INTERNATIONAL STANDARD

ISO 20043-1

First edition
2021-01

Measurement of radioactivity in the environment — Guidelines for effective dose assessment using environmental monitoring data —

Part 1: Planned and existing exposure situation

Mesurage de la radioactivité dans l'environnement — Lignes directrices pour l'évaluation de la dose efficace à l'aide de données de surveillance environnementale —

Partie 1: Situation d'exposition existante et planifiée

Reference number
ISO 20043-1:2021(E)

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Published in Switzerland

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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*.

A list of all the parts in the ISO 20043 series can be found on the ISO website.

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.

Introduction

Everyone is exposed to natural radiation. The natural sources of radiation are cosmic rays and naturally occurring radioactive substances existing in the Earth itself and inside the human body. Human activities involving the use of radiation and radioactive substances (NORM) cause radiation exposure in addition to the natural exposure. Some of those activities, such as the mining and use of ores containing naturally-occurring radioactive substances and the production of energy by burning coal that contains such substances, simply enhance the exposure from natural radiation sources. Nuclear installations use radioactive materials and produce radioactive effluent and waste during operation and on their decommissioning. The use of radioactive materials in industry, agriculture and research is expanding around the globe.

All these human activities generally also give rise to radiation exposures that are only a small fraction of the global average level of natural exposure. The medical use of radiation is the largest and a growing man-made source of radiation exposure in developed countries. It includes diagnostic radiology, radiotherapy, nuclear medicine and interventional radiology.

Radiation exposure also occurs as a result of occupational activities. It is incurred by workers in industry, medicine and research using radiation or radioactive substances, as well as by passengers and crew during air travel and for astronauts. The average level of occupational exposures is generally similar to the global average level of natural radiation exposure[1].

As the uses of radiation increase, so do the potential health risks and the public's concerns increase. Thus, all these exposures are regularly assessed in order to

a) improve the understanding of global levels and temporal trends of public and worker exposure,

b) evaluate the components of exposure so as to provide a measure of their relative importance, and

c) identify emerging issues that may warrant more attention and scrutiny. While doses to workers are usually directly measured, doses to the public are usually assessed by indirect methods using radioactivity measurement results performed on various sources: waste, effluent and/or environmental samples.

To ensure that the data obtained from radioactivity monitoring programs support their intended use, it is essential in the dose assessment process that stakeholders (the operators, the regulatory bodies, the local information committee and associations, etc.) agree on appropriate data quality objectives, methods and procedures for: the sampling, handling, transport, storage and preparation of test samples; the test method; and for calculating measurement uncertainty. An assessment of the overall measurement uncertainty also needs to be carried out systematically. As reliable, comparable and 'fit for purpose' data are an essential requirement for any public health decision based on radioactivity measurements, international standards of tested and validated radionuclide test methods are an important tool for the production of such measurement results. The application of standards serves also to guaranty comparability over time of the test results and between different testing laboratories. Laboratories apply them to demonstrate their technical competences and to complete proficiency tests successfully during interlaboratory comparisons, two prerequisites to obtain national accreditation.

Today, over a hundred international standards, prepared by Technical Committees of the International Organization for Standardization, including those produced by ISO/TC 85 working groups, and the International Electrotechnical Commission, are available for measuring radionuclides in different matrices by testing laboratories.

Generic standards help laboratories to manage the measurement process and specific standards describing test methods are used specifically by those in charge of radioactivity measurement. These later cover test methods for:

— Natural radionuclides, including ^{40}K, ^{3}H, ^{14}C and those originating from the thorium and uranium decay series, in particular ^{226}Ra, ^{228}Ra, ^{234}U, ^{238}U, ^{220}Rn, ^{222}Rn, ^{210}Pb, which can be found in every material from natural sources or can be released from technological processes involving naturally occurring radioactive materials (e.g. the mining and processing of mineral sands or phosphate fertilizer production and use), and

— Man-made radionuclides, such as transuranium elements (americium, plutonium, neptunium, and curium), ^{3}H, ^{14}C, ^{90}Sr and gamma emitting radionuclides found in waste, liquid and gases effluent and in environmental matrices (air, soil, water, biota) as a result of authorized releases into the environment and of fallout resulting from the explosion in the atmosphere of nuclear devices and accidents, such as those that occurred in Chernobyl and Fukushima. Radionuclides, such as ^{3}H and ^{14}C occur both naturally and as by-products of the operation of nuclear reactors.

The ICRP recognises three types of exposure situations[2] that are intended to cover the entire range of exposure situations: planned, emergency and existing exposure situations. Planned exposure situations involve the planned introduction and operation of sources (previously categorised as practices). Emergency exposure situations are situations requiring prompt action in order to avoid or to reduce adverse consequences. Existing exposure situations are exposure situations that already exist when a decision on control is taken, such as those caused by enhanced natural background radiation (e.g. exposure to radon in existing buildings).

The fraction of the background dose rate to man from environmental radiation, mainly gamma radiation, is very variable and depends on factors such as the radioactivity of the local rock and soil, the nature of building materials and the construction of buildings in which people live and work.

This document sets out principles and guidance for the radiological characterisation of the environment needed for checking the results of

— prospective assessment of dose to the public arising from exposure to ionizing radiation which may arise from planned discharges to the atmosphere and to the aquatic environment or following remediation action;

— retrospective assessment for dose that may be made for discharges or disposals that were not initially covered by an authorization/permit delivered by a national regulatory body (e.g. contaminated land or dose associated with accidental releases of radionuclides into the environment).

This document is one of a set of generic ISO Standards on measurement of radioactivity.

Example of dose assessment in different exposure situations, modified from Reference [3]

Situation	Type of assessment	
	Prospective	Retrospective
Planned	Determining compliance with the relevant dose constraint (dose limit or regulatory requirements). A prospective assessment includes the exposures expected to occur in normal operation.	Estimating dose to the public from past operations
Existing	Future prolonged exposures (e.g. after remediation)	Past exposures (e.g. occupancy of contaminated lands)
Emergency	Emergency planning (operational intervention level)	Actual impacts after emergency

Measurement of radioactivity in the environment — Guidelines for effective dose assessment using environmental monitoring data —

Part 1: Planned and existing exposure situation

1 Scope

These international guidelines are based on the assumption that monitoring of environmental components (atmosphere, water, soil and biota) as well as food quality ensure the protection of human health[2][4][5][6][7][8]. The guidelines constitute a basis for the setting of national regulations and standards, *inter alia*, for monitoring air, water and food in support of public health, specifically to protect the public from ionizing radiation.

This document provides

— guidance to collect data needed for the assessment of human exposure to radionuclides naturally present or discharged by anthropogenic activities in the different environmental compartments (atmosphere, waters, soils, biological components) and food;

— guidance on the environmental characterization needed for the prospective and/or retrospective dose assessment methods of public exposure;

— guidance for staff in nuclear installations responsible for the preparation of radiological assessments in support of permit or authorization applications and national authorities' officers in charge of the assessment of doses to the public for the purposes of determining gaseous or liquid effluent radioactive discharge authorizations;

— information for the public on the parameters used to conduct a dose assessment for any exposure situations to a representative person/population. It is important that the dose assessment process be transparent, and that assumptions are clearly understood by stakeholders who can participate in, for example, the selection of habits of the representative person to be considered.

Generic mathematical models used for the assessment of radiological human exposure are presented to identify the parameters to monitor, in order to select, from the set of measurement results, the "best estimates" of these parameter values. More complex models are often used that require the knowledge of supplementary parameters.

The reference and limit values are not included in this document.

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/IEC Guide 98-3, *Uncertainty of measurement — Part 3: Guide to the expression of uncertainty in measurement (GUM:1995)*

ISO/IEC Guide 99, *International vocabulary of metrology — Basic and general concepts and associated terms (VIM)*

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

ISO 80000-10, *Quantities and units — Part 10: Atomic and nuclear physics*

3 Terms and definitions

For the purposes of this document, the definitions given in ISO 80000-10, ISO/IEC Guide 98-3, ISO/IEC Guide 99, and the following 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 http://www.electropedia.org/

3.1
background
doses, dose rates or activity concentrations associated with natural sources, or any other sources in the environment that are not amenable to control

3.2
conversion coefficient
coefficient giving effective dose in an external exposure

3.3
data quality objectives
statement of the required detection limits, accuracy, reproducibility and repeatability of the required analytical and other data

Note 1 to entry: Generic data quality objectives can sometimes be set at national level. Data quality objectives can also embrace an amount of data required for an area of land (or part of a site) to enable sound comparison with generic guidelines or standards or for a site-specific or material-specific estimation of risk.

3.4
dose assessment
assessment of the dose(s) to an individual or group of people

Note 1 to entry: For example, assessment of the dose received or committed by an individual on the basis of results from workplace monitoring or bioassay.

Note 2 to entry: the term exposure assessment is also sometimes used.

3.5
dose coefficient
coefficient giving the committed effective dose from an internal exposure

3.6
emergency exposure situations
situation of exposure arising as a result of an accident, a malicious act or other unexpected event that requires prompt action in order to avoid or to reduce adverse consequences

3.7
existing exposure situations
situation of exposure that already exists when a decision on the need for control needs to be taken

Note 1 to entry: Existing exposure situations include exposure to natural background radiation that is amenable to control; exposure due to residual radioactive material that derives from past practices (3.13) that were never subject to regulatory control; and exposure due to residual radioactive material deriving from a nuclear or radiological emergency after an emergency has been declared to be ended.

3.8
hazard
potential for harm or detriment, especially for radiation risks; a factor or condition that might operate against safety

3.9
intended use
use in accordance with information provided with a product or system, or, in the absence of such information, by generally understood patterns of usage

3.10
model
analytical representation or quantification of a real system and the ways in which phenomena occur within that system, used to predict or assess the behaviour of the real system under specified (often hypothetical) conditions

[SOURCE: IAEA Safety Standard No. RS-G-1.8]

3.11
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 substances, and the interpretation of the results

[SOURCE: IAEA Safety Glossary Terminology used in Nuclear Safety and Radiation Protection – 2018 Edition]

3.12
planned exposure situations
situation of exposure that arises from the planned operation of a source or from a planned activity that results in an exposure due to a source

[SOURCE: IAEA Safety Glossary Terminology used in Nuclear Safety and Radiation Protection – 2018 Edition]

3.13
practice
human activity that introduces additional sources of exposure or exposure pathways or extends exposure to additional people or modifies the network of exposure pathways from existing sources, so as to increase the exposure or the likelihood of exposure of people or the number of people exposed

[SOURCE: IAEA Safety Standard No. RS–G–1.8]

3.14
quality assurance
planned and systematic actions necessary to provide adequate confidence that an item, process or service satisfy given requirements for quality, for example, those specified in the license

[SOURCE: IAEA Safety Standard No. RS-G-1.8]

3.15
radioactive discharges
radioactive substances arising from a source (3.22) within a practice (3.13) which are discharged as gases, aerosols, liquids or solids to the environment, generally with the purpose of dilution and dispersion or disposal

[SOURCE: IAEA Safety Standard No. RS-G-1.8]

3.16
representative person
individual receiving a dose that is representative of the doses to the more highly exposed individuals in the population

[SOURCE: ICRP Publication 101a. Annuals of the ICRP, 2006]

3.17
risk
combination of the probability of occurrence of harm and the severity of that harm

Note 1 to entry: The probability of occurrence includes the exposure to a hazardous situation, the occurrence of a hazardous event and the possibility to avoid or limit the harm.

3.18
risk assessment
overall process comprising a risk analysis and a risk evaluation

3.19
screening
type of analysis aimed at eliminating from further consideration factors that are less significant for protection or safety, in order to concentrate on the more significant factors

3.20
site
defined area, in this context often local target area

3.21
soil
surface layer of the Earth's crust composed of mineral particles, including organic matter

3.22
source
anything that may cause radiation exposure, such as by emitting ionization or radiation or by relating radioactive substances or materials, and can be treated as a single entry for protection and safety purposes

Note 1 to entry: For example, materials emitting radon are sources in the environment, a sterilization gamma irradiation unit is a source for the practice (3.13) of radiation preservation of food, an X ray unit may be a source for the practice (3.13) of radiodiagnosis; a nuclear power plant is part of the practice (3.13) of generating electricity by nuclear fission, and may be regarded as a source (e.g. with respect to discharges to the environment) or as a collection of sources (e.g. for occupational radiation protection purposes). A complex or multiple installation situated at one location or site may, as appropriate, be considered a single source for the purposes of application of safety standards.

[SOURCE: IAEA Safety Standard No. RS-G-1.8]

3.23
surface soil
upper part of a natural soil, generally dark-coloured and with a higher content of organic substances and nutrient when compared to the subsoil below

3.24
surface water
lakes, ponds, impounding reservoirs, springs, flowing (streaming) waters, estuaries, wetlands, inlets, canals, oceans within the relevant territorial limits, and all other bodies of water, natural or artificial, inland or coastal, fresh or salt

4 Symbols

$\bar{A}_r^a(t)$	$\bar{A}_r(t_0+1)$[average activity concentration in air a of a radionuclide *r* during a year from t_0+1 in $Bq \cdot m^{-3}$
E	annual effective dose in Sv
E_{ext}	annual effective dose of representative individual due to external exposure in Sv
E_{ing}	committed effective dose of representative individual due to ingestion in Sv
E_{inh}	committed effective dose of representative individual due to inhalation in Sv
$E_{ext,\ air}$	an external exposure of airborne radionuclides in air
$E_{ext,\ soil}$	an external exposure of airborne radionuclides deposited on soil surface
$E_{inh,\ T}(t_1)$	age dependent committed equivalent dose in tissue or organ, *T*, due to the inhalation of air during a year t_1;
$g_{ing,r}$	age dependent committed effective dose coefficient from radionuclide, *r*, by ingestion in $Sv \cdot Bq^{-1}$
$g_{inh,r}$	age dependent committed effective dose coefficient from radionuclide, *r*, by inhalation in $Sv \cdot Bq^{-1}$
$g_{ing,r,T}$	age dependent committed equivalent dose coefficient in tissue or organ, *T*, from radionuclide, *r*, by ingestion in $Sv \cdot Bq^{-1}$
$g_{inh,r,T}$	age dependent committed equivalent dose coefficient in tissue or organ, *T*, from radionuclide, *r*, by inhalation in $Sv \cdot Bq^{-1}$
$\dot{H}^*(10,t)$	annual average ambient gamma dose-equivalent rate at 10 mm depth in $Sv \cdot h^{-1}$
$H_{T,\ ext}$	committed equivalent dose in tissue or organ, *T*, in Sv
$H_{T,\ ing}$	committed equivalent dose in tissue or organ, *T*, from ingestion in Sv
$H_{T,\ inh}$	committed equivalent dose in tissue or organ, *T*, from inhalation in Sv
r	a given radionuclide part of a dose assessment
$\dot{V}$	age dependent breathing rate during a year in $m^3 \cdot year^{-1}$
w_T	tissue or organ weight factor

5 Principle

Radioactivity is a natural phenomenon common to every part of our environment and we are continuously exposed to these natural sources of radiation. Radiation and radioactive substances have many applications, ranging from power generation to uses in medicine, industry and agriculture. The radiation health risks to workers and the public and the impact on the environment that may arise from these applications are assessed and, when necessary, controlled.

The aim of the health risk assessment of radioactive releases (authorized or accidental) from a nuclear installation into the environment is to estimate the potential health consequences of human exposure to radiation. The impact could be local, regional or worldwide, and can result from existing, planned or nuclear emergency exposures. These assessments are performed to identify the needs and priorities to ensure public health protection and to inform national authorities (decision makers) and the public.

Health risk assessment requires an estimation of radiation doses to the public that usually cannot be measured directly. Therefore, for the purpose of protection of the public health, it is necessary to characterise an individual, either hypothetical or specific. This individual is defined as the ‘representative person’.

In the case of prospective assessment, for estimating the impact of future liquid or gaseous discharges from a particular emitter such as a nuclear facility, national regulations generally require dose calculations to be carried out, based on the maximal foreseen quantities of radionuclides to be released and considering conservative but realistic assumptions for determining the resulting quantities of radionuclides in different compartments of the environment and then for calculating the effective dose received by the representative person.

Complementarily to this approach, once the aforementioned facility is in operation, measurements of the real activity concentrations of radionuclides in different compartments of the environment can be carried out so as to check that they remain below those that were expected during the initial assessment, and the dose assessment of the facility can be calculated as it relates to actual liquid and gaseous discharges of the facility. In addition, radioactivity measurements in all the affected compartments of the environment can help to confirm or to acquire useful information on mechanisms of transfer of radionuclides in the environment, which is essential for enhancing robustness or for building confidence in the dose assessment.

Finally, dose calculations can also be carried out directly from the results of radioactivity measurements in the environment to determine the dose arising from exposure pathway.

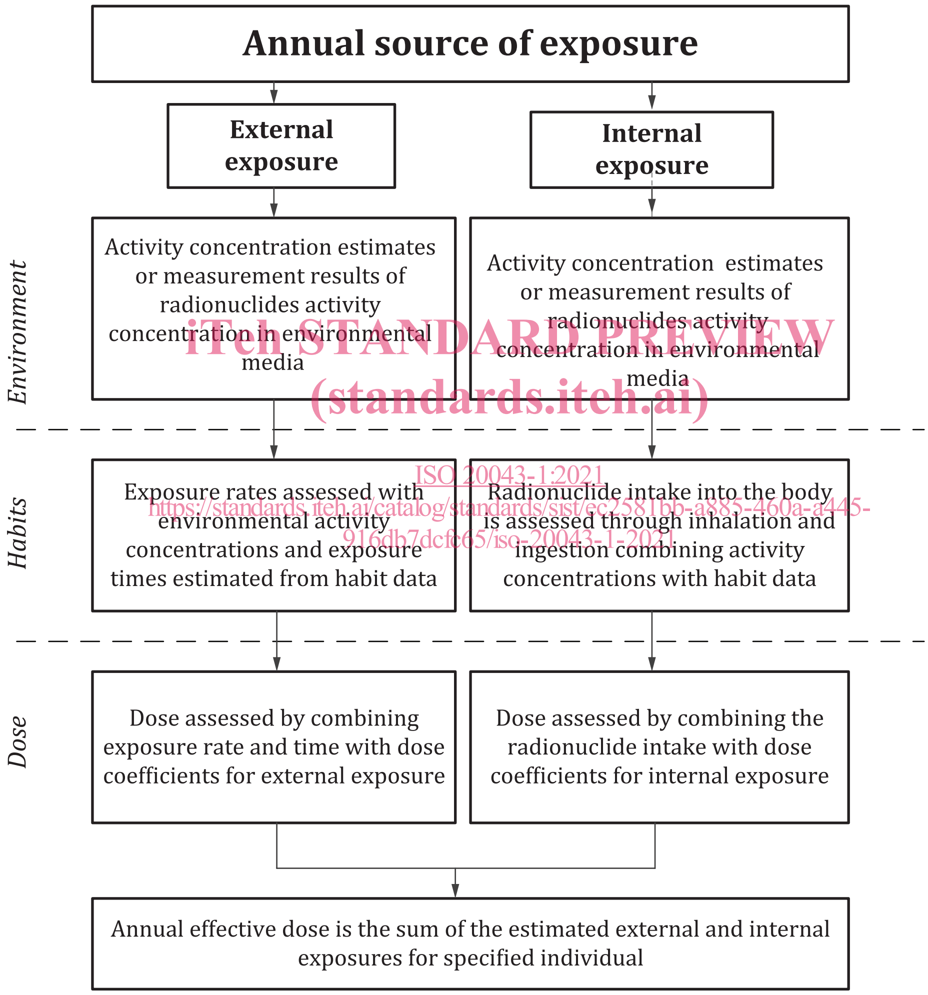

Figure 1 — Annual dose assessment process for specified individual modified from ICRP Publ. 101[3]

Dose assessment is a multistage process (see Figure 1) that follows the following stages:

— source identification and characterization, including data on the types and quantities of radionuclides and radiations emitted;

— environmental characterization, such as meteorological condition, type of biota, agricultural production, etc. and the activity concentration of radionuclides in environmental media and food arising from the source under investigation;