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

Part 2: **Nuclear emergency exposure situation**

Partie 2: Situations d'exposition d'urgence nucléaire

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Foreword

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

c) to 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 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 Standardization Organization for Standardizations, 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. The later 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 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;

— 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 1 below.

Table 1 — 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 2: Nuclear 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 must be performed to 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, 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 predominantly involving uncontrolled releases of gamma-emitters (e.g., nuclear power reactor emergencies). Events that would involve predominantly beta- or alpha-emitters would require additional consideration of the pathways, instrumentation, laboratory analysis, operational intervention levels, protective actions, etc., appropriate to their release. These additional considerations are not reviewed in detail in this standard;

— 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.

Generic mathematical models used for the assessment of radiological human exposure are presented to identify the parameters that shall 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 have to 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 radiological 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] or national authorities [FAO-WHO Codex Alimentarius (2015)].

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 $\int_0^{T_f} C_a \, dt$ at a given location and the total released activity $\int_0^{T_f} \dot{A} \, dt$.

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

Note 1 to entry: Dose from sources that are not under the permit of the site with the radioactive discharge are background sources from the perspective of the discharging site.

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
a 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 safety glossary 2018]

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. IAEA Safety Glossary: 2018 edition. Vienna: IAEA, 2019. 278 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 Safety Glossary 2018]

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

[SOURCE: IAEA Safety Glossary 2018]

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 Safety Glossary: 2018 edition. Vienna: IAEA, 2019. 278 p.]

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

[SOURCE: IAEA. IAEA Safety Glossary: 2018 edition. Vienna: IAEA, 2019. 278 p.]

Note 1 to entry: OILs are calculated levels, measured by instruments or determined by laboratory analysis, that correspond to an intervention level or action level.

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 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 Safety Glossary 2018]

3.11
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 2018]

3.12
radioactive discharges
radioactive substances arising from a source within facilities and activities which are discharged as gases, aerosols, liquids or solids to the environment, generally with the purpose of dilution and dispersion

[SOURCE: IAEA Safety Glossary 2018]

3.13
risk
combination of the probability of occurrence of harm and the severity of that harm

[SOURCE: ISO/IEC Guide 51:1999, Safety aspects – Guidelines for their inclusion in standards, 3.2]

3.14
risk analysis
systematic use of available information to identify hazards and to estimate the risk

[SOURCE: ISO/IEC Guide 51:1999, 3.10]

3.15
risk assessment
overall process comprising a risk analysis and a risk evaluation.[ISO/IEC Guide 51:1999, definition 3.12]

[SOURCE: IEC Guide 116:2010, 3.15]

3.16
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

3.17
source
anything (apparatus, substance, installation) that may cause radiation exposure, such as by emitting ionizing radiation or releasing radioactive substances or materials

[SOURCE: IAEA Safety Series No. 115:1996]

3.18
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-Safety Glossary 2018 Edition]

3.19
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 Safety Standard No. GS-G-2.1]

4 Symbols

$\dot{A}$	Total released activity rate (Bq s^{-1})
$\dot{A}_i$	Released activity rate of radionuclide i (Bq s^{-1})
$C_a(X)$	Activity concentration in the air due to the plume at location X (Bq m^{-3})
$C_{a,\beta\gamma}(X)$	Activity concentration of beta gamma emitters in the air due to the plume at location X (Bq m^{-3})
$C_{a,\alpha}(X)$	Activity concentration of alpha emitters in the air due to the plume at location X (Bq m^{-3})
$CTA_i(X)$	Atmospheric transfer coefficient of radionuclide i at location X (s m^{-3})
$DPUINH_i$	Committed effective dose per unit inhalation of radionuclide i (Sv Bq^{-1})
$DPUING_i$	Committed effective dose per unit ingestion of radionuclide i (Sv Bq^{-1})
$E_{\mathrm{p,exp}}(X)$	Effective dose rate due to external exposure from the plume at location X (Sv s^{-1})
$E_{\mathrm{d,exp}}(X)$	Effective dose rate due to external exposure from the ground deposition at location X (Sv s^{-1})
$E_{p,inh}(X)$	Effective dose due to inhalation at location X (Sv)
$E_{d,inh}(X)$	Effective dose due to resuspension from the ground deposition at location X (Sv)
$E_{ing}(X)$	Effective dose due to ingestion at location X (Sv)
$E_d(X)$	Effective dose due to the ground deposition at location X (Sv)
$E_p(X)$	Effective dose due to the plume at location X (Sv)

$\dot{A}$	Total released activity rate (Bq s^{-1})
$E_{p,ext}(X)$	Effective dose due to external exposure from the plume at location X (Sv)
$E_{d,ext}(X)$	Effective dose due to external exposure from the ground deposition at location X (Sv)
$FCDd_i$	Ambient dose equivalent rate conversion factor due to deposition of radionuclide i (Sv s^{-1} Bq^{-1} m^2)
$FCDpi$	Ambient dose equivalent rate conversion factor due to the plume of radionuclide i (Sv s^{-1} Bq^{-1} m^3)
GAL	Generic action level for foodstuffs (Bq Kg^{-1})
$H^*(10)$	Ambient dose equivalent at 10 mm depth (Sv)
$\dot{H}^*(10)$	Ambient dose equivalent rate at 10mm depth (Sv s^{-1})
$IC\beta\gamma_i$	Detector beta gamma emitter conversion factor of radionuclide i (counts s^{-1} Bq m^{-2})
$IC\alpha_i$	Detector alpha emitter conversion factor of radionuclide i (counts s^{-1} Bq m^{-2})
$H_{thy}(X)$	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)
$r_{net}(X)$	Net count rate resulting from a measurement in contact of the ground by a portable surface contamination detector at location X (s^{-1})
$r_{\beta\gamma/net}(X)$	Net count rate resulting from a measurement on the ground contact by a portable surface contamination beta gamma emitters detector at location X (s^{-1})
$r_{\alpha/net}(X)$	Net count rate resulting from a measurement on the ground contact by a portable surface contamination alpha emitters detector at location X (s^{-1})
R_{ing}	Ingestion transfer rate factor from the contaminated ground (m^2 s^{-1})
R_s	Resuspension factor from the contaminated ground to the air (m^{-1})
T_E	Exposure duration (s)
T_R	Activity release duration which is also the exposure duration due the plume (s)
Vd_i	deposit speed to the ground of radionuclide i (m s^{-1})

5 Principle

The purpose of monitoring in emergency exposure situation is to understand the radiation dose level in the environment at the site area and to provide information for judgment on implementation of protective measures such as evacuation and sheltering and iodine prophylaxis.

Therefore, in case of emergency, it is also possible to measure using a planned and existing monitoring system, as well as temporary monitoring systems and aircraft-mounted systems that enable a wide area for measurements. An illustration of monitoring systems used during a radiological emergency exposure situation is given in Annex A.

In a nuclear or radiological emergency, the practical goals of emergency response are[9]:

— to regain control of the situation and to mitigate consequences;

— to save lives;

— to avoid or to minimize severe deterministic effects;

— to render first aid, to provide critical medical treatment and to manage the treatment of radiation injuries;

— to reduce the risk of stochastic effects;

— to keep the public informed and to maintain public trust;

— to mitigate, to the extent practicable, non-radiological consequences;

— to protect, to the extent practicable, property and the environment;

— to prepare, to the extent practicable, for the resumption of normal social and economic activity.

Until recently, international guidance on emergency response preparation was based on a technical/analytical approach. To summarize, this approach modelled the emergency scenario, analysed the dose reduction options, and used intervention principles to select the best solution for implementation. In recent years, guidance has expanded to include a management approach (see Figure 1) that considers more than just the immediate event response. This expanded approach involves focusing not only on intervention principles, but also on goal setting for the outcome of emergency response. This expanded approach would be most critical for nuclear emergencies expected to impact the post-event radiological background conditions. Goals may be based on experience gained from past emergencies. In other words, the conception is to set a target value for keeping the dose of the public below a certain value and to make a plan. This shift in approach has been reflected recently in the international community's agreement on standards[10].

