Australian Government
Australian Radiation Protection and Nuclear Safety Agency

arpansa

Guide to calculation of 'cumulative equivalent dose' for the purpose of applying ionising radiation factors contained in Statements of Principles determined under Part XIA of the *Veterans' Entitlements Act 1986 (Cth)*

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Table of Contents

1. Introduction

1.1 Statements of Principles

Statements of Principles (SoPs) are legislative instruments under the *Legislation Act 2003* determined by the Repatriation Medical Authority (RMA). The SoPs set out factors linking particular kinds or injury, disease or death with relevant defence service. They are based on sound medical-scientific evidence (SMSE) and state the factors that must exist in a person's prior service for a particular disease, injury or death to be linked causally to that service.

The SoPs are used to determine eligibility for entitlements under the *Veterans' Entitlements Act 1986* (VEA) and the *Military Rehabilitation and Compensation Act 2004* (MRCA). Upon being determined by the RMA, the SoPs are registered under the *Legislation Act 2003* and are tabled in both Houses of the Australian Parliament. Unless disallowed by the Parliament, they remain binding on all levels of decision-makers.

1.2 Ionising radiation factors in SoPs

The RMA has included exposure to ionising radiation as a factor in SoPs for particular kinds of injury, disease or death. Examples of the ways in which claimants could potentially have been exposed to ionising radiation through service may include being present during or subsequent to the testing or use of nuclear weapons, undergoing diagnostic or therapeutic medical procedures involving ionising radiation, and being a member of an aircrew, leading to increased levels of exposure to cosmic radiation.

Drawing upon available SMSE, the RMA has specified the 'cumulative equivalent dose' of ionising radiation, which must as a minimum be received by an affected organ or tissue for the factor within the relevant SoP to apply.

The SMSE drawn upon by the RMA in regard to ionising radiation factors, and specification of the cumulative equivalent dose, has relied on studies in which individual exposure levels have been estimated. The process of retrospective assessment of dose to an individual is known as a dose reconstruction.

As a consequence, the process of dose reconstruction must be followed in assessing whether an individual claimant's exposure meets the ionising radiation factor in the relevant SoP. The circumstances of any relevant exposures to ionising radiation must be reviewed and a calculation made of cumulative equivalent dose to individual organs or tissues.

1.3 Dose reconstruction

Dose reconstruction depends on the quantity and quality of available dose monitoring information, the conditions under which the exposure arose, and the types of ionising radiation to which the individual was exposed. For complex dose reconstructions, specific characteristics, locations and activities of an exposed person need to be determined or estimated. Dose reconstruction is often faced with a lack of direct empirical evidence relating to an individual's level of ionising radiation exposure, so it requires research and technical analysis.

A successful application of a dose reconstruction uses approaches that combine available measurement data with mathematical dose reconstruction models to provide an estimate of dose and its uncertainty.

Dose reconstructions are technical tasks that require expertise in radiation dosimetry. The methodology specified in this document, underpinned by international best practice, sets out the essential steps required when undertaking a dose reconstruction, regardless of the type of exposure to the individual (occupational, environmental or medical).

2. Purpose

2.1 Incorporating the methodology of dose reconstruction

The Australian Radiation Protection and Nuclear Safety Agency (ARPANSA) is Australia's lead technical body in radiation protection, a field that depends on high level skills in radiation dosimetry.

At the request of the RMA, ARPANSA has prepared this document, which sets out the methodology of dose reconstruction of cumulative equivalent dose, which is used to determine whether an individual claimant's exposure meets the ionising radiation factor in the relevant SoP. The methodology outlined in this document is consistent with the approach used to determine the ionising radiation factors outlined in the SoPs for the particular kinds of injury, disease or death in which those factors appear.

In doing so, this document will also assist both the claimants and the Repatriation Commission and the Military Rehabilitation and Compensation Commission in assessing the eligibility for entitlements under the VEA and MRCA.

As section 14 of the *Legislation Act 2003* enables the RMA to incorporate writing in a separate document into a SoP by making reference to the document in the SoP, it is intended for the writing in this document to be so incorporated.

3. Definition of ionising radiation dose

The category of radiation that is defined as ionising comprises the types of radiation with sufficient energy to break chemical bonds, through the process of ionisation. Each ionisation involves the breaking away of an electron from an atom, accompanied by the release of energy which is absorbed by material surrounding the ionised atom. Compared to other types of radiation, ionising radiation deposits a large amount of energy into a small area. The three main types of ionising radiation are alpha particles, beta particles and high energy electromagnetic radiation, generally classified as gamma rays or x-rays, depending on their source. Neutrons are not directly ionising, but can lead to ionisation as explained below.

3.1 Types of radiation

Alpha (α) particles, made up of two protons and two neutrons, are highly ionising but are consequently unable to penetrate very far through matter and are brought to rest by a few centimetres of air or less than a tenth of a millimetre of living tissue.

Alpha particles cannot penetrate the layer of dead cells on the outside of human skin but could damage the cornea if exposure was directly to the open eye. Human exposure to radiation via alpha particles can only occur if a source of alpha particles enters the body through inhalation, ingestion or via a wound.

Beta (β) radiation consists of high-speed electrons and, being less ionising than alpha particles, can travel though many centimetres or even metres of air and though millimetres of skin or tissue. If beta-emitting substances are inhaled or ingested, that can lead to exposure to living cells and internal organs.

Gamma (γ) rays are a form of electromagnetic radiation consisting of a stream of photons. X-rays are identical to gamma rays, distinguished only by the way they are generated. Gamma and x rays are able to penetrate deep into the body.

Neutrons are particles that cannot cause ionisation directly, but can interact with material to cause ionisation. In tissues, neutrons can interact with hydrogen to cause ionisation, which can lead to greater biological damage when compared to gamma and x-rays.

3.2 Dosimetric quantities

The International System of Radiological Protection has been developed by the International Commission on Radiological Protection (ICRP) and is used world-wide as the common basis for radiological protection standards, legislation, guidelines, programmes and practice (ICRP 103, 2007). The ICRP is an independent, international organisation with experts representing the world's leading scientists and policy makers in the field of radiological protection.

The ICRP methodology for estimating the dose of ionising radiation received by specific organs or tissues is based on a number of characteristics of the radiation(s) involved, the organs or tissues exposed, and the pathways that lead to exposure. See Figure 1 for an overview of dosimetric quantities.

3.2.1 Absorbed dose

The fundamental dosimetric quantity used by the ICRP is the absorbed dose. The International System (SI) unit of absorbed dose is the gray (Gy), defined as an energy deposition of 1 joule/kilogram. While it can technically be defined at any point in matter, for the purpose of dose reconstruction, its value is obtained as an average over the mass of a specific tissue or organ, recognising that it is impractical to specify the relevant physical processes at a microscopic level (ICRP 103, 2007). Radiation weighting factors account for differences in distribution of energy deposited in microscopic regions of the particular tissue or organ.

This average dose is considered to be an accurate representation, for the purpose of defining the overall risk of specific harms, such as cancer, arising in the tissue or organ as a result of an exposure. For radiation exposures arising through sources external to the body, calculations are made on the homogeneity of the exposure and the penetration range of the radiation incident on the body. For internal exposures, specific mathematical models (referred to in section 4.2.2.1) take account of non-uniformity in the distribution and retention of the material that is the source of exposure.

3.2.2 Equivalent dose and radiation weighting factors

If a tissue is exposed to multiple sources of radiation, the various absorbed dose estimates for each type of radiation must be combined. To do this, the absorbed dose of each type of radiation must be multiplied by a radiation weighting factor, as recommended by the ICRP, which reflects the ability of the particular type of radiation to cause damage. The quantity obtained when the absorbed dose is multiplied by the radiation weighting factor is known as the equivalent dose. The unit of equivalent dose in SI units is the sievert (Sv).

The radiation weighting factor is assigned a factor of 1 for gamma and x-rays and the values for other types of radiation are related to this in accordance with their ionising densities (see Table 1). The ionisation density of beta radiation is similar to that of gamma and x-rays, so its weighting factor is also 1. Radiation weighting factors for neutrons are energy-dependent and range from 2.5 to 20. Alpha particles are assigned a radiation weighting factor of 20.

This enables a calculation of cumulative equivalent dose which is the total dose of ionising radiation received by a particular organ or tissue from external exposure, internal exposure or both, calculated in accordance with the methodology set out in this document.

The calculation of cumulative equivalent dose in this document can include exposures to therapeutic radiation, diagnostic radiation, cosmic radiation at high altitude, radiation from occupation-related sources and radiation from nuclear explosions or accidents. Multiple types of ionising radiation can be combined by accounting for their differing biological effect.

Table 1: Properties of commonly encountered radiations

Radiation type	Range in air	Range in tissue	Radiation weighting factor
Alpha	0.03 m	0.04 mm	20
Beta	3 m	5 mm	1
X, gamma	Very large	Through body	1
Fast neutron	Very large	Through body	2.5−20*
Thermal neutron	Very large	Through body	2.5

** Continuous function of energy*

3.2.3 Effective dose and tissue weighting factors

In addition to the effects of different radiation types, organs and tissues have differing sensitivities to radiation. To calculate exposure to the whole body or to multiple tissues or organs, the effective dose is calculated by multiplying the equivalent doses by the weighting factor for each tissue or organ, and summing across tissues and organs. ICRP have recommended tissue and organ weighting factors for various types and energies of radiation (ICRP 103, 2007). The SI unit of effective dose is also the sievert (Sv).

Thus, while absorbed dose in a specified tissue is a quantity that can, at least in theory, be measured by a radiation detection device, the equivalent dose and the effective dose incorporate weighting factors based on data arising from animal and epidemiological studies of specific health outcomes.

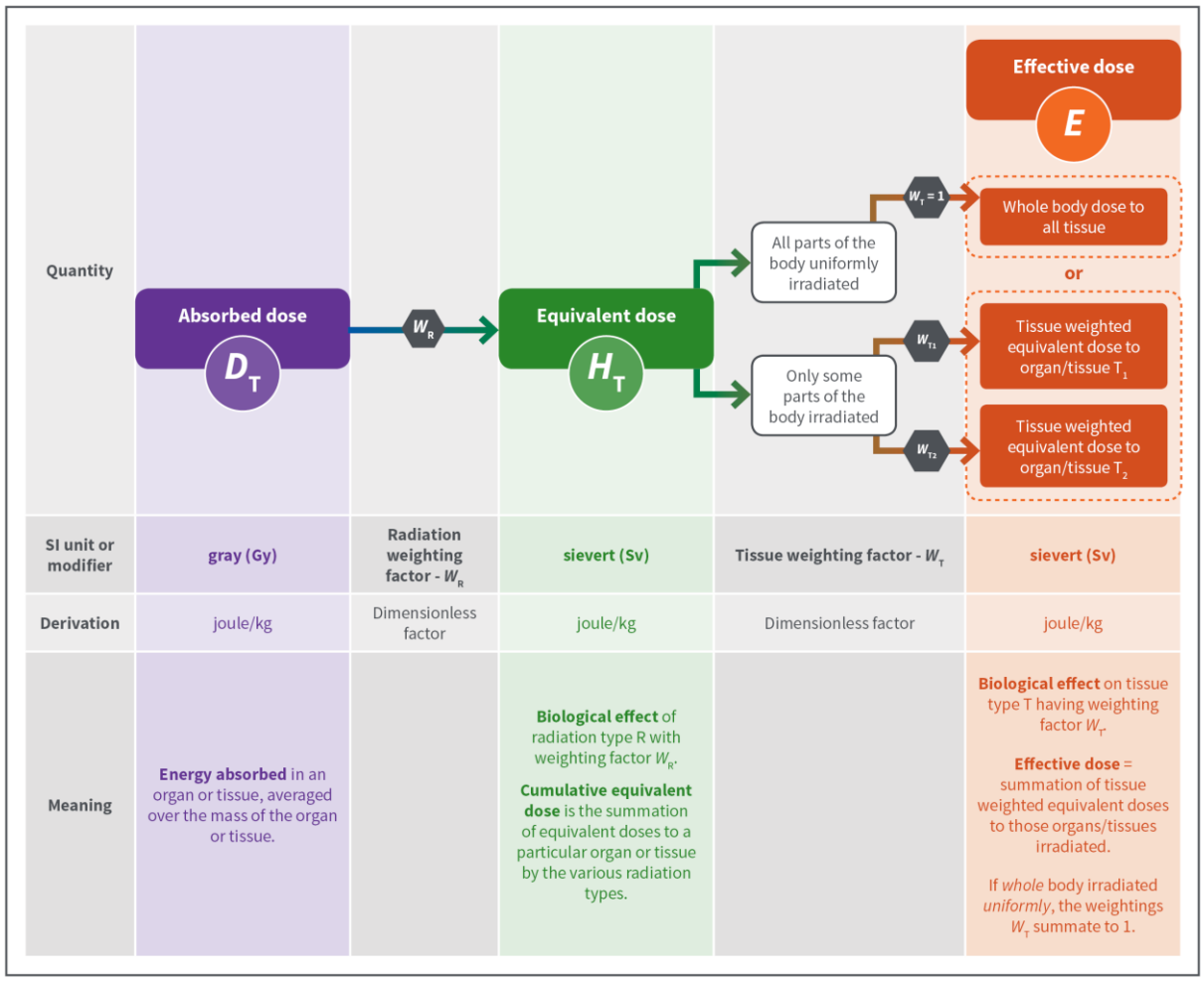

Figure 1: Overview of dosimetric quantities

4. Dose reconstruction methodology

Although all dose reconstructions are similar in that they attempt to estimate doses from historical occurrences to individuals, there are several broad categories within which dose reconstructions have many common concerns, challenges and limitations. In this report, dose reconstructions are categorised with respect to exposures that are occupational, environmental or medical.

An occupational dose reconstruction is concerned with estimating past radiation exposures received by individuals as a result or condition of their employment. An environmental dose reconstruction is typically taken when an individual is exposed to radiation or radioactive materials that have been released into the environment. A medical dose reconstruction is the retrospective dose estimation of radiation exposure that was received by a patient during a diagnosis of, or treatment for, a medical condition or disease.

While placing exposed individuals into the appropriate category is often a clear choice, there can be occasions when more than one category could be appropriate. These need to be considered when developing an exposure scenario and identifying exposure pathways.

When undertaking a dose reconstruction where there may initially be a lack of specific information about the individual, an estimate of dose can be undertaken using a conservative approach. This approach may use plausible worst-case exposure scenarios and exposure parameters to estimate dose. If the resultant dose is approaching or exceeding a level of concern, then a more complex assessment may be warranted involving the collection of additional data and a more detailed analysis to establish a more representative estimate of dose.

Experience has shown that no two dose reconstructions are alike; however a general methodology can be applied. The dose reconstruction methodology can be divided into five essential steps. These steps are based on those described in the report, *Radiation Dose Reconstruction: Principles and Practices, Recommendations of the National Council on Radiation Protection and Measurements* (NCRP, 2009).

Dose reconstruction essential steps

Step 1: Defining the exposure scenarios

The term exposure scenario refers to assumptions about conditions of exposure for an individual who is the subject of a dose reconstruction. It incorporates a description of the individual's relevant characteristics, including their activities at locations where radiation exposure could have occurred, times spent at those locations and a description of sources of radiation exposure.

Step 2: Identifying the exposure pathways

Once an exposure scenario is defined, the associated pathways of exposure of organs and tissues to ionising radiation emitted by external and internal sources must be identified. Exposure from external sources located on or outside the body are of concern when radiation penetrates the epidermis of the skin. Exposures from internal sources occur from radionuclides incorporated in the body.

Step 3: Developing and implementing a method for dose estimation

A combination of data and modelling is required for the estimation of dose. The more closely related the data are to an estimate of dose, the fewer are the demands placed on the application of modelling. The complexity of modelling should be commensurate with the needs of a dose reconstruction and the types, quality and quantity of data that can be used to implement a model.

Step 4: Evaluating Uncertainties

In order to establish the credibility of the results, an analysis of all uncertainties, including uncertainties in exposure scenarios and uncertainties in data and models used to estimate dose, must be considered and taken into account to an extent appropriate to the purpose and objectives of a dose reconstruction and the quality and quantity of available data.

Step 5: Presenting and interpreting results

A presentation and interpretation of a dose reconstruction must provide a reasonably complete, coherent and understandable picture of the analyses and results of the dose reconstruction that allows others to judge the adequacy of the dose reconstruction for its intended purpose and whether the objectives have been met.

4.1 Step 1: Defining the exposure scenarios

An exposure scenario is a conceptual representation of an exposure situation to be considered in a dose reconstruction that incorporates two kinds of information:

- A description of individuals of concern, including their relevant characteristics, their relevant activities at locations where radiation exposure could have occurred, and times spent at those locations; and
- A description of sources of radiation exposure.

Development of appropriate exposure scenarios is the cornerstone of the dose reconstruction process, and there is no single approach to defining exposure scenarios that is suitable in all cases. To obtain realistic estimates of dose, an exposure scenario may need to include many details about characteristics and activities of individuals and sources of radiation exposure. If detailed information is unavailable, an exposure scenario can be highly simplified and use conservative assumptions.

The most appropriate approach can depend on the types, quality and quantity of available information and the purpose and objectives of a dose reconstruction. It is essential to properly document scenarios used in a dose reconstruction to permit a critical evaluation by others.

A description of the subjects of a dose reconstruction involves an identification of relevant intrinsic characteristics (e.g., age, sex, ethnicity, and health status) and relevant activities at locations and times of potential exposure (e.g., lifestyle, occupation including associated movements and responsibilities, and living habits including sources of food and water). In developing exposure scenarios, the term activities should be interpreted broadly to include any relevant factors other than the intrinsic characteristics of an individual or population. For example, in an environmental dose reconstruction, a description of relevant activities could include information on the construction of the person's home.

4.2 Step 2: Identifying exposure pathways

There are two broad categories in which exposure to radiation can occur, namely external and internal. Once an exposure scenario is defined, the associated pathways of exposure from external and internal sources must be identified. In some cases, exposure pathways are few in number (sometimes only one) and are essentially defined by the exposure scenario itself; an example is medical exposure to an external source of x-rays. In other cases, such as scenarios for exposure of the public to radionuclides in the environment, many pathways of exposure from external and internal sources may need to be identified and considered.

4.2.1 External exposure pathways

External exposure occurs from radiation sources which are outside the body. The radiation needs to have sufficient energy to penetrate the outer layers of skin and irradiate organs and tissues. Due to their low penetrating power, alpha particles and low-energy beta particles do not contribute to external exposure. External exposures occur from photons, electrons with sufficient energy and neutrons. External exposure stops as soon as the source is removed or people move away from the area, provided contamination is not present on the person's body or clothing.

Examples of external exposure include:

- Radiation emitted by a specific source, such as a nuclear detonation, contaminated object or a device that produces radiation
- Medical procedures which use a radiation field such as an x-ray machine or a CT scanner
- Immersion exposure from contaminated air or water
- Deposition exposure from contaminated ground surface
- Cosmic radiation exposure

4.2.1.1 Basics of external exposure dosimetry

The absorbed dose to an organ or tissue of concern due to exposure to radiation from an external source generally depends on the following factors:

- Characteristics of the source, including the source geometry, the total emission or emission rate of different radiations from the source, and the energy and angular distributions of the emitted radiations
- Transport of radiations from the source to the location of an individual to give an estimate of the fluence or fluence rate of radiations and their energy and angular distributions at the body surface, taking into account the distance from the source
- Transport of the radiations incident on the body surface to the location of the organ or tissue of concern, taking into account scattering and absorption of the radiations in other tissues
- Deposition of energy in the organ or tissue of concern to give an estimate of absorbed dose or dose rate

It is not always necessary to determine the external dose using the factors above and complex modelling. Appropriate combinations of measurements, physical models and conversion coefficients can often be used. In the case of external exposure, international bodies have undertaken complex modelling in order to create conversion coefficients to convert external exposure measurements into dose. Examples of dose conversion coefficients for external exposure include ICRP 74 (1996), ICRP 116 (2010) and Federal Guidance Report No.12 (Eckerman and Ryman, 1993).

4.2.2 Internal exposure pathways

Internal exposure occurs from radiation sources which are inside the body. Once the radiation enters the body it can irradiate organs and tissues. In this case alpha particles are not shielded by outer skin layers and contribute to exposure. Internal exposure will continue until the radionuclides in the body have either decayed away or have been excreted.

Examples of internal exposure include:

- Inhalation of airborne radionuclides
- Inhalation from radionuclides resuspended from the ground surface
- Ingestion of radionuclides in contaminated food or water
- Ingestion of radionuclides through inadvertent means, such as transfer from hand to mouth
- Absorption of radionuclides through the skin or a wound
- Injection or insertion of radionuclides into the body

4.2.2.1 Basics of internal exposure dosimetry

The absorbed dose to an organ or tissue of concern due to internal exposure depends on:

- Dosimetric modelling: The absorbed dose to a target organ based on the activity in the source organ. The target and source organ can be the same; and
- Biokinetic modelling: The activity of the radionuclide to a specific organ or tissue following an intake, known as the source organ, and the transit of the radionuclide in the body over time based on the physical and chemical form of the radionuclide. The ICRP recommends the use of different biokinetic models based on the radionuclide and method of intake, in particular the respiratory model for inhalation and alimentary tract model for ingestion, although each model is derived from a general model, which is presented in ICRP 130 (2016).

Extensive research has been undertaken in internal exposures to develop dosimetric and biokinetic models, and to link these models to epidemiological evidence (ICRP 103, 2007).

ICRP has used the dosimetric and biokinetic models to calculate dose coefficients for the various target organs per unit intake of radionuclides by workers and by members of the public (ICRP 119, 2012). Dose coefficients (sievert/becquerel) are based on models for specific routes of intake and the appropriate element specific systemic models, and are calculated for committed periods after time of intake, typically 50 years for adults or 70 years for children. For dose reconstructions of radionuclides with short retention times in the body, it is appropriate to use the dose coefficients based on the standard committed period of 50 years for adults and 70 years for children, as the dose is delivered relatively quickly after intake. For dose reconstructions of radionuclides with long retention times in the body, it may be more appropriate to estimate the dose as a function of time after the intake, using the appropriate dose coefficient for a given time period. The ICRP also provides dose coefficients at various time steps (ICRP CD, 2011).

4.3 Step 3: Developing and implementing a method for dose estimation

Once an exposure scenario is defined, associated exposure pathways are identified and suitable data are collected, radiation doses in organs or tissues of concern can be estimated.

A combination of data and modelling is required for the estimation of dose. The more closely related the data are to an estimate of dose, the fewer are the demands placed on the application of modelling. The complexity of modelling should be commensurate with the needs of a dose reconstruction, the level of assessment and the types, quality and quantity of data that can be used to implement a model.

4.3.1 External dose assessment method

When undertaking an external dose assessment, ideally personal dosimetry measurements would be available to form the basis of the assessment. Examples of personal dosimetry include film and thermoluminescent dosimetry badges. The ICRP has developed conversion coefficients to convert from personal dosimetry measurements into absorbed doses based on exposure geometries (ICRP 74 (1996) and ICRP 116 (2010)).

Environmental measurement may also be used to estimate the external exposure as shown in Figure 2. Dose rate measurements when multiplied by the exposure time provide a means to estimate the external exposure. This exposure can also be converted to an absorbed dose using the relevant conversion coefficients.

Other environmental measurements such as the amount of contamination in the air, water or ground can also be used to assess the external exposure, along with other factors such as the exposure time and any habit factors affecting the exposure such as shielding by buildings. The Federal Guidance Report No.12 (Eckerman & Ryman 1993) provides external dose coefficients to calculate absorbed dose and effective dose due to contamination. FGR 12 (1993) assumes uniformly distributed radionuclides and provides dose coefficients for external exposure pathways, including immersion from contaminated air or water, and deposition exposure from contaminated ground.

In the case of external exposure to cosmic radiation, the rate of exposure is well categorised and depends largely on the year of exposure, altitude and latitude. Obtaining these details enables the exposure to cosmic radiation to be assessed.

In the case of medical procedures which result in an external dose, such as an x-ray procedure, the dose may have been reported. In the absence of a reported dose, characteristics of the procedure such as type of scan, radiation field, etc., are required to make an estimate of the external exposure.

4.3.2 Internal dose assessment method

The internal dose is the combination of the intake and the appropriate dose coefficient. The most current models and recommendations from the ICRP shall be used to assess the internal dose.

Ideally, intake would be determined from direct measurements such as bioassay data and whole body measurements. Bioassay data includes, but is not limited to:

- Urine samples
- Faecal Samples
- *In vivo* measurements

Biokinetic modelling can be used to estimate the initial intake based on the direct measurements and the rate of elimination from the body. Multiple samples over various time periods can help to provide a more accurate representation of the intake.

Indirect methods based on environmental conditions may also be used to estimate intake (see Figure 2). Estimates of intake due to:

- Inhalation can be made by measurements or estimates using models of airborne concentrations, time spent exposed to the airborne concentration and breathing rate
- Ingestion can be made by measurements or estimates using models of radionuclides in water or food and estimates of ingestion rates.

In the case of medical procedures which result in an internal dose, such as a nuclear medicine scan, the dose may have been reported. In the absence of a reported dose, characteristics of the procedure, such as radionuclide used, activity, etc., are required to make an estimate on the internal exposure.

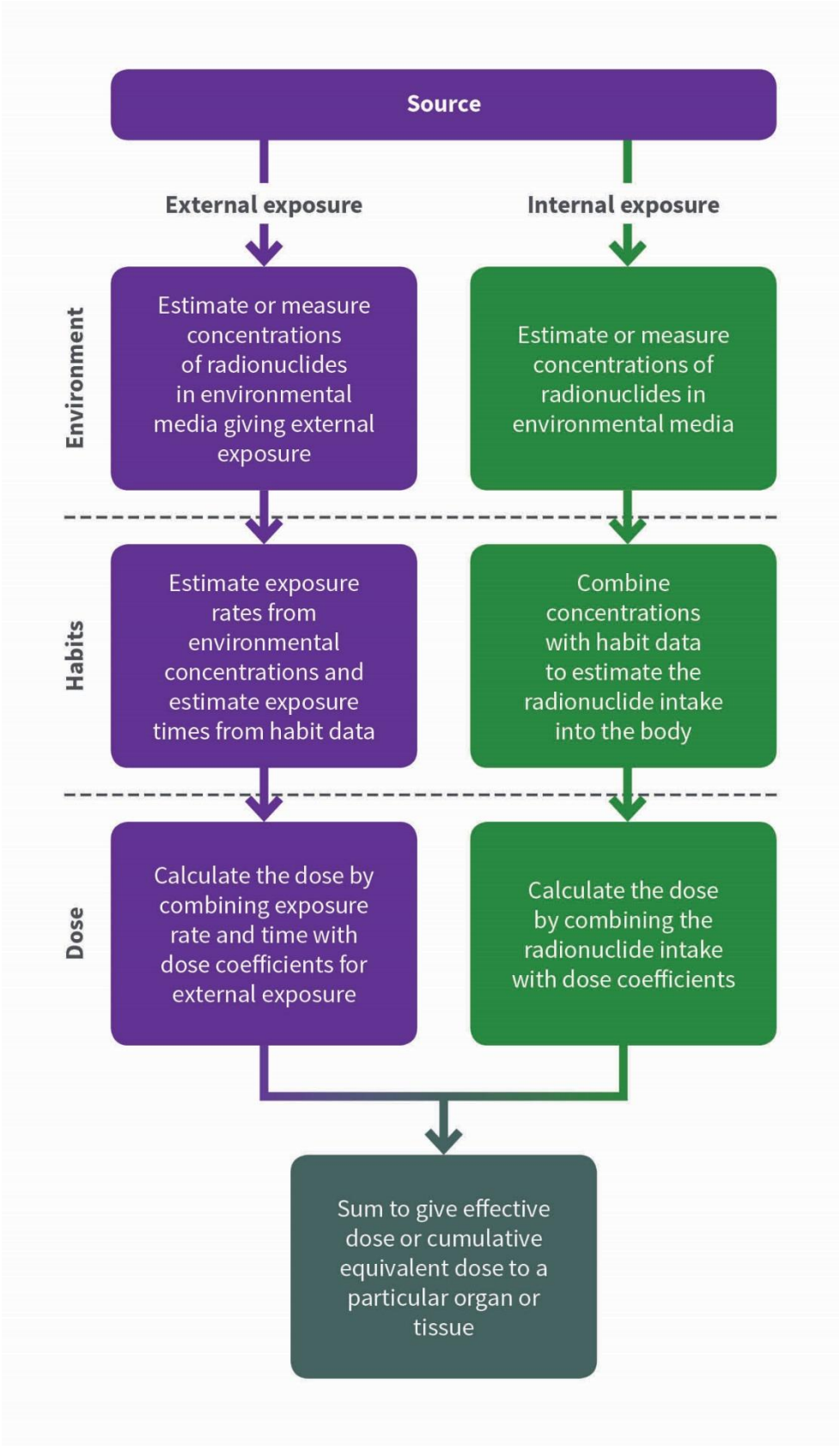

Figure 2: Dose calculation process for external (left) and internal (right) exposures based on estimates or measurements of contamination (ICRP 101, 2006)

4.4 Step 4: Evaluating uncertainties

An analysis of uncertainty to an extent appropriate to the purpose and objectives of a dose reconstruction and the quality and quantity of available data is essential to establishing the credibility of results. The essential purpose of an uncertainty analysis is to provide a credible range within which there is a high degree of confidence that the true dose to an individual or population lies. All uncertainties, including uncertainties in exposure scenarios and uncertainties in data and models used to estimate dose, must be considered, documented and taken into account in an appropriate manner in a dose reconstruction.

Approaches to evaluating uncertainty can involve a substantial degree of subjective scientific judgment, in addition to more rigorous methods of statistical uncertainty analysis, depending on the importance of judgment in developing the assumptions, data and models used to estimate dose. In any dose reconstruction, a suitable approach should be chosen on the basis of availability and quality of information to evaluate uncertainty and the intended use of the resulting estimates of dose and their uncertainty.

4.5 Step 5: Presenting and interpreting results

The dose reconstruction must present the methods, assumptions, results and conclusions in a manner that is understandable. The results should be interpreted by discussing them in the context of the defined purpose and objective. The dose reconstruction should be presented with enough information to allow the assessment to be reproduced if required.

Details which should be presented in a dose reconstruction include:

- The purpose and objectives
- The exposure scenarios
- Exposure pathways
- Key assumptions
- Data used (either the raw data or a reference to the data source)
- Models and equations used (documented or referenced)
- Discussion of uncertainties
- Results of the reconstruction
- Key conclusions

5. Glossary

Absorbed dose

The fundamental dosimetric quantity used by the ICRP. The SI unit of absorbed dose is the gray (Gy), defined as an energy deposition of 1 joule/kilogram, averaged over the mass or defined volume of a tissue or organ.

Becquerel

The becquerel (symbol Bq) is the SI unit of radioactivity.

Bioassay measurement

Any procedure used to determine the nature, activity, location or retention of radionuclides in the body by direct (*in vivo*) measurement or by in vitro analysis of material excreted or otherwise removed from the body.

Biokinetic modelling

The activity of the radionuclide to a specific organ or tissue following an intake, known as the source organ, and the transit of the radionuclide in the body over time based on the physical and chemical form of the radionuclide.

Dose coefficient

Primarily describes the dose per unit intake, but is also used to describe other coefficients linking quantities or concentrations of activity to doses or dose rates, such as the external dose rate at a specified distance above a contaminated surface.

Dose reconstruction

The process of retrospective assessment of dose to an individual.

Dosimetric modelling

The absorbed dose to a target organ based on the activity in the source organ, where the source and target organ can be the same.

Effective dose

A summation of the tissue or organ equivalent doses, each multiplied by the appropriate tissue weighting factor, used to represent to the total health detriment. The SI unit for equivalent dose is joule/kilogram, termed the sievert (Sv).

Equivalent dose

The product of the absorbed dose in an organ or tissue and the radiation weighting factor of the radiation type. The SI unit for equivalent dose is joule/kilogram, termed the sievert (Sv).

Radiation weighting factor

A unitless number by which the absorbed dose in a tissue or organ is multiplied to account for the differences in harm caused by the different radiation types, the result being the equivalent dose.

Tissue weighing factor

A unitless number by which the equivalent dose in a tissue or organ is multiplied to represent the relative contribution of that tissue or organ to the total health detriment.

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