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

Part 2: **Emergency 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 2: Situations d'exposition d'urgence nucléaire

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Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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This document was prepared by Technical ISO/TC 85, *Nuclear energy, nuclear technologies, and radiological protection*, Subcommittee SC 2, *Radiological protection*.

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

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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 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 material (NORM) 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. 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 crew during air travel and by astronauts. The average level of occupational exposures is generally similar to the global average level of natural radiation exposure[4].

As the uses of radiation increase, so do the potential health risk 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 measurements 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 guarantee 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 ISO Technical Committees, including those produced by this Technical Committee, 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. The latter cover test methods for:

— natural radionuclides, including ^{40}K, tritium, ^{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, and ^{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), tritium, ^{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 tritium and ^{14}C, occur both naturally and as by-products of the operation of nuclear reactors.

The International Commission on Radiological Protection (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 require 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. on remediated land).

The fraction of the background dose rate to man from environmental radiation, mainly gamma radiation, varies considerably, 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, and

— retrospective assessment for dose that may be made for discharges or disposals that were not initially covered by or authorized 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 are shown in the table below.

Example of dose assessment in different exposure situations, modified from Reference [6]

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

Generic mathematical models used for the assessment of radiological human exposure are presented to identify the parameters that should be monitored 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.

Since the Fukushima Daichi nuclear power plant accident in March 2011, an effective emergency response after a nuclear facility accident is re-emphasized and is summarized as follows. In the initial stages of an accident, decision makers collect and report monitoring data promptly and determine appropriate protective measures for the population, such as sheltering, evacuation, and the distribution of iodine prophylaxis. Teams need to collect reliable information and make adequate decisions for protective measure determinations. Appropriate prearranged procedures aid in the response to emergency exposure situations. Also, decision makers should consider the possibility of coincident events, such as natural disasters and infectious diseases occurring at the same time.

For emergency exposure situations, operational intervention levels are derived from IAEA Safety Standards [IAEA GSG-2][19].

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

Part 2:
Emergency 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 is performed to ensure the protection of human health[5][7][8][9][10][11][12]. The guidelines constitute a basis for the setting of national regulations, standards, and 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, biota) and food;

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

— guidance that addresses actions appropriate for an event involving uncontrolled releases of gamma-emitters (e.g. nuclear power reactor emergencies) and also events that would involve beta- or alpha-emitters would require additional consideration of the pathways, instrumentation, laboratory analysis, operational intervention levels, protective actions, etc., appropriate to their release;

— 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 to 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.

This document refers to various published ISO documents. When appropriate, this document also refers to national standards or other publicly available documents.

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

3 Terms and definitions

For the purposes of this document, the terms and 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 https://www.electropedia.org/

3.1
atmospheric transfer coefficient
coefficient which characterizes the radioactivity dispersion in the atmosphere at a given location

Note 1 to entry: In the case of a continuous release, it is the ratio between the activity concentration in the air (C_a) at a given location and the released activity rate ($\dot{A}$). In the case of a puff release of a duration T_f it is the ratio between $\int_0^{T_\mathrm{f}} C_a \, \mathrm{d}t$ at a given location and the total released activity $\int_0^{T_\mathrm{f}} \dot{A} \, \mathrm{d}t$.

Note 2 to entry: The atmospheric transfer coefficient at a given location depends on the distance between the released position and the given location, the release height, the wind speed and the atmospheric stability, which is characterized by either normal or weak diffusion according to the temperature difference between 100 m altitude and the ground level. A diffusion is weak when this temperature difference is positive.

Note 3 to entry: The atmospheric transfer coefficient is usually calculated by valid computer code on the basis of a mathematical model of atmospheric dispersion.

3.2
background (dose)

dose or dose rate (or an observed measure related to the dose or dose rate) attributable to all sources other than the one(s) specified

Note 1 to entry: Strictly, this applies to measurements of dose rate or count rate from a sample, where the background dose rate or count rate must be subtracted from all measurements. However, background is used more generally, in any situation in which a particular source (or group of sources) is under consideration, to refer to the effects of other sources. It is also applied to quantities other than doses or dose rates, such as activity concentrations in environmental media

[SOURCE: IAEA. Vienna: IAEA, 2022. 246 p.]

3.3
detection alarm level
real time measurement value corresponding to an acceptable false alarm rate

Note 1 to entry: When the detection alarm level increases false alarm rate decreases.

Note 2 to entry: The detection alarm level usually far more exceeds the decision threshold.

3.4
emergency action level
EAL
specific, predetermined, observable criterion used to detect, recognize and determine the emergency class

Note 1 to entry: An emergency action level could represent an instrument reading, the status of a piece of equipment or any observable event, such as a fire.

[SOURCE: IAEA. Vienna: IAEA, 2022. 246 p.]

3.5
emergency exposure situation
exposure situation that arises as a result of an accident, a malicious act or other unexpected event, and requires prompt action in order to avoid or to reduce adverse consequences

Note 1 to entry: This may include unplanned exposures resulting directly from the emergency and planned exposures to persons undertaking actions to mitigate the consequences of the emergency. Emergency exposure may be occupational exposure or public exposure.

[SOURCE: IAEA. Vienna: IAEA, 2022. 246 p.]

3.6
monitoring
radiation 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. Vienna: IAEA, 2022. 246 p.]

3.7
environmental monitoring
measurement of external dose rates due to sources in the environment or of radionuclide concentrations in environmental media

[SOURCE: IAEA. Vienna: IAEA, 2022. 246 p.]

3.8
existing exposure situation
exposure situation which already exists when a decision on the need for control needs to be taken

Note 1 to entry: Existing exposure situation includes exposure to background radiation and exposure to residual radioactive material from a nuclear or radiological emergency after the emergency exposure situation has been declared ended.

[SOURCE: IAEA. Vienna: IAEA, 2022. 246 p.]

3.9
operational intervention level
OIL
set level of a measurable quantity that corresponds to a generic criterion

[SOURCE: IAEA. Vienna: IAEA, 2022. 246 p.]

Note 1 to entry: Operational intervention levels are typically expressed in terms of dose rates or of activity of radioactive material released, time integrated air activity concentrations, ground or surface concentrations, or activity concentrations of radionuclides in environmental, food or water samples.

Note 2 to entry: An operational intervention level is used immediately and directly (without further assessment) to determine the appropriate protective actions on the basis of an environmental measurement.

3.10
precautionary action zone
PAZ
area around a facility for which arrangements have been made to take urgent protective actions in the event of a nuclear or radiological emergency to avoid or to minimize severe deterministic effects off the site

Note 1 to entry: Protective actions within this area are to be taken before or shortly after a release of radioactive material or an exposure, on the basis of the prevailing conditions at the facility.

[SOURCE: IAEA. Vienna: IAEA, 2022. 246 p.]

3.11
planned exposure situation
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. Vienna: IAEA, 2022. 246 p.]

3.12
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 avoid or limit the harm.

[SOURCE: ISO/IEC Guide 51:2014, 3.9]

3.13
screening
type of analysis aimed at eliminating the further consideration of factors that are less significant for protection or safety, in order to concentrate on the more significant factors

[SOURCE: ISO 20043-1:2021, 3.19]

3.14
source
anything that may cause radiation exposure, such as by emitting ionizing radiation or by releasing radioactive substances or radioactive materials and can be treated as a single entity for purposes of protection and safety

[SOURCE: IAEA. Vienna: IAEA, 2022. 246 p.]

3.15
source term
amount and isotopic composition of radioactive material released (or postulated to be released) from a facility

Note 1 to entry: Used in modelling releases of radionuclides to the environment, in particular in the context of accidents at nuclear installations or releases from radioactive waste in repositories.

[SOURCE: IAEA. Vienna: IAEA, 2022. 246 p.]

3.16
urgent protective action planning zone
UPZ
area around a facility for which arrangements have been made to take urgent protective actions in the event of a nuclear or radiological emergency to avert doses off the site in accordance with international safety standards

Note 1 to entry: Protective actions within this area are to be taken on the basis of environmental monitoring or, as appropriate, prevailing conditions at the facility.

[SOURCE: IAEA. Vienna: IAEA, 2022. 246 p.]

4 Symbols

Table 1 — Symbols

Symbol	Definition	Unit
$\dot{A}$	Released activity rate	$Bq \cdot s^{-1}$
$\dot{A}_i$	Released activity rate of radionuclide *i*	$Bq \cdot s^{-1}$

Table 1 *(continued)*

$C_a(X)$	Activity concentration in the air due to the plume at location X	$Bq \cdot m^{-3}$
$C_{a,\beta\gamma}(X)$	Activity concentration of beta gamma emitters in the air due to the plume at location X	$Bq \cdot m^{-3}$
$C_{a,\alpha}(X)$	Activity concentration of alpha emitters in the air due to the plume at location X	$Bq \cdot m^{-3}$
$CTA_i(X)$	Atmospheric transfer coefficient of radionuclide i at location X	$s \cdot m^{-3}$
$E_{\text{inh}}(i)$	Committed effective dose per unit inhalation of radionuclide i	$Sv \cdot Bq^{-1}$
$E_{\text{ing}}(i)$	Committed effective dose per unit ingestion of radionuclide i	$Sv \cdot Bq^{-1}$
$\dot{E}_{\text{p,ext}}(X)$	Effective dose rate due to external exposure from the plume at location X	$Sv \cdot s^{-1}$
$\dot{E}_{\text{d,ext}}(X)$	Effective dose rate due to external exposure from the ground deposition at location X	$Sv \cdot s^{-1}$
$\dot{E}_{\text{d,ext}}$	Effective dose rate due to external exposure from the ground deposition	$Sv \cdot s^{-1}$
$E_{\text{p,inh}}(X)$	Effective dose due to inhalation at location X	Sv
$E_{\text{d,inh}}(X)$	Effective dose due to resuspension from the ground deposition at location X	Sv
$E_{\text{ing}}(X)$	Effective dose due to ingestion at location X	Sv
$E_{\text{d}}(X)$	Effective dose due to the ground deposition at location X	Sv
$E_{\text{p}}(X)$	Effective dose due to the plume at location X	Sv
$E_{\text{p,ext}}(X)$	Effective dose due to external exposure from the plume at location X	Sv
$E_{\text{d,ext}}(X)$	Effective dose due to external exposure from the ground deposition at location X	Sv
$f_{\text{CDd}i}$	Ambient dose equivalent rate conversion factor due to deposition of radionuclide i	$(Sv \cdot s^{-1} \cdot Bq^{-1}) \cdot m^{2}$
$f_{\text{CDp}i}$	Ambient dose equivalent rate conversion factor due to the plume of radionuclide i	$(Sv \cdot s^{-1} \cdot Bq^{-1}) \cdot m^{3}$
L_{GA}	Generic action level for foodstuffs	$Bq \cdot kg^{-1}$
$H^{*}(10)$	Ambient dose equivalent at 10 mm depth	Sv
$\dot{H}^{*}(10)$	Ambient dose equivalent rate at 10 mm depth	$Sv \cdot s^{-1}$
$I_{\text{C}\beta\gamma i}$	Detector beta gamma emitter conversion factor of radionuclide i	$(counts \cdot s^{-1}) \cdot Bq \cdot m^{-2}$
$I_{\text{C}\alpha i}$	Detector alpha emitter conversion factor of radionuclide i	$(counts \cdot s^{-1}) \cdot Bq \cdot m^{-2}$
$H_{\text{thy}}(X)$	Committed equivalent dose to the thyroid at location X	Sv
$OIL\left[X, E\frac{Y(Y)}{H(Y)}, \text{type of measurement}\right]$	Operational intervention level at location X corresponding to an effective or equivalent dose limitation at location Y for a given type of measurement	unit of the measurement type