g. urine sample, measurement of tritium concentration; whole body count, measurement of ^{60}Co; thyroid count, measurement of ^{131}I).

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For each measurement the conditions of measurement shall be recorded [e.g. counting time, equipment and method used for the measurement, limit of detection, name of operator of the equipment, background count, calibration (including the individual parameters taken into account for the calibration)].

An inventory of the equipment available for measurement shall be kept. For each item of equipment the identity of the equipment (e.g. name, type or model number, and serial number), the name of the supplier, and the date of purchase should be recorded.

For each item of equipment requiring regular servicing, a log shall be kept showing the date on which servicing was carried out and when the next service is due.

For each item of equipment requiring regular calibration, the protocol for conducting that calibration including the means of ensuring traceability to national or international standards shall be documented.

For each item of equipment requiring regular calibration, the date and results of calibration and the date when the next calibration is due should be shown in the equipment log.

12.1.4 Dose assessment

The procedure for calculating doses shall be documented. This shall include the assumptions made in respect of route of intake, temporal pattern of intake, default or specific value of AMAD, chemical and physical nature of the radioactive material together with assumptions on the absorption parameters values.

The dose calculation shall be recorded if it is done manually. If an internal dose calculation software is used to calculate the dose, it shall be documented, including version and date, and all parameters used in the calculation shall be recorded.

Following internal contamination, the recording level is the level of dose specified by the regulatory body at or above which values of dose received by workers are to be entered in their individual exposure records. Results falling below this level may be recorded or shown as "below dose recording level". The measurements results themselves should always be maintained in the worker records.

When the regulatory body doesn't set a recording level and doesn't stipulate that all doses must be recorded, a recording level may be set for significant individual exposure. In this case it should be set at a value corresponding (having regard to the length of the monitoring interval) to a committed effective dose from intake in one year no higher than 1 mSv.

12.2 Reporting

12.2.1 Routine monitoring programmes

Arrangements shall be made to ensure that the results of all measurements and dose assessments are reported to the client's dose record-keeping service accurately and in reasonable time. Where individuals have not submitted samples or attended for in vivo monitoring within the tolerances shown in Table 5, the report shall state this fact.

Each report shall identify the results unambiguously so that the identity of the individual worker and the date to which the measurement(s) relate are clear.

Results shall be expressed in terms of 50-year committed effective dose from intakes of radioactive material arising during the monitoring interval. Results below the predefined recording level may be reported as "below recording level".

Where activities of radioactive material during the monitoring interval have been detected, the nature of the radioactive material (where known) shall be stated in the report together with the assumptions on the absorption type. Where no activities have been detected, the report shall state the value of the detection limit of the radionuclide, intakes of which cannot be ruled out.

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