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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.

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 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·s^{-1}
$\dot{A}_i$	Released activity rate of radionuclide *i*	Bq·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*	$s{\cdot}m^{-3}$
$E_{inh}(i)$	Committed effective dose per unit inhalation of radionuclide *i*	$Sv{\cdot}Bq^{-1}$
$E_{ing}(i)$	Committed effective dose per unit ingestion of radionuclide *i*	$Sv{\cdot}Bq^{-1}$
$\dot{E}_{p,ext}(X)$	Effective dose rate due to external exposure from the plume at location *X*	$Sv{\cdot}s^{-1}$
$\dot{E}_{d,ext}(X)$	Effective dose rate due to external exposure from the ground deposition at location *X*	$Sv{\cdot}s^{-1}$
$\dot{E}_{d,ext}$	Effective dose rate due to external exposure from the ground deposition	$Sv{\cdot}s^{-1}$
$E_{p,inh}(X)$	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
$E_{p,ext}(X)$	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
f_{CDdi}	Ambient dose equivalent rate conversion factor due to deposition of radionuclide *i*	$(Sv{\cdot}s^{-1}{\cdot}Bq^{-1}){\cdot}m^{2}$
f_{CDpi}	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	$Sv{\cdot}s^{-1}$
$I_{C\beta\gamma i}$	Detector beta gamma emitter conversion factor of radionuclide *i*	$(counts{\cdot}s^{-1}){\cdot}Bq{\cdot}m^{-2}$
$I_{C\alpha i}$	Detector alpha emitter conversion factor of radionuclide *i*	$(counts{\cdot}s^{-1}){\cdot}Bq{\cdot}m^{-2}$
$H_{thy}(X)$	Committed equivalent dose to the thyroid at location *X*	Sv
$OIL\left[X, E\dfrac{Y(Y)}{H(Y)}, \text{type of measurement}\right]$	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

Table 1 *(continued)*

$r_{net}(X)$	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	$m^2 \cdot s^{-1}$
R_s	Resuspension factor from the contaminated ground to the air	m^{-1}
T_E	Exposure duration	h
T_R	Activity release duration which is also the exposure duration due the plume	h
V_{di}	deposit speed to the ground of radionuclide *i*	$m \cdot s^{-1}$

5 Principle

The purpose of monitoring in emergency exposure situation is to understand the radiation dose level in the environment 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 evaluate radiation dose levels using a planned and existing monitoring system, as well as temporary monitoring systems including aircraft-mounted systems that enable the monitoring of a wide area.

In a nuclear or radiological emergency, the practical goals of emergency response are[13]:

— 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 preparedness and response were 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.

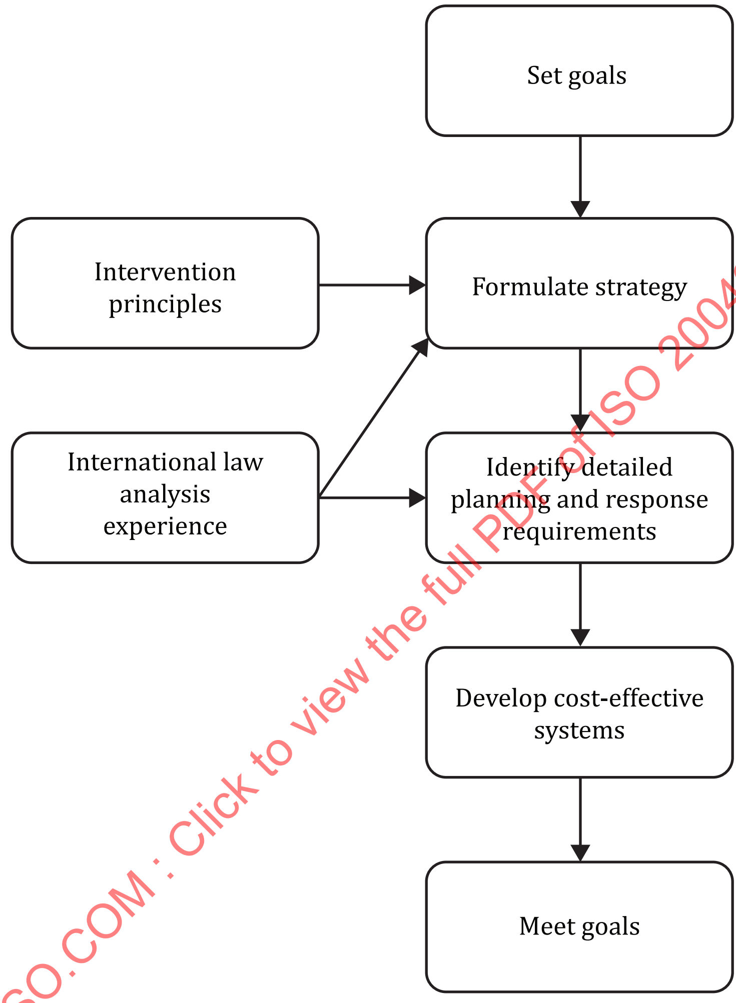


Figure 1 — Management approach for emergency exposure situation modified from Reference [14]

The system of generic and optional criteria is described in Table 2[13]. Facilities with a stringency of requirements for preparedness and response arrangements of hazard are classified as category I, II and III.

Emergency preparedness category IV applies to activities with a minimum level of hazard, which is assumed to apply for all states and areas. Emergency preparedness category V applies to the off-site areas where arrangements for preparedness and response are warranted to deal with contamination resulting from a release of radioactive material from a facility in emergency preparedness category I or II.

Table 2 — Five categories of nuclear and radiation related hazards for the purposes of the requirements[13]

Category	Description
I	Facilities, such as nuclear power plants, for which on-site events (including not considered in the design) are postulated that could give rise to severe deterministic effects off the site that would warrant precautionary urgent protective actions, urgent protective actions or early protective actions, and other response actions to achieve the goals of emergency response in accordance with international standards, or for which such events have occurred in similar facilities.
II	Facilities, such as some types of research reactors and nuclear reactors used to provide power for the propulsion of vessels (e.g. ships and submarines), for which on-site events are postulated that could give rise to doses to people off the site that would warrant urgent protective action or early protective actions and other response actions to achieve the goals of emergency response in accordance with international standards, or for which such events have occurred in similar facilities. Emergency preparedness category II (as opposed to emergency preparedness category I) does not include facilities for which on-site events (including those not considered in the design) are postulated that could give rise to severe deterministic effects off the site, or for which such events have occurred in similar facilities.
III	Facilities, such as industrial irradiation facilities or some hospitals, for which on-site events are postulated that could warrant protective actions and other response actions on the site to achieve the goals of emergency response in accordance with international standards, or for which such events have occurred in similar facilities. Category III (as opposed to category II) does not include facilities for which events are postulated that could warrant urgent protective action or early protective actions off the site, or for which such events have occurred in similar facilities.
IV	Activities and acts that could give rise to a nuclear or radiological emergency that could warrant urgent protective actions to achieve the goals of emergency response in accordance with international standards in an unforeseeable location. These activities and acts include: (a) transport of nuclear or radioactive material and other authorized activities involving mobile dangerous sources such as industrial radiography sources, nuclear powered satellites or radioisotope thermoelectric generators; and (b) theft of a dangerous source and use of a radiological dispersal device or radiological exposure device. This category also includes: (i) detection of elevated radiation levels of unknown origin or of commodities with contamination; (ii) identification of clinical symptoms due to exposure to radiation; and (iii) a transnational emergency that is not in category V arising from a nuclear or radiological emergency in another State. Category IV represents a level of hazard that applies for all States and jurisdictions.
V	Areas within emergency planning zones and emergency planning distances in a State for facility in category I or II located in another State.

In particular, plans are required in advance for the following items in order to effectively implement off- site emergency protection measures for facilities in emergency preparedness categories I and II.

Operational intervention levels (OIL) and emergency action levels (EAL) are criteria (e.g. specific observables or other indicators) to be used in decision-making. Meeting the criteria would trigger the need to implement appropriate protective actions and other responses. Annex A provides an example of OILs used for assessing the results of field monitoring and screening of foodstuff concentrations from laboratory analysis. In the emergency, it is necessary for the government to manage radiation monitoring and ensure that wide area monitoring can be implemented.

When an event is severe enough that impacts are quite widespread or may require an extended clean-up time, two types of zones may be established. A precautionary action zone (PAZ) may be established for preventive emergency protection to keep doses below the expected dose of intervention to prevent severe deterministic effects. An urgent protective action planning zone (UPZ) would also be established to urgently implement protective action measures to prevent to doses off-site in accordance with international standards. Protective actions within the UPZ area are to be taken on the basis of environmental monitoring or, as appropriate, prevailing conditions at the facility.

In emergency exposure situations, the operating organization (registrant or licensee) is in charge of source monitoring and near field environmental monitoring. The regulatory body is in charge of large scale and also near field environmental monitoring.

6 Implementation system of monitoring and emergency response plan

6.1 General

Monitoring and emergency response are implemented when a nuclear or radiological emergency occurs. Monitoring is carried out appropriately taking into account the circumstances and progress of the accident. Consideration of the event phase, i.e. early, pre-release and release, and post-release, will guide the type of monitoring and actions to implement. When monitoring occurs, the health and safety of the staff performing the monitoring should be considered in procedures.

6.2 Plan and implementation system

In general, the government prepares an emergency response planning in advance, which includes an emergency monitoring plan, on behalf of their population to prepare for nuclear emergencies. These plans are coordinated with radiological facility staff and response organisations (e.g. police, fire, emergency medical services, radiological response teams and health care facilities). Plans should aim to compile and distribute information and collect, process, and interpret monitoring and event data in a format compatible with efficient event response. Appropriate staffing, expertise, and training should be part of planning. The emergency monitoring plan includes the specific implementation system and responsible staff, according to the accident type.

Instruments, supplies, equipment, communication systems, facilities and manuals should be provided for performing the specified function or task required in response to a nuclear or radiological emergency. Arrangements should be established with the laboratories analysing the environmental and biological samples during the emergency response. Emergency planning should consider whether these facilities would remain operational for normal business, close, or focus on emergency response under postulated emergency conditions.

Appropriate staging of adequate emergency response supplies is important. Radiation measurement devices, distribution, quantity and location. Establish a transportation method, and provisions to prepare immediately in case of emergency exposure situation. Adequate personal protective equipment for field teams should also be considered. For example, typical types of equipment located in laboratories for emergency exposure situation are as follows.

Instruments for measuring ambient dose rate in the environment:

— survey meter (e.g. NaI scintillation survey meter and/or ionization chamber);

— electronic dosemeter.

Instruments for integrated dose measurement:

— passive dosimeters (TLD, RPLD, OSL);

— film badges;

— electronic personal dosemeter.

Instruments for collection and measurement of radionuclides in the air:

— air sampler with activated charcoal cartridge for determination of ^{131}I;

— aerosol sampler;

— Ge semiconductor detector;

— NaI scintillation spectrometer;

— ZnS scintillation detector;

— GM counter.

Instruments for measurement of radionuclides activity in the environmental samples:

— Ge semiconductor detector;

— NaI scintillation spectrometer;

— in-situ Ge semiconductor spectrometer;

— Si semiconductor spectrometer;

— (low background) GM counter;

— liquid scintillation counter.

Instruments for measurement of surface contamination:

— GM counter;

— ZnS scintillation counter;

— plastic scintillation counter.

Some instruments may be usable in the field if background can be adequately reduced or measured.

International cooperation and exchange of data and information can be provided assistance in preparedness and response for a nuclear or radiological emergency.

6.3 Urgent response phase monitoring

Prior to an anticipated radiological release, priority should be given to accessing information on the likely composition of the release and the critical meteorological data (including wind speed, wind direction and data on precipitation) that would indicate where contamination might occur. Monitoring instrumentation appropriate to the anticipated release composition should be staged for use.

During the urgent response phase (a few hours and days after the release), the environmental monitoring teams should be assembled and deployed in the populated areas. The anticipated size of the release will guide the distance at which population centre teams are deployed. If the projected release is large, several actions are appropriate. Existing plans to request assistance from other organizations should be implemented.

If an instrumented aircraft is available and ensure radiation protection for workers completely, arrangements carry out flight to provide timely and rapidly monitoring of the external gamma dose rate in contaminated area.

Once a release has occurred the most useful measurements will typically be those of external gamma dose rates in the plume and from the deposition of radionuclides on the ground. Measurements of these types can be made most easily and rapidly from airborne platforms, if available. Otherwise, measurements of external gamma dose rates in air can be made on the ground by properly instrumented field teams. An early goal should be to determine the general plume boundary and where the OILs might be exceeded and thus where protective actions should be taken.

OILs should be established in advance that would allow dose rate measurements to be interpreted immediately in terms of the intervention needed. Training and exercising to the emergency plans will expedite their proper implementation and highlight issues that may be encountered during an actual event. In accidents of some types the presence of short lived radionuclides may be very important in terms of the early doses to members of the public. When interventions are being considered, allowance should be made for these early doses due to short lived radionuclides.

Depending on the nature of the release, it may be advisable to set up ground-based air samplers after a release has occurred to monitor for the presence of fallout and resuspended radionuclides. The resuspension of radionuclides does not usually give rise to an important pathway of exposure unless alpha-emitters have been released.

Making measurements rapidly of external gamma dose rates in air over appropriate areas will define whether a predetermined OIL may have been exceeded. These measurements should be repeated on a frequent basis, at least hourly, at locations of possible intervention, and due consideration should be given to meteorological data and feedback from the previous surveys. For large installations at which major accidents might be anticipated, possible locations of substantial radionuclide deposition may be predefined, and provisions made for performing such measurements from an aircraft.

In-plume air sampling during a release for the measurement of concentrations and compositions of radionuclides (e.g. ^{85}Kr and/or ^{131}I), which provide necessary data for the evaluation of external dose or inhalation hazard. Whether such measurements can be made or not, the simple measurement of the external dose rate in air should also be made.

The plume may contain radioactive noble gases (e.g. ^{85}Kr and/or ^{133}Xe), these materials emit gamma radiation that can expose people in the vicinity of the passing plume.

In order to protect of emergency workers in an emergency, the following are required;

— training those emergency workers designated;

— managing, controlling and recording the doses received;

— provision of appropriate specialized protective equipment and monitoring equipment and prevention of contamination;

— provision of iodine thyroid blocking, as appropriate, if exposure due to radioactive iodine is possible;

— medical examination, longer term medical actions and psychological counselling, as appropriate;

— collection and transmission of information to ensure safety.

6.4 Early response phase monitoring

In the early response phase (a few hours and days after the release and deposition have stopped in the particular area of interest) of a severe accident involving airborne contamination, the priorities for environmental measurement and sampling are as follows[15].

Immediately after the release and deposition have stopped, measurements of the external dose rate in air due to ground deposition should be made to detect any offsite locations where OILs are exceeded. This will provide a basis for additional evacuations; short- or long- term relocation recommendations; or restrictions on the consumption of food stuffs and on using feedstuffs. In addition, to better characterize the release, field gamma spectrometry should be performed in the deposition area. The simultaneous measurement of the external gamma dose rate in air and on the ground would provide an opportunity to estimate radionuclide specific deposition densities for other locations for which there were only the simple measurements of external gamma dose rate in air.

The specification of locations where continuous measurements of the external gamma dose rate in air can be made. This will be useful in projecting doses over time and in redefining OILs, if appropriate.

After the end of the release or after passage of the plume, surface soil sampling for the radionuclide concentrations will give values for ground deposition. These measurements would supplement the field gamma spectrometry measurements. If there is a possibility that beta- or alpha-emitters were released, i.e. radionuclides undetectable by means of field gamma spectrometry, these samples would be processed with the appropriate instrumentation. And the results also provide the input data necessary to assess the need for food restrictions and the possible disposal of foodstuffs.

Soil sampling after the end of the release or after passage of the plume for the measurement of radionuclide concentrations will give values for ground deposition to supplement the deposition values determined by field gamma spectrometry. If there is a possibility that radionuclides were released that cannot be detected by means of field gamma spectrometry, these samples should be processed for the detection of pure beta (e.g. ^{90}Sr) and alpha (e.g. U and/or Pu isotopes) emitters.

Samples of pasture, milk and other foodstuffs and water should be collected, and measurements should be made to assess the potential exposure of the population and for the purposes of the implementation of interventions such as the restriction of foodstuffs. Milk is especially important in the event of a reactor accident or criticality accident because of the associated releases of radioiodine. Recommended intervention levels for radionuclides in foodstuffs are provided in the document[16]. If it is suspected that releases of tritium from nuclear power stations (especially heavy water reactor), nuclear fuel reprocessing plants and other tritium-related facilities have occurred, measurements of tritium in the environment.

6.5 Transition phase monitoring

Once a release has stopped and deposition levels have stabilized, further information can be acquired rapidly by the use of field gamma spectrometry. This technique can identify the deposition densities of all gamma-emitting radionuclides; such information can then be used to project integrated external doses to the affected population. If needed, the more detailed information can be used to derive revised OILs for the situation. Field gamma spectrometry requires advance preparation and extensive calibration of the instruments used. The information that can be obtained is valuable in determining any further actions that might be required.

The results of field gamma spectrometry should be supplemented as soon as possible by means of the collection of representative samples of soil from precisely specified and measured areas. These results can be used to confirm the field gamma spectrometry results, but more importantly, analyses should be undertaken to determine any suspected deposition of radionuclides, i.e. pure alpha or beta emitters, that could not be measured by field gamma spectrometry. When short-lived radionuclides may be present, more timely analyses of soil samples will provide more information.

After the early response phase has been determined and any necessary interventions have been performed, sampling programs should be established to determine whether longer term interventions, such as temporary relocations and restrictions on foodstuffs, should be implemented. Vegetables and other locally grown produce, drinking water supplies and milk from local dairies need to be checked by comparison with the OILs. The extent and the nature of such sampling programs will depend on the extent and the scale of the release and the demographics of the location in terms of local agricultural activities and the population distribution.

The public should be promptly provided with results of environmental monitoring or of other activities that directly involve them, their homes, their communities or their workplaces, as well as with interpretations of the results in terms of health risks and advice on protective actions, if any, on the basis of monitoring data and other relevant data.

7 Guidance on emergency measurement

7.1 General

Implementation systems of emergency monitoring are roughly divided into measurement of ambient dose equivalent rate and measurement of radioactivity in environmental samples. Each subject is described below. (See also Reference [15].)

7.2 Ambient dose equivalent

Dose rates can be measured in several different contexts. There are continuous measurement systems (temporary or permanently sited), field surveys (air or deposition on surface soil), vehicle and aircraft monitoring (deposition on surface soil).

It is typical that the ambient dose equivalent rate used as OIL is Sv/h, whereas in the monitoring post, the measurement result is usually described in Gy/h. These can be typically considered as equivalent for gamma measurements.

Environmental monitoring routinely occurs in the vicinity of nuclear facilities to confirm that results adequately are below comparing with public dose limits and to verify the expected low levels of radioactive material emissions. These systems and samples may be used in response to a nuclear emergency. A particular advantage is that the normal radiological condition at these stations is established, and the systems are in place to maintain sample chain of custody and analyses.

In an emergency exposure situation, it is likely that routine facility monitoring would require supplementation with event-specific sampling. Rather than field team monitoring, it is possible to continuously measure an ambient dose equivalent with a temporary (portable) monitoring post, placed at a strategically located site.

Any temporary monitoring equipment should have an associated procedure that standardizes its monitoring role. For example, based on the OILs examples in Annex A, the ambient dose equivalent rate is measured at 1 m above the ground level. Photography of the new established monitoring equipment can also be informative to confirm station setup and local conditions.

7.3 Measurement by survey meter and monitoring vehicle

In addition to monitoring stations and portable monitoring posts, survey meters and monitoring vehicles are also useful methods.

As long as access is available, these methods can be utilized for checking the radiation dose rate between fixed measurement points. Using the monitoring vehicle, it is possible to continuously measure the radiation dose rate in the contamination area due to deposit, and it is also possible to understand the distribution of the radiation dose rate in a wide area.

According to the default OIL[17], the ambient dose equivalent rate should be measured at 1 m above the ground level but note that monitoring vehicles may have different heights and shielding. Assessors should take these differences into account when interpreting the measurement data.

7.4 Aerial monitoring

Aerial monitoring is useful when access by car or other means is not available due to the disaster for extensive and rapid monitoring of radioactive materials deposited on the ground surface. For severe events, plume boundaries may be defined or confirmed. The purpose of the aerial monitoring will depend on the instrumentation and sampling systems installed and maintained, and the ability of qualified staff to collect the data. Aerial monitoring is also useful when monitoring staff cannot act because of disaster.

7.5 Radiation monitoring on surface water

Impacted surface waters are generally cleared of people during a radiological emergency. The immediacy of monitoring surface waters will depend on the nature of the event and the purpose of the monitoring. Such monitoring may be done for release estimation, determining the extent of the contamination plume, or potential dose. Biota impact determinations are generally done after the event has stabilized, since the initial concerns of the immediate event response are human health and safety and preservation of infrastructure/facilities. Ambient water and sediment are typically sampled and analysed. Biota samples, such as aquatic animals and vegetation, should be made routinely. When surface waters are impacted, a site should expect to implement long-term sampling programs, until the potential risk is diminished. The use of the impacted waters for potable water sources will also need to be considered in surface water monitoring.

7.6 Environmental media and food monitoring

7.6.1 General

Monitoring will determine the extent of the loss of control of the radioactive material and the pathways by which people may be exposed. Environmental media include airborne material, precipitation, soil, foodstuffs, milk and drinking water. The soil samples include terrestrial soil, sea sediment, river sediment, and lake sediment, generally taken from the surface to shallow depths. Foodstuff samples should take into account the food culture in a region. For foodstuffs, milk and drinking water that may be immediately contaminated and consumed, e.g. surface water or vegetable, meat or fish, sampling for short-lived radionuclides should be done promptly for the best dose assessment input. If their samples are immediately contaminated but authorities are confident that consumption can be halted, such prompt sampling would not be necessary. Radioactivity concentration in the sample varies with time, sample should be taken promptly and analysed as soon as possible. In particular, if it is assumed that a short half-life nuclide is included in the sample, it is necessary to analyse immediately.

7.6.2 Measurement of radioactive materials in environmental media

The purpose of measuring the concentration of radioactive materials in the atmosphere, soil, and ambient water sources is to collect information in the emergency exposure situation due to nuclear disaster and to provide information for evaluating radiation effects to residents and the environment. Such sampling may be done using field teams, collecting samples from routine monitoring programs, from vehicles, or from aircraft. While rough sampling can provide some information, quality-controlled sample collection, chain of custody, and sample analysis would provide more defensible data.

7.6.3 Measurement of radioactive materials in food and drink

An effective method of limiting dose to the public is to assure that radioactive material concentrations in food are below pre-established criteria. One criterion implemented in Japan may be applied to events where caesium and iodine emissions from a reactor accident are a concern; the concentration of radioactive material in food products in the area where the measured ambient radiation dose rate exceeds 0,5 μSv/h is measured[18]. This criterion eliminates the need for extensive food and drink sampling. This criterion would not be appropriate for alpha-contamination events.

8 Discussion of Default OILs

8.1 Radiation monitoring for OIL 1

In order to prevent exposure from the ground surface (radioactive material deposited on the ground), inhalation of resuspended radioactive material, ambient dose equivalent should be measured within several hours. The initial value is 1 000 μSv/h as the ambient dose equivalent rate measured at 1 m above the ground surface. The ambient dose equivalent rate is measured to judge the implementation of radiation protection based on OIL 1.

8.2 Radiation monitoring for OIL 2

OIL2 is a measurable value that corresponds to a generic criterion. It is typically expressed in terms of ambient dose equivalent rates, time integrated air activity concentrations, ground, or surface concentrations. In order to reduce the risk of stochastic effects from the ground surface contamination (radioactive material deposited on the ground) from inhalation of resuspended radioactive substances.

8.3 Radiation monitoring for OIL 6

OIL6 are measured values of concentrations in food, milk or water that warrant the consideration of restrictions on consumption so as to keep the effective dose to any person below 10 mSv per year. See Table 3.

Table 3 — Example of initial value from OIL 6[18]

Nuclides	Water, milk, milk products Bq/kg	Vegetable, cereal, meat, egg, fish others Bq/kg
^{131}I	300	2 000
Cs	200	500
Pu and other alpha emitters in trans-U series	1	10
U isotopes	20	100

9 Projected dose assessment based on monitoring results

9.1 General

OIL is a criterion for determining urgent protective and early phase protective actions based on the results obtained by environmental monitoring. Therefore, it is not only a value for specific protective measures such as evacuation except for food restrictions (OIL5 and OIL6).

Effective dose, equivalent dose and RBE weighted absorbed dose are used in evaluating radiation-induced effects of a nuclear or radiation emergency. Dosimetric quantities and their application in emergency exposure situation are given in Figure 2[16].

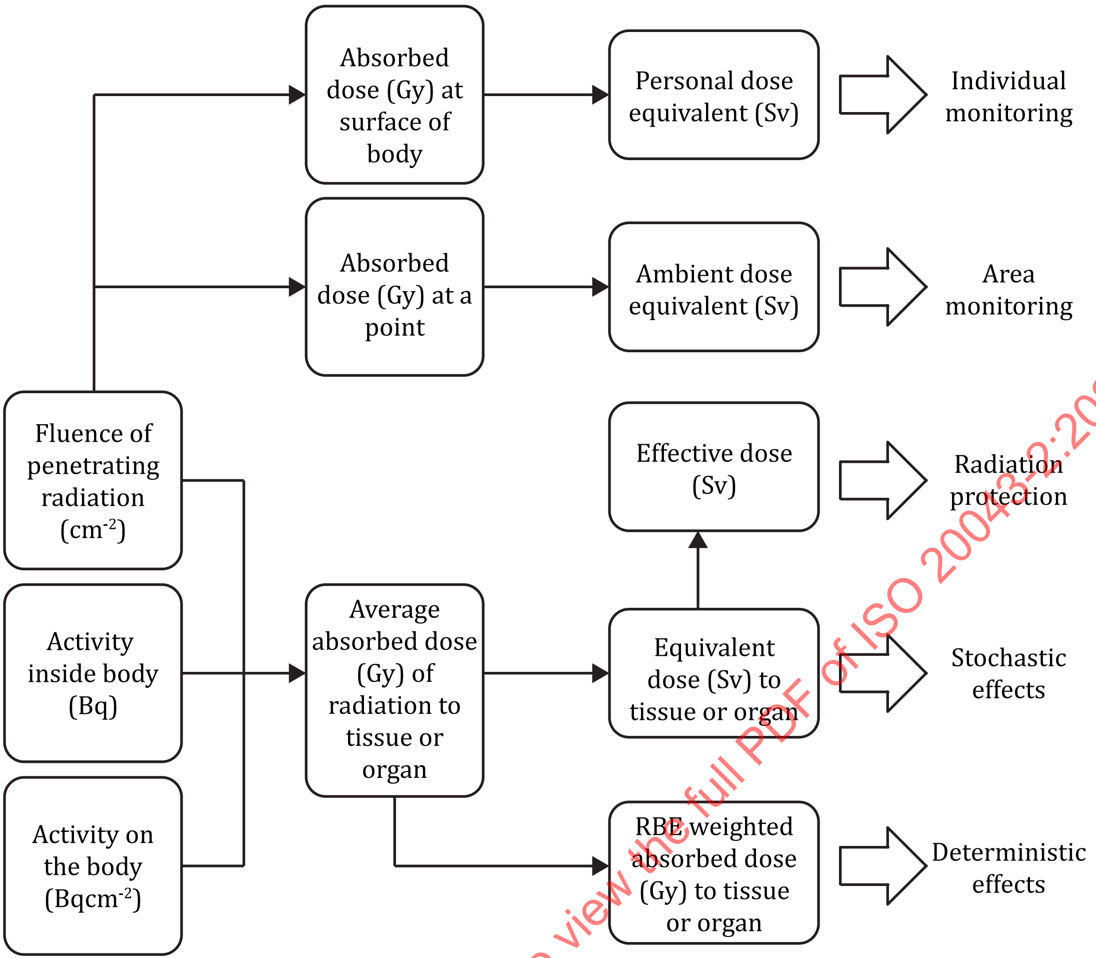
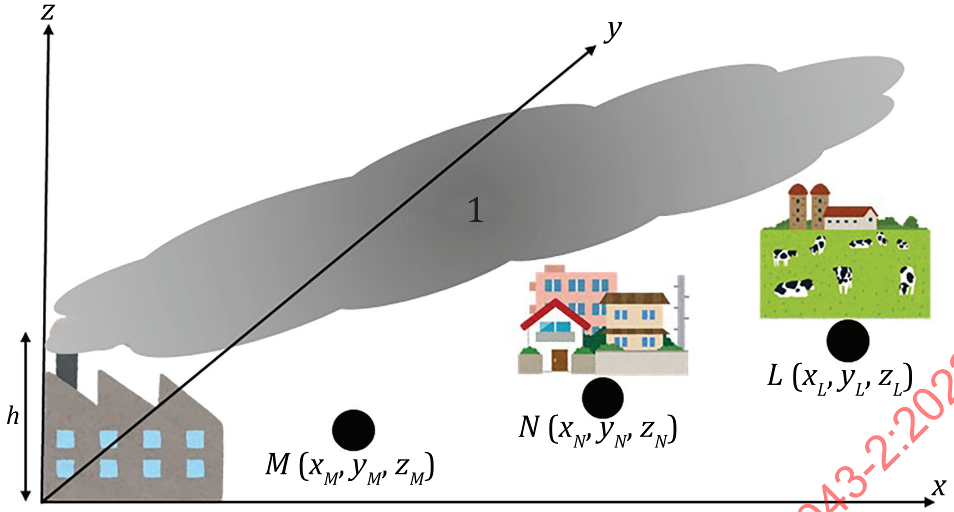


Figure 2 — Dosimetric quantities and their application in emergency exposure situation modified from IAEA No. GSG-2[16]

9.2 Projected dose assessment during a release

During this phase the objective is to be able to evaluate as quickly as possible the prospective short-term doses due to the plume that could be received by the population located within the wind direction, so they can take appropriate protective actions (sheltering, evacuation, iodine prophylaxis).

For that purpose, continuous measurement of dose rate $\dot{D}_p$ and if possible, activity concentration in the air C_α due to the plume are carried out on a location M within the wind direction in the axis of the release (see Figure 3).



Key

1	plume
x, *y*, *z*	cartesian coordinates
M	measurement location with Cartesian coordinates (x_M, y_M, z_M) in the release axis
N	population location with Cartesian coordinates (x_N, y_N, z_N) in the release axis
L	agricultural location with Cartesian coordinates (x_L, y_L, z_L) in the release axis
h	release height

Figure 3 — Behaviour of plume in the environment

The effective dose due to the plume at the population location *N* (see Figure 3) is given by Formula (1).

$$E_{\mathrm{p}}(N)=E_{\mathrm{p,ext}}(N)+E_{\mathrm{p,inh}}(N) \quad (1)$$

NOTE 1 During the plume passage the effective dose due to inhalation of the resuspension of the activity deposited on the ground is negligible compared to the effective dose due to inhalation of the plume.

NOTE 2 During the plume passage the effective dose due to external exposure from the ground deposition is negligible compared to the effective dose due to external exposure of the plume.

NOTE 3 The effective dose due to external exposure is evaluated by the ambient dose equivalent at 10 mm depth measurement quantity ($H^*(10)$).

NOTE 4 the effective dose due to inhalation is evaluated from the activity concentration measurement in the air.

If iodine is involved in the released source term, it may be necessary to evaluate the committed equivalent dose at the thyroid due to the plume inhalation at the population location *N* (see Figure 3).

From effective dose due to the plume at location *N*, $E_{\mathrm{p}}(N)$, and if necessary committed equivalent dose to the thyroid at location *N*, $H_{\mathrm{thy}}(N)$, the operational intervention levels (OIL) can then be established in advance that would allow ambient dose equivalent rate and if possible activity concentration measurements due to the plume at location *M*, to be interpreted immediately in term of prospective dose assessment to anticipate appropriate protective actions towards population living at location *N* (sheltering, evacuation, iodine prophylaxis).

The prospective dose assessment and thus associated OILs require assumption on:

— the source term;

— the length of exposure for external exposure;

— the length of exposure, the breathing rate, the age of the concerned public, the physico-chemical form of the involved radionuclides (aerosol size, lung absorption speed) for inhalation exposure.

An example of OILs determination at measurement location M in order to assess projected dose at a dwelling location N during a plume passage is given in Annex B.

Within hours, it may be necessary:

— at the measurement location M, to conduct surface sampling of the soil and an air sampling followed by appropriate radioactivity measurements in order to check the coherency of the pre-determined radionuclides repartition $\frac{\dot{A}_i}{\dot{A}}$ of the source term and thus the OILs being used;

— at the dwelling location N, to conduct dose rate measurement, surface sampling of the soil and an air sampling followed by appropriate radioactivity measurements in order to check the coherency of the projected dose assessment.

Within days, the mixture of radionuclides over the affected area should be determined and the OILs being used to make decisions should be revised, if warranted.

9.3 Projected dose assessment after a plume passage

This situation is still illustrated by Figure 3 (without the plume). During this phase the objective is to be able to evaluate as quickly as possible the prospective doses, due to the deposition, and, if applicable, due to the resuspension that can be received by the public frequenting or living in the area:

— dwelling in contaminated area;

— consuming agricultural products from contaminated area;

in order to take appropriated protective actions (evacuation, restrictions on local products consumption).

For that purpose, evaluation of $\dot{E}_{\mathrm{d,ext}}$ and surface activity are carried out on a location M in the axis of the release (see Figure 3). $\dot{E}_{\mathrm{d,ext}}$ is given as result of ambient dose equivalent rate $\dot{H}^*(10)$ measurement and the surface activity is given as a net count rate, $r_{\mathrm{net}}(M)$, resulting from a measurement by a portable surface contamination detector

— at the population location N (see Figure 3), and

— at agricultural location L (see Figure 3).

The effective dose due to the deposition is given by Formula (2):

$$E_{\mathrm{d}}(N) = E_{\mathrm{d,ext}}(N) + E_{\mathrm{d,inh}}(N) + E_{\mathrm{ing}}(N) \quad (2)$$

NOTE 1 The effective dose due to external exposure is evaluated by the ambient dose equivalent at 10 mm depth measurement quantity ($H^*(10)$).

NOTE 2 If necessary, the dose equivalent at the skin due to contact with the contaminated ground can be evaluated in order to avoid potential deterministic effect.

In general, criteria for stopping consumption of local products are based on radioactivity concentration limitation values also called generic criteria (GC) for foodstuffs, then instead of projected dose, the determination of a projected activity concentration of a product cultivated at location L.

GC is established at levels of dose that approaching the thresholds for severe deterministic effects and in terms of dose that can be projected or dose that has already been received.

The OIL should be established in advance that would allow ambient dose equivalent rate and surface contamination (expressed in counts, s^{-1}) measurements due to the deposition at location M, to be interpreted immediately in term of prospective dose assessment to anticipate appropriate protective actions such as:

— evacuation of population living at location *N* whose criteria are based on external and internal exposure limitation values from inhalation of resuspended ground contamination and from ingestion due to contact with contaminated ground;

— stopping consumption of local products at agricultural area location *L* whose criteria are based on activity concentration limitation values.

The prospective dose assessment and thus associated OILs require assumption on:

— the length of exposure and the fraction likely to be transferred on the skin for external exposure;

— the length of exposure, the resuspension factor, the breathing rate, the age of the concerned public and the physical-chemical form of the involved radionuclides (aerosol size, lung absorption speed) for inhalation exposure and;

— the fraction likely to be ingested, the chemical form of the involved radionuclides (gut transfer factor) and the age of the concerned public for ingestion due to contact exposure;

— the production yield per cultivated area of the product, the daily consumption of the product, the duration of consumption of the product, the chemical form of the involved radionuclides (gut transfer factor) and the age of the concerned public for ingestion of the product exposure.

An example of OILs determination at measurement location *M* in order to assess projected dose at a dwelling location *N*, due to deposition after a plume passage is given in Annex C.

Within hours, it may be necessary:

— at the measurement location *M*, to conduct surface sampling of the soil followed by appropriate radioactivity measurements in order to check the coherency of the pre-determined radionuclides repartition $\frac{A_i}{A}$ of the source term and thus the OILs being used;

— at the dwelling location *N*, to conduct dose rate measurement, direct surface contamination measurement, surface sampling of the soil followed by appropriate radioactivity measurements in order to check the coherency of the projected dose assessment;

— at the agricultural location *L*, to conduct dose rate measurement, direct surface contamination measurement, surface sampling of the soil and crops sampling followed by appropriate radioactivity measurements in order to check the coherency of the projected activity concentration assessment of cultivated products.

Within days, the mixture of radionuclides over the affected area should be determined and the OILs being used to make decisions should be revised, if warranted.

10 Laboratory management

10.1 Laboratory staff management

In advance, laboratory staff are required to have knowledge of the sample collection, measurement and analytical procedure to maintain precision, and the necessity to avoid contamination and unexpected exposure. The laboratory manager makes sure that personnel relevant for emergency response take part in regular training and exercises. Therefore, laboratory staff are able to perform their assigned response in an emergency.

10.2 Sample management

The laboratory may have a large number of high priority samples for a few days. If possible, screening measurements would help to pre-screen samples prior to bringing and accessing them in the laboratory. Very high-level activity samples may be brought in. The laboratory has to store samples separately to avoid cross contamination. In addition to preventing cross-contamination very high radioactivity samples may be required handling separately, as they may contaminate the high-sensitive equipment in laboratory. Laboratories may be required the potential to develop protocols for handling very high radioactivity samples.

10.3 Quality management

Laboratory should have management system to keep quality assurance (traceability, avoid cross contamination, keep a detection limit, and reduce uncertainty) as well as establishment of manuals and education of staffs. Quality assurance should include robust quality management in emergency exposure situations[1][2][3][20].

10.4 Publication of results

The results of the emergency monitoring should be published for the public with accurately, promptly, truthful, and clearly information through appropriate media. In addition, an easily understandable explanation is required for public.

Annex A
(informative)

OILs for assessing the results of field monitoring and screening of foodstuff concentrations from laboratory analysis

Table A.1 — Default OILs for field survey measurements[16]

OIL	OIL value	Response action (if the OIL is exceeded)
OIL 1	Gamma 1 000 µSv/h at 1 m from surface or a source, 2 000 counts/s direct beta surface contamination measurement, 50 counts/s direct alpha surface contamination measurement	— Immediately evacuate or provide substantial shelter; — Provide for decontamination of evacuees; — Reduce inadvertent ingestion; — Stop consumption of local produced, rainwater and milk from animals grazing in the area; — Register and provide for a medical examination of evacuees; — If a person has handled a source with a dose rate equal to or exceeding 1 000 µSv/h at 1 m, provide an immediate medical examination:; any pregnant women who have handled such a source should receive immediate medical evaluation and dose assessment.
OIL 2	Gamma 100 µSv/h at 1 m from surface or a source, 200 counts/s direct beta surface contamination measurement, 10 counts/s direct alpha surface contamination measurement	— Stop consumption of local produced, rainwater and milk from animals grazing in the area until they have been screened and contamination levels have been assessed using OIL5 and OIL6; — Temporarily relocate those living in the area; before relocation, reduce inadvertent ingestion; register and estimate the dose to those who were in the area to determine if medical screening is warranted; relocation of people from the areas with the highest potential exposure should begin within days; — If a person has handled a source with a dose rate equal to or exceeding 100 µSv/h at 1 m, provide medical examination and evaluation; any pregnant women who have handled such a source should receive immediate medical evaluation and dose assessment.
OIL 3	Gamma 1 µSv/h at 1 m from surface, 20 counts/s direct beta surface contamination measurement, 2 counts/s direct alpha surface contamination measurement	— Stop consumption of non-essential local produced, rainwater and milk from animals grazing in the area until it has been screened and contamination levels have been assessed using OIL5 and OIL6; — Screen local produce, rainwater and milk from animals grazing in the area out to at least 10 times the distance to which OIL3 is exceeded and assess samples using OIL5 and OIL6; — Provide for iodine thyroid blocking (prophylactic stable iodine usage), as appropriate, if exposure due to radioactive iodine is possible; — Estimate the dose of those who may have consumed food, milk or rainwater from the area where restrictions were implemented to determine if medical screening is warranted.

Table A.1 *(continued)*

OIL	OIL value	Response action (if the OIL is exceeded)
OIL 4	Gamma 1 µSv/h at 10 cm from the skin, 1 000 counts/s direct beta skin contamination measurement, 50 counts/s direct alpha skin contamination measurement	Skin contamination — Provide for skin decontamination and reduce inadvertent ingestion; — Register and provide for a medical examination.
OIL 5	Gross beta: 100 Bq/kg or Gross alpha: 5 Bq/kg for food, milk and water concentrations	Above OIL5: Assess using OIL6 Below OIL5: Safe for consumption during the emergency phase
OIL6	Determination of radionuclide concentrations and evaluation of OIL 6 value each radionuclide	— Stop consumption of non-essential15 food, milk or water and conduct an assessment on the basis of realistic consumption rates. Replace essential food, milk and water promptly, or relocate people if replacement of essential food, milk and water is not possible; — For fission products (e.g. containing iodine) and iodine contamination, consider providing iodine thyroid blocking if replacement of essential food, milk or water is not immediately possible; — Estimate the dose to those who may have consumed food, milk or rainwater from the area where restrictions were implemented to determine if medical screening is warranted.

Annex B
(informative)

Example of operational intervention levels determination related to living area during plume passage

B.1 Protective action criteria in location *N* (see Figure 3)

The protective actions are defined as follow according to effective dose, E_p, due to direct fallout (plume and deposition):

$E_p(N) < 10$ mSv	No protective action
10 mSv $< E_p(N) <$ 50 mSv	Sheltering of population
$E_p(N) > 50$ mSv	Evacuation of population

B.2 Real time monitoring in location *M* (see Figure 3)

— Quantification of $E_{p,ext}(M)$ from $\dot{H}^*(10)$ measurement with a detection alarm level set up at a net value of 50 nSv·h^{-1} (background level of 100 nSv·h^{-1});

— Beta/gamma emitters activity concentration in the air, $C_{a,\beta\gamma}(M)$ beta gamma with a detection alarm level set up at 40 Bq/m^3 (response time 15 min);

— Alpha emitters activity concentration in the air, $C_{a,\alpha}(M)$ alpha with a detection alarm level set up at 4 Bq/m^3 (response time 15 min).

B.3 Operational intervention levels (OIL) description

— $OIL[M, E_p(N) = 10 \text{ mSv}, \dot{H}^*(10)]$;

— $OIL[M, E_p(N) = 10 \text{ mSv}, C_{a,\beta\gamma}]$;

— $OIL[M, E_p(N) = 10 \text{ mSv}, C_{a,\alpha}]$.

and

— $OIL[M, E_p(N) = 50 \text{ mSv}, \dot{H}^*(10)]$

— $OIL[M, E_p(N) = 50 \text{ mSv}, C_{a,\beta\gamma}]$;

— $OIL[M, E_p(N) = 50 \text{ mSv}, C_{a,\alpha}]$.

Those OILs will help to anticipate the amount of time T_R needed to put in place the protective actions towards population living at location *N*, T_R being also the activity release duration.

B.4 Localisation of *M* and *N*

— *M* is located at 500 m from the emission source;

— *N* is located at 2 km from the emission source.

B.5 Source term description

Radionuclide	^{137}Cs	^{90}Sr	^{239}Pu
Aerosols size (µm)	1	1	1
Chemical form	All compounds	All compounds	Insoluble oxide
Lung absorption speed	Fast	Moderate	Slow
$\frac{\dot{A}_i}{\dot{A}}$	0,8	0,19	0,01

B.6 Dose factors

Radionuclide	^{137}Cs	^{90}Sr	^{239}Pu
f_{CDp} $(Sv \cdot s^{-1} \cdot Bq^{-1}) \cdot m^3$	$2,75 \times 10^{-14}$	$1,98 \times 10^{-16}$	$4,24 \times 10^{-18}$
f_{CDd} $(Sv \cdot s^{-1} \cdot Bq^{-1}) \cdot m^2$	$5,53 \times 10^{-16}$	$5,60 \times 10^{-18}$	$3,67 \times 10^{-19}$
$E_{inh}(i)$[a] $Sv \cdot Bq^{-1}$	$4,60 \times 10^{-9}$	$3,74 \times 10^{-8}$	$1,60 \times 10^{-5}$

[a] For an adult.

B.7 Condition of release

Release height	Condition of diffusion	Wind speed	Rain
0 m	weak	5 m s^{-1}	NO

Then

Radionuclide	^{137}Cs	^{90}Sr	^{239}Pu
$CTA(M)$ $s \cdot m^{-3}$	$1,11 \times 10^{-4}$	$1,11 \times 10^{-4}$	$1,10 \times 10^{-4}$
$CTA(N)$ $s \cdot m^{-3}$	$1,09 \times 10^{-5}$	$1,11 \times 10^{-5}$	$1,10 \times 10^{-5}$
V_{di} $m \cdot s^{-1}$	$5,00 \times 10^{-3}$	$5,00 \times 10^{-3}$	$5,00 \times 10^{-3}$

B.8 Operational intervention levels (OIL) values at location *M* for projected dose at location *N*

— $\dot{H}*(10)$ measurement at location *M*

OIL values are calculated considering a given $E_p(N)$ value from Formula (B.1) :

$$\dot{H}^*(10)T_R = E_p(N)\frac{\sum i\left[\frac{\dot{A}_i}{\dot{A}}CTA_i(M)f_{CDp_i}\right]}{\sum i\left[\frac{\dot{A}_i}{\dot{A}}CTA_i(N)f_{CDpi}\right]+\dot{q}_r\sum i\left[\frac{\dot{A}_i}{\dot{A}}CTA_i(N)E_{inh}(i)\right]} \quad (B.1)$$

$\dot{H}^*(10)T_R$ being the measurement of the effective dose due to external exposure from the plume at location *M*, $E_{p,ext}(M)$ (Sv)

Then

$OIL[M, E_p(N) = 10\text{ mSv}, \dot{H}^*(10)]$	
$\dot{H}^*(10)T_R$ =44 µSv (B.1)	
$\dot{H}^*(10)$ **net measurement at location *M*** µSv/h	T_R h
$5{,}0 \times 10^{-2}$ (detection alarm level)	$8{,}79 \times 10^{2}$
$5{,}0 \times 10^{-1}$	$8{,}79 \times 10^{1}$
$5{,}0 \times 10^{0}$	$8{,}79 \times 10^{0}$
$5{,}0 \times 10^{1}$	$8{,}79 \times 10^{-1}$

and

$OIL[M, E_p(N) = 50\text{ mSv}, \dot{H}^*(10)]$	
$\dot{H}^*(10)T_R$ =220 µSv (B.1)	
$\dot{H}^*(10)$ **net measurement at location *M*** µSv/h	T_R h
$5{,}0 \times 10^{-2}$ (detection alarm level)	$4{,}39 \times 10^{3}$
$5{,}0 \times 10^{-1}$	$4{,}39 \times 10^{2}$
$5{,}0 \times 10^{0}$	$4{,}39 \times 10^{1}$
$5{,}0 \times 10^{1}$	$4{,}39 \times 10^{0}$
$5{,}0 \times 10^{2}$	$4{,}39 \times 10^{-1}$

— Activity concentration in the air at location *M*

OIL values are calculated considering a given $E_p(N)$ value from Formula (B.2):

$$C_a(M)T_R = E_p(N)\frac{\sum i\left[\frac{\dot{A}_i}{\dot{A}}CTA_i(M)\right]}{\dot{q}_r\sum i\left[\frac{\dot{A}_i}{\dot{A}}CTA_i(N)E_{\text{inh}}(i)\right]+\sum i\left[\frac{\dot{A}_i}{\dot{A}}CTA_i(N)f_{\text{CDp}i}\right]} \quad (B.2)$$

And the effective dose due to inhalation of the plume at location *M* (Sv) is given by Formula (B.3):

$$E_{\text{p,inh}}(M) = C_a(M)T_R\dot{q}_r\sum i\left[\frac{\dot{A}_i}{\dot{A}}E_{\text{inh}}(i)\right] \quad (B.3)$$

Then

$OIL[M, E_p(N) = 10\text{ mSv}, C_{a,\beta\gamma}/C_{a,\alpha}]$			
$C_a(M)\ T_R = 5{,}7 \times 10^5$ Bq·m^{-3} h (B.2) corresponding to $E_{\text{p,inh}}(M)$ = 116 mSv (B.3)			
$C_a(M)$ Bq·m^{-3}	$C_{a,\beta\gamma}(X)$ Bq·m^{-3}	$C_{a,\alpha}(X)$ Bq·m^{-3}	T_R h
$4{,}40 \times 10^{1}$	$4{,}40 \times 10^{1}$ (detection alarm level)	< detection alarm level	$1{,}4 \times 10^{4}$
$4{,}40 \times 10^{2}$	$4{,}40 \times 10^{2}$	$4{,}04 \times 10^{0}$ (detection alarm level)	$1{,}4 \times 10^{3}$
$4{,}40 \times 10^{3}$	$4{,}0 \times 10^{3}$	$4{,}04 \times 10^{1}$	$1{,}4 \times 10^{2}$

