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CRITERIA FOR USE IN PREPAREDNESS AND RESPONSE FOR A NUCLEAR OR RADIOLOGICAL EMERGENCY

(Revision of GSG-2)

DS527

DRAFT SAFETY GUIDE

CONTENTS

1. INTRODUCTION

BACKGROUND

1.1. Principle 9 of the Fundamental Safety Principles (Ref. [1] para 3.36) states that emergency preparedness and response plans must include criteria that are set in advance. Therefore, general safety requirements call for governments to ensure that pre-established operational criteria are derived for initiating the different parts of an emergency plan (Ref. [2] Requirement 5, para 4.28(4)). Such criteria help determine when different protective and other response actions should be taken. This Safety Guide gives guidance and recommendations on how to establish these operational criteria..

1.2. In 2011, IAEA Safety Standards Series No. GSG-2, Criteria for Use in Preparedness and Response for a Nuclear or Radiological Emergency[1] was published, and was jointly sponsored by the Food and Agriculture Organization of the United Nations (FAO), the IAEA, the International Labour Organization (ILO), the Pan American Health Organization (PAHO), and the World Health Organization (WHO).

1.3. In 2015, IAEA Safety Standards Series No. GSR Part 7, Preparedness and Response for a Nuclear or Radiological Emergency [1] was published and was jointly sponsored by 13 international organizations. GSR Part 7 [1] establishes requirements for an adequate level of preparedness for and response to a nuclear or radiological emergency, irrespective of the initiator of the emergency. IAEA Safety Standards Series No. GSR Part 3, Radiation Protection and Safety of Radiation Sources: International Basic Safety Standards [2], jointly sponsored by the IAEA and seven other international organizations, was published in 2014.

1.4. Some of the guidance and recommendations originally provided in GSG-2 have been upgraded to requirements in GSR Part 7 [1] and GSR Part 3 [2]. Other topics, such as the protection strategy and default operational intervention levels have been documented in greater detail in EPR series publications [3, 4, 5, 6, 7].

1.5. This Safety Guide is a revision of GSG-2, which it supersedes. It takes account of new developments, experience gained, and changes made in the relevant publications since 2011. This Safety Guide was developed with due consideration of the relevant safety requirements for response to a nuclear or radiological emergency established in GSR Part 7 [1] and GSR Part 3 [2], as well as relevant ICRP recommendations [8, 9]).

[1] FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS, INTERNATIONAL ATOMIC ENERGY AGENCY, INTERNATIONAL LABOUR OFFICE, PAN AMERICAN HEALTH ORGANIZATION, WORLD HEALTH ORGANIZATION, Criteria for Use in Preparedness and Response for a Nuclear or Radiological Emergency, IAEA Safety Standards Series No. GSG-2, IAEA, Vienna (2011).

OBJECTIVE

1.6. The objective of this Safety Guide is to present a coherent set of criteria for supporting decision making regarding protective actions and other response actions necessary to meet the goals of emergency response defined in GSR Part 7 [1]. This Safety Guide includes an emphasis on operational criteria, including operational intervention levels, emergency action levels, observables and indicators, in support of Requirements 5, 7, 9 and 12–14 of GSR Part 7 [1]. This Safety Guide also addresses Requirements 43, 44 and 45 of GSR Part 3 [2].

1.7. This Safety Guide should be used in conjunction with GSR Part 7 [1], with due account to be taken of the guidance and recommendations provided in IAEA Safety Standards Series Nos DS504, Arrangements for Preparedness and Response for a Nuclear or Radiological Emergency [10], DS534, Protection Strategy for a Nuclear or Radiological Emergency [11], GSG-11, Arrangements for the Termination of a Nuclear or Radiological Emergency [12], GSG-14, Arrangements for Public Communication in Preparedness and Response for a Nuclear or Radiological Emergency [13] and SSG-65, Preparedness and Response for a Nuclear or Radiological Emergency Involving the Transport of Radioactive Material [14].

1.8. This Safety Guide is aimed at emergency planners and other personnel in operating organizations, response organizations and regulatory bodies with responsibilities to develop and establish criteria for taking protective actions and other response actions, and/or to develop emergency plans and procedures to implement the criteria.

SCOPE

1.9. The guidance and recommendations provided in this Safety Guide relate to emergency[2] preparedness and response for a nuclear or radiological emergency, irrespective of its cause.

1.10. The guidance and recommendations in this Safety Guide are based on the reference levels and generic criteria provided in GSR Part 7 [1] and GSR Part 3 [2] that are related to the development of operational criteria for implementing protective actions and other response actions to protect workers, emergency workers, helpers and the public in the event of an emergency.

1.11. This Safety Guide addresses the criteria to support decision making on taking urgent protective actions, precautionary protective actions and other response actions in an emergency. Examples of the operational criteria, including operational intervention levels (OILs), emergency action levels (EALs), observables and indicators are provided in this Safety

[2] In the context of this Safety Guide, the term ‘emergency’ is used for conciseness of the document and is intended to mean a nuclear or radiological emergency, unless otherwise specified.

Guide. The method used for the development of operational criteria is described in general terms.

1.12. This Safety Guide only addresses emergency exposure situations. It addresses neither existing nor planned exposure situations. Recommendations on adapting or lifting protective actions and other response actions during the transition phase to an existing or planned exposure situation, including the use of relevant operational criteria, are provided in GSG-11 [12].

1.13. This Safety Guide does not provide detailed guidance on the arrangements necessary for developing and maintaining an effective emergency response capability. Detailed recommendations on developing and maintaining an effective emergency response capability are provided in DS504 [10], GSG-14 [13] and SSG-65 [14].

1.14. This Safety Guide cannot take into account all factors that are site area[3], local or state specific or specific to a particular type of emergency. The users of this Safety Guide should work with interested parties to adapt the recommendations in the preparedness stage, so as to take account of local, social, political, economic, environmental, demographic and other factors.

1.15. The recommendations on the operational criteria presented in this Safety Guide are based solely on considerations of the radiological aspects of an emergency or response to an emergency. However, the suitability of implementing protective actions and other response actions is not solely based on radiation protection. Decision makers should also consider various additional factors, including health, social, economic, environmental, security and psychological, before making any final decision on actions to be taken in response to an emergency.

1.16. Decision makers in an emergency and the public might have only a limited or no understanding of the principles of radiation protection, the risks associated with radiation exposure and the appropriate actions that can be taken to reduce these risks. This Safety Guide, therefore, also provides a plain language explanation of the operational intervention levels to assist in the communication of their purpose and the associated protective actions and other response actions.

1.17. The terms used in this Safety Guide are defined in GSR Part 7 [1] and are as described in the IAEA Nuclear Safety and Security Glossary [15]

[3] Site area is defined as "a geographical area that contains an authorized facility, authorized activity or source, and within which the management of the authorized facility or authorized activity or first responders may directly initiate emergency response actions. This is typically the area within the security perimeter fence or other designated property marker. It may also be the controlled area around industrial radiography work or an inner cordoned off area established by first responders around a suspected hazard" [16]. The terms 'on-site' and 'off-site' mean within and outside the boundary of the site area, respectively.

STRUCTURE

1.18. Section 2 provides guidance and recommendations on the emergency response criteria to be established within a protection strategy for a nuclear or radiological emergency. Section 3 provides recommendations on the guidance values for emergency workers. Section 4 provides guidance and recommendations on operational criteria. The three appendices provide additional recommendations on the use of operational intervention levels, emergency action levels, and observables and indicators, respectively. The Annex provides additional information on the use of dosimetric quantities.

2. EMERGENCY RESPONSE CRITERIA IN A PROTECTION STRATEGY

PROTECTION STRATEGY FOR A NUCLEAR OR RADIOLOGICAL EMERGENCY

2.1. The concept of protection strategy is introduced in Requirement 5 of GSR Part 7 [1], which states:

> "**The government shall ensure that protection strategies are developed, justified and optimized at the preparedness stage for taking protective actions and other response actions effectively in a nuclear or radiological emergency.**"

2.2. Paragraph 4.28 of GSR Part 7 [1] states [footnote omitted]:

> "Development of a protection strategy shall include, but shall not be limited to, the following:
>
> (1) Consideration shall be given to actions to be taken to avoid or to minimize severe deterministic effects and to reduce the risk of stochastic effects. Deterministic effects shall be evaluated on the basis of relative biological effectiveness (RBE) weighted absorbed dose to a tissue or organ. Stochastic effects in a tissue or organ shall be evaluated on the basis of equivalent dose to the tissue or organ. The detriment associated with the occurrence of stochastic effects in individuals in an exposed population shall be evaluated on the basis of the effective dose.
>
> (2) A reference level expressed in terms of residual dose shall be set, typically as an effective dose in the range of 20–100 mSv, acute or annual, that includes dose contributions via all exposure pathways. This reference level shall be used in conjunction with the goals of emergency response…and the specific time frame in which particular goals are to be achieved.

(3) On the basis of the outcome of the justification and the optimization of the protection strategy, national generic criteria for taking protective actions and other response actions, expressed in terms of projected dose or of dose that has been received, shall be developed with account taken of the generic criteria in Appendix II [of GSR Part 7]. If the national generic criteria for projected dose or received dose are exceeded, protective actions and other response actions, either individually or in combination, shall be implemented.

(4) Once the protection strategy has been justified and optimized and a set of national generic criteria has been developed, pre-established operational criteria (conditions on the site, emergency action levels (EALs) and operational intervention levels (OILs)) for initiating the different parts of an emergency plan and for taking protective actions and other response actions shall be derived from the generic criteria. Arrangements shall be established in advance to revise these operational criteria, as appropriate, in the course of a nuclear or radiological emergency, with account taken of the prevailing conditions as they evolve."

2.3. Guidance on the concept of the protection strategy for a nuclear or radiological emergency, and the development, justification and optimization of such a strategy are provided in DS534 [11]. As indicated in Paragraph 4.28 of GSR Part 7 [2] and DS534 [11], establishing a national reference level, generic criteria, and operational criteria are three of the main steps of the step-by-step approach for the development of a protection strategy.

REFERENCE LEVELS FOR A NUCLEAR OR RADIOLOGICAL EMERGENCY

2.4. The use of reference levels in an emergency exposure situation is described in GSR Part 3 [2] and ICRP Publication 103 [8]. As stated in para. 1.24 of GSR Part 3 [2] "The reference level represents the level of dose or the level of risk above which it is judged to be inappropriate to allow exposures to occur and below which the optimization of protection and safety is implemented. The value chosen for the reference level will depend on the prevailing circumstances for the exposures under consideration". The reference level is a tool for optimization of the protection strategy and protective actions: priority is given to those groups for whom the dose exceeds reference levels, and then optimization of protection and safety is applied to exposures below reference levels, as long as interventions are justified (i.e., do more good than harm), radiological and non-radiological factors considered . The reference level is not a limit; it serves as a boundary condition in identifying the range of options for the purposes of optimization and has a role in both emergency preparedness and response.

2.5. The reference level is expressed in terms of residual dose. For a nuclear or radiological emergency, a residual dose typically in the range of 20–100 mSv effective dose should be used (see para 1.27 of GSR Part 3 [2]).

2.6. With regard to residual dose, para. 4.52 of GSG-11 [12] states:

> "…The residual dose expresses the accumulated exposure from the initiation of the emergency through a specified period, with account taken of the implementation of the protection strategy, if any[33].
>
> [33] For emergency exposure situations that may result in doses over a period of less than one year, the residual dose will be the total dose from all exposure pathways for the entire duration of the emergency. For a large scale emergency resulting in longer term exposures due to residual radioactive material in the environment, the residual dose will encompass the total dose from all exposure pathways over one year from the onset of the emergency. For residual doses to be used during the response, the total residual dose includes the doses received from all exposure pathways (received dose) and the doses expected to be received in future (projected residual dose), with account taken of the implementation of the protection strategy, if any."

2.7. For an emergency response during the urgent response phase, there is no time for a specific optimization process due to the urgency associated with decision making and implementation of protective actions in an effective manner. Instead, a justified and optimized protection strategy for the urgent response phase should be prepared and agreed on at the preparedness stage. As the emergency evolves (particularly towards the transition phase; see paras 2.11–2.14 of GSG-11 [12]), justification and optimization of protection should take place, including the use of an appropriate reference level.

2.8. During the emergency response, the doses incurred by individuals after the protection strategy has been implemented should be compared against the applicable reference level, providing an opportunity to assess the effectiveness of the protection strategy and the need for adjustments to address prevailing circumstances. Adjustments might be taken in terms of the implementation of protective actions under an unchanged reference level or in terms of the reference level. With the adjustment of the reference level, further protective actions can be determined and implemented so that they (taking into account the resources available) focus on those groups and/or individuals who would benefit most from such actions, which mean those groups and/or individuals whose residual doses exceed the reference level. It should be noted that assessing the doses received by members of the public is not immediate.

2.9. Specific numerical values for national reference levels are established or approved by the government, the regulatory body or another relevant authority (see para. 1.24 of GSR Part 3 [2]). The values selected will depend on a range of circumstances, including national and local conditions (e.g. the prevailing economic and societal circumstances, and the available national, regional, and local resources and capabilities), the phase of the emergency under consideration, the practicality of reducing or preventing exposures and the availability of options to reduce or prevent exposures (see also para. 1.28 of GSR Part 3 [2]).

2.10. In selecting a national reference level, the following should be considered:

(a) International recommendations and findings, notably the recommendations of the International Commission on Radiological Protection (ICRP) [8, 9], and IAEA safety standards (specifically GSR Part 3 [2] and GSR Part 7 [1]).

(b) Scientific evidence of harm from ionizing radiation[4], such as the levels at which no discernible increase in the incidence of radiation induced cancers is expected [16]. This may help in prioritizing actions and applying a graded approach to protect affected populations before optimization can be considered.

(c) Results of the hazard assessment (see Requirement 4 of GSR Part 7 [1]) which identify hazards and potential consequences from an emergency and therefore help in determining the range of residual doses that might be achieved by implementing the protection strategy.

(d) Uncertainties in the assessment of potential consequences from an emergency, for example, so as to ensure a sufficient margin in the chosen value for the national reference level.

(e) The availability of options for reducing exposures below the reference level. The results of the hazard assessment may help identify if there are available protective actions to decrease residual doses.

(f) The practicability of further reducing or preventing exposures.

(g) Consistency between the national reference level selected and subsequent national criteria (generic and operational) for implementing specific protective actions (see Figure 1).

(h) Recognition of the evolution of the emergency. Residual doses are expected to decrease as the pre-planned protective actions and other response actions are implemented and may allow the application of different reference levels at different times and in different areas.

(i) The level at which the reference level for existing exposure situations is set, to allow for a smooth transition from one exposure situation to another.

(j) The results of justification and optimization processes, taking account of socio-economic impacts, acceptability, and the need for transboundary coordination.

GENERIC CRITERIA FOR A NUCLEAR OR RADIOLOGICAL EMERGENCY

2.11. After the establishment and approval of specific numerical values for national reference levels, the national radiation protection framework should be completed with generic criteria. In that view, Paragraph 4.28 (3) of GSR Part 7 [1] states:

> "On the basis of the outcome of the justification and the optimization of the protection strategy, national generic criteria for taking protective actions and other response actions,

[4] Current epidemiological data show that radiation induced cancers (the excess number of cancer cases above background cancer cases) could be statistically detected in large populations exposed at doses above 100 mSv delivered at high dose rates. These data are based on epidemiological studies of well defined populations (e.g. the survivors of the atomic bombings in Japan and patients undergoing radiological medical procedures). Epidemiological studies have not demonstrated such effects in individuals exposed at low doses (less than 100 mSv) delivered over a period of many years [16][37].

expressed in terms of projected dose or of dose that has been received, shall be developed with account taken of the generic criteria in Appendix II [of GSR Part 7]. If the national generic criteria for projected dose or received dose are exceeded, protective actions and other response actions, either individually or in combination, shall be implemented."

2.12. The generic criteria expressed in terms of projected dose and received dose, refer not only to the effective dose but also, as appropriate, to the equivalent dose to an organ or tissue and the relative biological effectiveness (RBE) weighted absorbed dose[5] to an organ or tissue considering which of these quantities is indicative of the possible radiation induced health effects.

2.13. Appendix II of GSR Part 7 [1] provides the following justified and optimized generic criteria:

(a) For doses for which protective actions and other response actions are expected to be taken under any circumstances in a nuclear or radiological emergency to avoid or to minimize severe deterministic effects (see table II.1 of GSR Part 7 [1]);

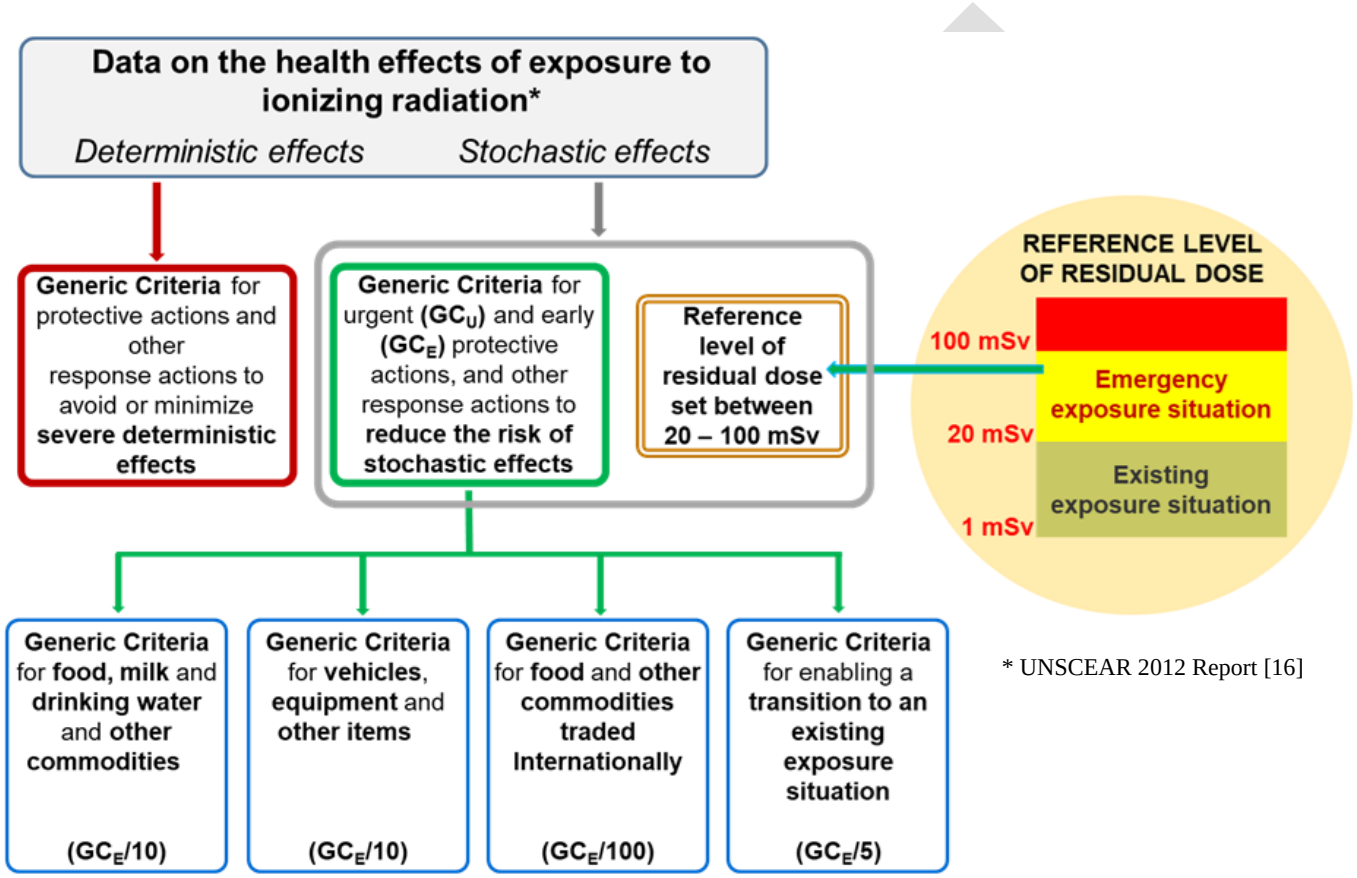
(b) For doses for which protective actions and other response actions are expected to be taken, if they can be taken safely, in a nuclear or radiological emergency to reasonably reduce the risk of stochastic effects (see tables II.2–II.4 of GSR Part 7 [1]);

(c) For doses for which restriction of international trade is warranted in a nuclear or radiological emergency, with due consideration of non-radiological consequences (see table II.5 of GSR Part 7 [1]);

(d) For doses for use as a target dose for the transition to an existing exposure situation (see II.15–II.16 of GSR Part 7 [1]).

2.14. The selection of the reference level and the generic criteria in accordance with GSR Part 7 [1] is illustrated in Fig. 1.

[5] The RBE weighted averaged absorbed dose in an organ or tissue is defined as the product of the averaged absorbed dose in an organ or tissue and the relative biological effectiveness. The unit used to express the RBE weighted absorbed dose is the gray (Gy). For details see Annex.



* UNSCEAR 2012 Report [16]

FIG. 1. The selection of the reference level and the generic criteria in accordance with GSR Part 7 **[1]**

2.15. As noted in footnote e of table II.2 of GSR Part 7 [2] and para. 4.81 (c) of GSG-11 [13], the implementation of protective actions at doses lower than the generic criteria should also be considered. There is a need for thorough justification and optimization to ensure that: the actions taken will do more good than harm, social and economic factors being considered; and the level of protection achieved is the best under the prevailing circumstances, which is not necessarily the option with the lowest dose. If the received doses do not exceed the generic criteria, there is no need for individuals to receive medical follow-up in relation to early detection and effective treatment of radiation induced health effects.

GENERIC CRITERIA THAT AIM TO AVOID OR MINIMIZE SEVERE DETERMINISTIC EFFECTS

2.16. The generic criteria that aim to avoid or minimize severe deterministic effects[6] are associated with doses that, based on Ref. [16], can result in deterministic effects in an individual. These criteria are provided for RBE weighted absorbed dose to an organ or tissue.

2.17. If the projected doses exceed the generic criteria for protective actions and other response actions to avoid or minimize severe deterministic effects (see Table II.1 of GSR Part 7 [1]), then urgent protective actions and other response actions should be initiated before (precautionary urgent protective actions) or shortly after a release of radioactive material or an exposure, on the basis of prevailing conditions [1]. Taking precautionary urgent protective actions effectively ensures that severe deterministic effects will be reasonably minimized or prevented.

2.18. If the received doses exceed the generic criteria for protective actions and other response actions to avoid or minimize severe deterministic effects (see Table II.1 of GSR Part 7 [1]), other response actions for treatment and management of severe deterministic effects, and mitigation of non-radiological consequences, should be implemented.

2.19. The generic criteria for protective actions and other response actions to avoid or minimize severe deterministic effects, from table II.1 of GSR Part 7 [1], are reproduced in Table 1 of this Safety Guide.

TABLE 1. GENERIC CRITERIA FOR PROTECTIVE ACTIONS AND OTHER RESPONSE ACTIONS TO AVOID OR MINIMIZE SEVERE DETERMINISTIC EFFECTS

[6] A deterministic effect is considered to be a severe deterministic effect if it is fatal or life threatening or if it results in a permanent injury that reduces quality of life. Deterministic effects are also referred to as 'harmful tissue reactions' (GSR Part 7 [1], Ref. [15]).

Acute external exposure (<10 h)		
$AD_{\text{red marrow}}$ [a]	1 Gy	If the dose is projected: — Take precautionary urgent protective actions immediately (even under difficult conditions) to keep doses below the generic criteria; — Provide public information and warnings; — Carry out urgent decontamination.
AD_{fetus}	0.1[b] Gy	
AD_{tissue} [c]	25 Gy at 0.5 cm	
AD_{skin} [d]	10 Gy to 100 cm^2	
Acute internal exposure due to an acute intake (Δ = 30 d[e])		
$AD(\Delta)_{\text{red marrow}}$	0.2 Gy for radionuclides with atomic number $Z \geq 90$[f] 2 Gy for radionuclides with atomic number $Z \leq 89$[f]	If the dose has been received: — Perform immediate medical examination, medical consultation and indicated medical treatment; — Carry out contamination control; — Carry out immediate decorporation[g] (if applicable); — Conduct registration for longer term medical follow-up; — Provide comprehensive psychological counselling.
$AD(\Delta)_{\text{thyroid}}$	2 Gy	
$AD(\Delta)_{\text{lung}}$ [h]	30 Gy	
$AD(\Delta)_{\text{colon}}$	20 Gy	
$AD(\Delta')_{\text{fetus}}$ [i]	0.1[b] Gy	

[a] $AD_{\text{red marrow}}$ represents the average RBE weighted absorbed dose to internal tissues or organs (e.g. red marrow, lung, small intestine, gonads, thyroid) and to the lens of the eye from exposure in a uniform field of strongly penetrating radiation.

[b] At 0.1 Gy there would be only a very small probability of severe deterministic effects to the fetus and only during certain periods post-conception (e.g. between 8 and 15 weeks of in utero development), and only if the dose is received at high dose rates. During other periods post-conception and for lower dose rates, the fetus is less sensitive. There is a high probability of severe deterministic effects at 1 Gy. Therefore, 1 Gy is used as the generic criterion for doses to the fetus received within a short period of time: (i) in the hazard assessment, to identify facilities and activities, on-site areas, off-site areas and locations for which a nuclear or radiological emergency could warrant precautionary urgent protective actions to avoid or to minimize severe deterministic effects; (ii) for identifying situations in which exposure is dangerous to health; and (iii) for making arrangements for applying decisions on urgent protective actions and other response actions to be taken off the site to avoid or to minimize the occurrence of severe deterministic effects (e.g. establishing a precautionary action zone).

[c] Dose delivered to 100 cm^2 at a depth of 0.5 cm under the body surface in tissue due to close contact with a radioactive source (e.g. source carried in the hand or pocket).

[d] The dose is to the 100 cm^2 dermis (skin structures at a depth of 40 mg/cm^2 (or 0.4 mm) below the surface).

[e] $AD(\Delta)$ is the RBE weighted absorbed dose delivered over a period of time Δ by the intake (I_{05}) that will result in a severe deterministic effect in 5% of exposed individuals. This dose is calculated as described in appendix I of Ref. [17].

[f] Different generic criteria are used to take account of the significant difference in RBE weighted absorbed dose from exposure at the intake threshold values specific for these two groups of radionuclides.

[g] Decorporation is the action of the biological process, facilitated by chemical or biological agents, by means of which incorporated radionuclides are removed from the human body. The generic criterion for decorporation is based on the projected dose without decorporation.

[h] For the purposes of these generic criteria, 'lung' means the alveolar–interstitial region of the respiratory tract.

[i] $AD(\Delta')_{\text{fetus}}$ represents the average RBE weighted absorbed dose to the embryo or fetus from internal exposure. For this particular case, 'Δ'' refers to the period of in utero development of the embryo and fetus.

2.20. The generic criteria in Table 1 are given separately for internal exposure due to intakes of radioactive material and for external exposure. For external exposure, the threshold for the development of deterministic effects depends on the dose, the dose rate and the RBE of the tissue/organ and radiation. For internal exposure, the threshold depends on many factors, such as activity intake, half-life, route of intake, the radiation emitted and the biokinetics and the metabolism of the radionuclide. In order to take all of these factors into account, in the case of inhalation or ingestion of radioactive material, the 30 day committed RBE weighted absorbed dose is used to specify the threshold for the possible onset of severe deterministic effects in the organ concerned. Establishing threshold values in terms of the 30 day committed RBE weighted dose relative to the intake thresholds leads to a decrease in the range of threshold values depended on the characteristics of the radionuclide from three orders of magnitude (for the intake) down to a factor of three (for the dose)[19]. GSR Part 3 [3] provides the values of RBE for the development of severe deterministic effects.

GENERIC CRITERIA FOR PROTECTIVE ACTIONS AND OTHER RESPONSE ACTIONS TO REDUCE THE RISK OF STOCHASTIC EFFECTS

2.21. The generic criteria that aim to reduce the risk of stochastic effects, and the upper bound of the range of reference level are associated with doses that, based on Ref. [16], can result in an increased incidence of stochastic effects in a population that could be attributed to radiation exposure through epidemiological studies and data, although radiation induced cancers cannot be unequivocally attributed to radiation exposure on an individual basis. The reference level and the generic criteria related to stochastic effects serve different purposes: In a protection strategy, generic criteria are used as the radiological basis to implement protective actions and other response actions (see para. **Error! Reference source not found.**), whereas the reference level serves as a boundary condition in identifying the range of options for the purpose of optimization of the protection strategy and protective actions (see para. 2.4).

2.22. If the projected doses exceed the generic criteria for protective actions and other response actions to reduce the risk of stochastic effects (see table II.2 of GSR Part 7 [1]), urgent protective actions or early protective actions should be implemented, taking into consideration the radiation dose rates, together with other response actions, to reduce the risk of stochastic effects and mitigate non-radiological consequences as far as reasonably practicable. Taking effective urgent and early protective actions aims at ensuring that minimal or no increase in the incidence of cancers above background which could be attributed to radiation exposure of the affected population. Restrictions on food, milk and drinking water using these criteria are to be applies before sampling and analysis of food, milk and drinking water are carried out. Such restrictions apply as long as replacements of food, milk and drinking water or other alternatives are available to ensure they would not result in severe malnutrition, dehydration or other severe health impacts.

2.23. If the received doses are assessed to exceed the generic criteria for protective actions and other response actions to reduce the risk of stochastic effects (see table II.2 of GSR Part 7 [1]), in a timely manner individuals should be registered, and should be provided with health screening based on the equivalent doses to specific radiosensitive organs (as the basis for longer term medical follow-up) and counselling to allow informed decisions to be made in individual circumstances[7].

2.24. The generic criteria from appendix II of GSR Part 7 [1] for emergency response actions taken to reduce the risk of stochastic effects, and actions for enabling a transition to an existing exposure situation are reproduced in Table 2 of this Safety Guide.

TABLE 2. GENERIC CRITERIA RELATED TO EMERGENCY RESPONSE ACTIONS TAKEN TO REDUCE THE RISK OF STOCHASTIC EFFECTS, AND ACTIONS FOR ENABLING A TRANSITION TO AN EXISTING EXPOSURE SITUATION

Basis for taking:	**Urgent protective actions and other response actions**	**Early protective actions and other response actions**	**Longer term medical actions**	**Restrictions on** - **Food, milk and drinking water and other commodities** - **Vehicles, Equipment and other items**	**Actions to enable a transition to an existing exposure situation**
Generic criteria	Projected dose	Projected dose	Received dose	Projected dose[a]	Projected dose
$\boldsymbol{H}_{\mathbf{thyroid}}$[b]	50 mSv[c] in the first 7 days	-	-	-	-
$\boldsymbol{E}$[d]	100 mSv in the first 7 days	100 mSv in the first year	100 mSv in a month	10 mSv in the first year	20 mSv per year
$\boldsymbol{H}_{\mathbf{fetus}}$[e]	100 mSv in the first 7 days	100 mSv for the full period of in-utero development	100 mSv for the full period of in-utero development	10 mSv for the full period of in-utero development	20 mSv for the full period of in-utero development

[a] The doses from ingestion of food, milk and drinking water or use of other commodities, vehicles equipment and other items are considered.

[b] The equivalent dose to the thyroid ($H_{thyroid}$) only due to exposure to radioiodine.

[c] This generic criterion applies only for administration of iodine thyroid blocking if exposure due to radioactive iodine is involved.

[d] Effective dose.

[e] H_{fetus} is the equivalent dose to the embryo or fetus, derived as the sum of the dose from external exposure and the maximum committed equivalent dose to any organ of the embryo or fetus from intake to the embryo or fetus for different chemical compounds and different times relative to conception.

[7] More detailed guidance is provided in EPR-Medical 2024 [38]

Generic criteria for food, milk, and drinking water and other commodities

2.25. Suggested values of Generic criteria, for food, milk and drinking water and other commodities to reduce the risk of stochastic effects have been established, in terms of projected dose, in table II.3 of GSR Part 7 [1]. The values were chosen as 1/10 of the values of the generic criteria given in table II.2 of GSR Part 7 [1] for early protective actions and other response actions. This is to ensure that the dose via all exposure pathways, including ingestion, will generally not exceed the generic criteria given for early protective actions and other response actions. The application of these criteria for taking actions on food, milk and drinking water is supported by the sampling and analysis of food, milk and drinking water. This sampling and analysis would also provide a basis for discontinuing restrictions imposed on food, milk and drinking water.

Generic criteria for vehicles, equipment, and other commodities

2.26. Generic criteria for vehicles, equipment and other items to reduce the risk of stochastic effects are established, in terms of projected dose, in table II.4 of GSR Part 7 [1]. The values were chosen as 1/10 of the values of the generic criteria given in table II.2 of GSR Part 7 [1] for early protective actions and other response actions. This is to ensure that the dose via all exposure pathways, including the use of such vehicles, equipment and other items, will not generally exceed the generic criteria given for early protective actions and other response actions. If restrictions of using vehicles, equipment and other items are necessary, they are applied for non-essential use. For essential use, such restrictions are applied as long as replacements are available.

Generic criteria for food and other commodities traded internationally

2.27. With regard to the mitigation of the impacts on international trade of a nuclear or radiological emergency and associated protective actions and other response actions, para. 5.91 of GSR Part 7 [1] states:

> "Arrangements shall be made to mitigate the impacts on international trade of a nuclear or radiological emergency and associated protective actions and other response actions, with account taken of the generic criteria in Appendix II [of GSR Part 7]. These arrangements shall provide for issuing information to the public and interested parties (such as importing States) on controls put in place in relation to traded commodities, including food, and on vehicles and cargoes being shipped, and on any revisions of the relevant national criteria."

2.28. With regard to food traded internationally, para. II.12 of GSR Part 7 [1] states [citation omitted]:

> "The generic criteria for food traded internationally derive from the level used by the Joint FAO/WHO Codex Alimentarius Commission. These generic criteria, and generic criteria for other commodities traded internationally that could contain radionuclides following a nuclear or radiological emergency, are established at 1/100 of the generic criteria given in Table II.2 [of GSR Part 7] for early protective actions and other response actions to ensure that doses to the public would be a small fraction of those for which actions are warranted to reduce the risk of stochastic effects."

2.29. The generic criteria for food and other commodities traded internationally and the examples of the other response actions that should be taken in case those generic criteria are exceeded are given in table II.5 of GSR Part 7 [1], and the relevant criteria are reproduced in Table 3 of this Safety Guide.

TABLE 3. GENERIC CRITERIA FOR TAKING RESTRICTIONS ON THE INTERNATIONAL TRADE OF FOODSTUFF AND OTHER COMMODITIES

Basis for taking restrictions on the international trade of:	Food, milk and drinking water, and other commodities
Generic criteria for the projected dose	
E[a]	1 mSv in the first year
H_{fetus}[b]	1 mSv for the full period of in-utero development

[a] Effective dose.

[b] H_{fetus} is the equivalent dose to the embryo or fetus, derived as the sum of the dose from external exposure and the maximum committed equivalent dose to any organ of the embryo or fetus from intake to the embryo or fetus for different chemical compounds and different times relative to conception.

Generic criteria for enabling the transition to an existing exposure situation

2.30. With regard to the termination of a nuclear or radiological emergency, para. 5.100 of GSR Part 7 [1] states:

> "The government shall ensure that, as part of its emergency preparedness, arrangements are in place for the termination of a nuclear or radiological emergency. The arrangements shall take into account that the termination of an emergency might be at different times in different geographical areas. The planning process shall include as appropriate: … (d) Conditions, criteria and objectives to be met for enabling the termination of a nuclear or radiological emergency".

2.31. The suggested values of generic criteria for enabling the transition to an existing exposure situation are established as 1/5 of the values of the generic criteria given in table II.2 of GSR Part 7 [1] for early protective actions and other response actions, considering the lower bound of the reference level for emergency exposure situations which is also consistent with the reference level for existing exposure situations (see paras 1.26 and 1.27 of GSR Part 3 [2]).

Need for operational criteria for a nuclear or radiological emergency

2.32. The generic criteria defined in terms of projected dose and dose that has been received are not measured in practice and cannot be used directly to implement response actions in an emergency. At the preparedness stage, there is a need to establish operational criteria (values of measurable quantities or observables and indicators) as a surrogate for the generic criteria for the implementation of protective actions and other response actions, as illustrated in Fig. 2. Operational criteria used in an emergency include operational intervention levels (OILs. For detail see Appendix I), emergency action levels (EALs. For detail see Appendix II), observables (e.g. increased dose rates, package damage) and indicators (e.g. labels, placards, UN marking) on the site (DS504 [10]). The operational criteria can be used immediately and directly to determine the need for appropriate protective actions and other response actions.

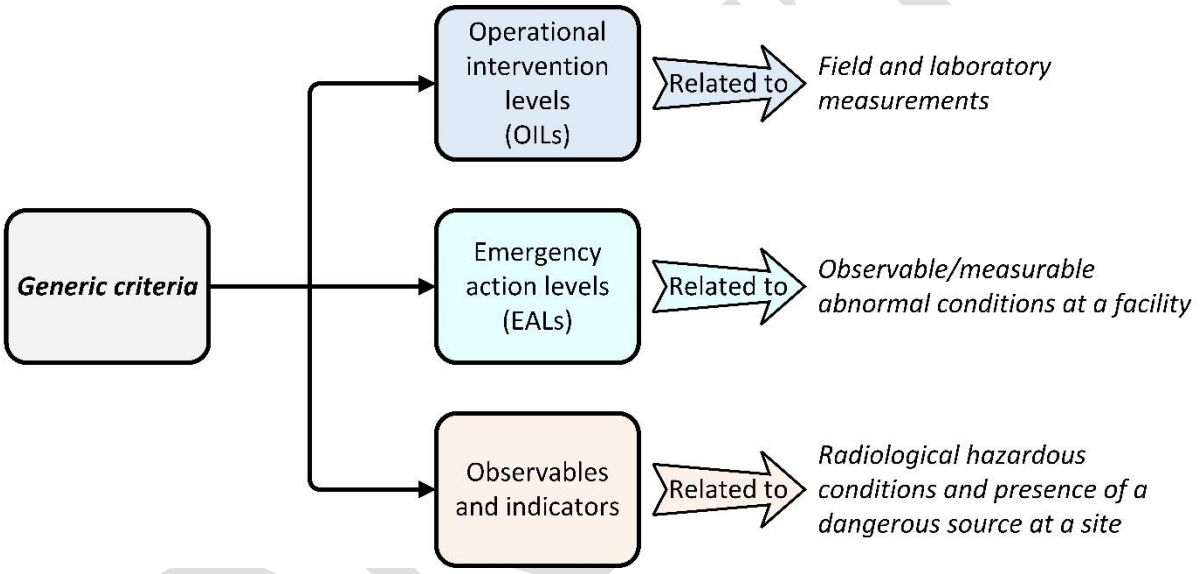


FIG. 2. The relation between the generic criteria and operational criteria.

RISK OF SEVERE DETERMINISTIC EFFECTS AS A BASIS FOR OPERATIONAL CRITERIA FOR A NUCLEAR OR RADIOLOGICAL EMERGENCY

2.33. The risk associated with a radioactive release or an exposure that could result in severe deterministic effects is the basis for the operational criteria for decision makers to take urgent protective actions under any circumstances to protect the public, emergency workers and helpers in an emergency by keeping doses below those approaching the generic criteria(*) set out.

2.34. The generic criteria to avoid or minimize severe deterministic effects(*) should be used as the dosimetric criteria [3] to assist in determining the EALs[8] (see para. 4.28(4) of GSR Part 7 [2]). They should also be used to help determine the size of the precautionary action zone[9] (PAZ) around facilities in EPC I (see para. 5.38 (a) (i) of GSR Part 7 [1]).

2.35. The generic criteria in to avoid or minimize severe deterministic effects(*) are used in defining radioactive sources that are considered dangerous [10] [17]. The indicators of the presence of dangerous sources and the observable conditions at the site of emergencies occurring in relation to activities and acts in EPC IV are the operational criteria used in implementing urgent protective actions to avoid or to minimize severe deterministic effects.

2.36. The generic criteria to avoid or minimize severe deterministic effects(*) should be taken into account in determining the guidance values for restricting the exposure of emergency workers (see Section 3).

PROJECTED DOSE AS A BASIS FOR OPERATIONAL CRITERIA FOR A NUCLEAR OR RADIOLOGICAL EMERGENCY

2.37. The projected dose is the basis for operational criteria for decision makers to take actions that meet the following three objectives:

(a) To avoid or minimize severe deterministic effects by keeping the doses below the generic criteria(*) at which urgent protective actions are warranted under any circumstances;

(b) To take effective protective actions and other response actions to reasonably reduce the risk of stochastic effects by keeping the doses below the generic criteria (**);

(c) To ensure the safety of emergency workers in the tasks being undertaken through the use of the guidance values (***)(see Section 3).

2.38. The potential for projected doses to exceed the generic criteria(*, **) in a nuclear or radiological emergency should be taken into account in determining OILs[10] at the preparedness stage (See [5]).

* suggestions of numerical values for generic criteria are provided in Table 1(same on the next page).

[8] An emergency action level (EAL) is a specific, predetermined criterion for observable conditions used to detect, recognize and determine the emergency class [15].

[9] In contrast, the generic criteria for urgent protective actions and other response actions in Table 2 are used in determining the size of the urgent protective action planning zone [3].

** suggestions of numerical values for generic criteria are provided in Table 2.

*** suggestions of numerical values for generic criteria are provided in Table 4.

[10] OILs are operational criteria that allow the prompt implementation of protective actions and other response actions on the basis of radiation monitoring or analysis results (see para. 4.5).

2.39. When assessing projected doses for the derivation of operational criteria, the members of the public that are likely to receive the highest doses should be considered. For this purpose, the dose to the representative person[11] should be estimated.

DOSE THAT HAS BEEN RECEIVED AS A BASIS FOR OPERATIONAL CRITERIA FOR A NUCLEAR OR RADIOLOGICAL EMERGENCY

2.40. The dose that has been received is the basis for operational criteria to support the following actions:

(a) To provide medical care, as necessary, when the dose received exceeds the generic criteria for actions to avoid or minimize severe deterministic effects (*);

(b) To consider the need for medical follow-up for early detection and effective treatment of radiation induced cancers if the dose received exceeds the generic criteria for actions to reduce the risk of stochastic effects(**);

(c) To provide counselling to those exposed, including pregnant women, so that they can make informed decisions concerning the further course of their treatment if the dose received exceeds the generic criteria for actions to avoid or minimize severe deterministic effects or actions to reduce the risk of stochastic effects(*, **);

(d) To provide a basis for placing the health hazard in perspective when communicating with affected individuals.

2.41. The dose that has been received supports decisions for urgent and longer term medical actions (see Requirement 12 of GSR Part 7 [1]). Examples of urgent actions are medical triage at the site of an emergency and specialized treatment in a hospital shortly after exposure to radiation or contamination. These actions are initiated and performed on the basis of medical symptoms and observations. However, in the performance of medical triage at the site, observables, indicators and radiation survey data should be taken into account when they become available. Decisions on the implementation of medical actions in the hospital (e.g. the extent of exposed tissue to be excised during surgical treatment for local radiation injury and the efficiency of decorporation for internal contamination (Ref. [7]) are strongly dependant on the supporting dosimetric information. Long term medical follow-up[12] of exposed persons should start early during the response and continue for an extended period of time.

[11] The representative person is an individual receiving a dose that is representative of the doses to the more highly exposed individuals in the population [15] . ICRP Publication 101 [28] indicates that the dose to the representative person is the equivalent of, and replaces, the mean dose in the 'critical group'.

[12] There are different reasons to perform long term medical follow-up of the persons affected, such as to provide advanced medical care, to reduce their concern with regard to their health status and to advance scientific knowledge. The reason for follow-up studies has to be carefully explained to those involved.

2.42. Medical records made during an emergency (especially on the site) should be focused on clinical symptoms and other observations, without including assumptions of causal association with radiation exposure[13].

2.43. Registration and long term medical follow up should be provided to detect and treat late deterministic effects[14], as well as radiation induced cancers. Long term medical follow-up should be justified based on the following:

(a) Long term medical follow-up is always justified when the received dose exceeds the generic criteria in Table 1.

(b) Justification of long term medical follow-up at levels of dose below the generic criteria in Table 1 involves the identification of populations at higher risk of developing radiation induced cancers, considering the generic criteria for longer term medical actions given in Table 2. Medical follow-up should always result in more benefit than harm in terms of public health. One reason for establishing a registry and providing medical follow-up is for the early detection of disease[15]. The level of exposure of radiosensitive organs expressed in equivalent dose and the possibility of detecting cancer among the exposed population should be taken into account when establishing the registry.

3. GUIDANCE VALUES FOR RESTRICTING THE EXPOSURE OF EMERGENCY WORKERS AND HELPERS IN AN EMERGENCY

3.1. Paragraph 5.54 of GSR Part 7 [2] requires that the relevant requirements for occupational exposure in planned exposure situations established in GAR Part 3 [3] are applied, on the basis of a graded approach, for emergency workers. Paragraph 5.55 of GSR Part 7 [2] requires that the operating organization and response organizations shall ensure that no emergency worker[16] is subject to an exposure in an emergency that could give rise to an effective dose in excess of 50 mSv other than:

(a) Actions to save human life or prevent serious injury;

[13] Such assumptions might lead to anxiety and unjustified medical examination. Determining the cause of the symptoms requires analysis by experts.

[14] They are also referred to as 'late tissue reaction' and might occur within months to years (e.g. cataract and circulatory disease) after irradiation [8, 36].

[15] It is assumed that early diagnosis of cancer will result in more efficient treatment and hence in reduced morbidity and mortality. Thyroid cancer screening following emergencies involving the release of radioactive isotopes of iodine has proved very effective for earlier diagnosis and treatment of children exposed following the Chernobyl accident [31].

[16] Emergency worker is a person having specified duties as a worker in response to an emergency. This may include workers employed, both directly and indirectly, by registrants and licensees, as well as personnel of response organizations, such as police officers, firefighters, medical personnel, and drivers and crews of vehicles used for evacuation. Emergency workers may or may not be designated as such in advance of an emergency. Emergency workers not designated as such in advance of an emergency are not necessarily workers prior to the emergency [15].

(b) Actions to prevent severe deterministic effects or prevent the development of catastrophic conditions that could significantly affect people and the environment; or

(c) Actions to avert a large collective dose.

The above actions would likely be carried out while there is still a lack of information about the radiological situation in which the action is to be performed, and the uncertainties are large. Because of the urgency associated with those actions and their importance, detailed planning of the work of emergency workers might not be possible, and the human and equipment resources might not be fully in place[17]. Therefore, doses to emergency workers exceeding an effective dose of 50 mSv can be justified to ensure the net benefit of the overall response efforts. Paragraph 5.56 of GSR Part 7 [1] requires that national guidance values are established for restricting the exposures of emergency workers performing such tasks, with account taken of the guidance values given in appendix I of GSR Part 7 [1].

3.2. Table I.1 of GSR Part 7 [1] provides guidance values for restricting exposure of emergency workers, and is reproduced with additional guidance in Table 4 of this Safety Guide. Dose restrictions to be applied for helpers in an emergency[18] are provided in para 5.57 of GSR Part 7 [2] and also given in Table 4.

3.3. Paragraph 4.122 of GSG-11 [12] states:

> "Actions to avert a large collective dose may extend through the early response phase and into the transition phase of an emergency because of the range of activities that are warranted to allow the timely resumption of social and economic activity. During the transition phase, knowledge and understanding of the situation where the work needs to be carried out increases, and there is no need to take urgent decisions on the deployment of workers. Thus, any work in the transition phase should be undertaken only after detailed planning. As a result, the protection of emergency workers in the transition phase should be applied stringently, in accordance with the requirements for occupational radiation protection for planned exposure situations, including the application of dose limits for occupational exposure".

TABLE 4[19]. DOSE RESTRICTIONS FOR EMERGENCY WORKERS AND HELPERS

Task	**Guidance value[a]**		
	$H_p(10)$[b]	E[c]	AD_T[d]

[17] Therefore, the relative requirements of GSR Part 3 (including Requirements 12, 20, 21 and 25) might not be met.

[18] A helper in an emergency is a member of the public who willingly and voluntarily helps in the response to a nuclear or radiological emergency. Helpers in an emergency are protected and are aware that they could be exposed to radiation while helping in response to a nuclear or radiological emergency [2].

[19] The doses in this table are not applicable during the transition phase [13].

Emergency workers			
Lifesaving actions	<500 mSv	<500 mSv	$<\frac{1}{2}AD_{T,\ Table\ 1}$[e]
	This value may be exceeded — with due consideration of the generic criteria in Table 1 — under circumstances in which the expected benefits to others clearly outweigh the emergency worker's own health risks, and the emergency worker volunteers to take the action and understands and accepts these health risks.		
Actions to prevent severe deterministic effects and actions to prevent the development of catastrophic conditions that could significantly affect people and the environment	<500 mSv	<500 mSv	$<\frac{1}{2}AD_{T,\ Table\ 1}$[e]
Actions to avert a large collective dose, such as: - Actions to keep the affected facility or source stable - Monitoring (environmental, source, individual)	<100 mSv	<100 mSv	$<\frac{1}{10}AD_{T,\ Table\ 1}$[e]
Other activities, such as: - Remedial actions including decontamination on the site and off the site - Repair of the affected facility and restoration of the relevant essential infrastructure - Management of radioactive waste and conventional waste - Environmental, source and individual monitoring - Medical management of contaminated patients - Implementation of corrective actions	Dose limits for occupational exposure in planned exposure situations established in Schedule III of GSR Part 3 [2]		
Helpers			
Specified activities in the national arrangements, such as:	$\boldsymbol{E}$[c]		
- Restoring essential infrastructure (e.g. roads, public transport networks) - Management of conventional waste	≤50 mSv		

[a] These values are set to be two to ten times lower than the generic criteria in Table 1 and they apply to:

(a) The dose from external exposure to strongly penetrating radiation for $H_p(10)$. Doses from external exposure to weakly penetrating radiation and from intake or skin contamination should be prevented by all possible means. If prevention is not feasible, the effective dose and the RBE weighted absorbed dose to a tissue or organ have to be limited to minimize the health risk to the individual in line with the risk associated with the guidance values given here.

(b) The total effective dose and the RBE weighted absorbed dose to a tissue or organ via all exposure pathways (i.e. dose from external exposure and committed dose from intakes), which are to be estimated as early as possible to enable any further exposure to be restricted as appropriate.

[b] Personal dose equivalent $H_p(d)$, where d = 10 mm.

[c] Effective dose.

[d] RBE weighted absorbed dose to a tissue or organ.

[e] The generic criteria in terms of RBE weighted absorbed dose to a tissue or organ are given in Table 1.

3.4. Paragraph 5.57 of GSR Part 7 [1] states:

"The operating organization and response organizations shall ensure that emergency workers who undertake emergency response actions in which doses received might exceed an effective dose of 50 mSv do so voluntarily[30]; that they have been clearly and comprehensively informed in advance of associated health risks as well as of available

protective measures; and that they are, to the extent possible, trained in the actions that they might be required to take. Emergency workers not designated as such in advance shall not be the first emergency workers chosen for taking actions that could result in their doses exceeding the guidance values of dose for lifesaving actions, as given in Appendix I. Helpers in an emergency shall not be allowed to take actions that could result in their receiving doses in excess of an effective dose of 50 mSv."

"[30] The voluntary basis for response actions by emergency workers is usually covered in the emergency arrangements."

3.5. Paragraph I.4 of GSR Part 7 [1] states:

"Severe deterministic effects to a fetus could possibly occur following an equivalent dose to the fetus of greater than 100 mSv. Consequently, in the response to a nuclear or radiological emergency, female workers who are aware that they are pregnant or who might be pregnant need to be (1) informed of this risk and (2) excluded from taking actions that might result in an equivalent dose to the embryo and fetus exceeding 50 mSv for the full period of in utero development of the embryo and fetus."

This includes female workers who might reasonably expect to be pregnant.

In the preparedness phase, all female staffs designated as emergency workers should be offered to be informed on the risks associated with radiological exposure during pregnancy.

3.6. Paragraph 4.19 of GSG-7 [18] states:

"emergency workers can be…divided into three categories:

(a) Category 1. Emergency workers undertaking mitigatory actions and urgent protective actions on the site, including lifesaving actions, actions to prevent serious injury, actions to prevent the development of catastrophic conditions that could significantly affect people and the environment, actions to prevent serious deterministic effects and actions to avert a large collective dose… They are likely to be operating personnel at the facility or undertaking the activity, but they may be personnel from the emergency services… They should receive training in occupational radiation protection."

(b) Category 2. Emergency workers undertaking urgent protective actions off the site (e.g. evacuation, sheltering and radiation monitoring) to avert a large collective dose. They are most likely to be police, firefighters, medical personnel, and drivers and crews of evacuation vehicles. Every effort should be made to designate emergency workers in Category 2 as such at preparedness stage. They are to have pre-specified duties in an emergency response and should receive training in

occupational radiation protection on a regular basis as first responders. They are not normally considered to be occupationally exposed to radiation, and their employers are response organizations.

(c) Category 3. Emergency workers undertaking early protective actions and other response actions off the site (e.g. relocation, decontamination and environmental monitoring) as well as other actions aimed at enabling the termination of the emergency. Emergency workers in Category 3 may or may not be designated as such at the preparedness stage. They may or may not normally be considered to be occupationally exposed to radiation, and they may or may not have received any relevant training, including training in radiation protection."

Emergency workers in Category 1 are required to be designated as such at the preparedness stage and Category 2 emergency workers are not the first choice for taking lifesaving actions (see para. 5.57 of GSR Part 7 [1]). Category 3 emergency workers should carry out those actions in which they will not receive a dose exceeding limits for occupational exposure in planned exposure situations established in Schedule III of GSR Part 3 [3][20].

3.7. Emergency workers and helpers in an emergency are required to be given medical attention appropriate for the dose they may have received or at their request (see para. 5.59 and Appendix II of GSR Part 7 [1]). The doses received and information on any consequent health risks are required to be communicated to such workers and helpers (see para. 5.61 of GSR Part 7 [1]).

4. OPERATIONAL CRITERIA FOR A NUCLEAR OR RADIOLOGICAL EMERGENCY

4.1. Operational criteria used in an emergency should include EALs, observables and indicators on the site, and OILs (see para.2.32).

EALS

4.2. EALs are specific criteria for observable or measurable abnormal conditions at a facility (in EPC I, II or III), which are used to detect and recognize an emergency and determine the emergency class. These criteria are required to be pre-established (see para. 4.28 (4) of GSR Part 7 [1]), and should then be implemented as recommended in DS504 [10]. Appendix II of this Safety Guide provides recommendations on the development and use of EALs and the

[20] The three categories of emergency workers likely require different types of profiles. However, it might be envisaged that emergency workers help in more than one category (as long as their overall exposure does not exceed limits for occupational exposure in planned exposure situations), especially in case of shortage of emergency workers.

conditions to be considered in the development of EALs for the classification of emergencies at a light water reactor (LWR) nuclear power plant[21].

OBSERVABLES AND INDICATORS

4.3. Predefined indicators or observables are among the operational criteria that should be used for recognizing the nature and severity of the conditions at a site and implementing urgent protective actions in an emergency occurring in acts and activities in EPC IV.

4.4. DS504 [10] provides recommendations on the radius of the inner cordoned off area in which urgent protective actions should initially be taken on the basis of the indicators and observables identified by responders upon their arrival at the site. The size of the cordoned off area may be expanded on the basis of the relevant monitoring results and OILs (see Appendix I of this Safety Guide). Reference [19] provides a list of observables and indicators that can be used by responders to identify a dangerous source, together with the actions to be taken to protect responders and the public. Those observables and indicators are reproduced in Appendix III of this Safety Guide. Ref. [17] provides guidance on the activity of a radionuclide that, if not controlled, should be considered to constitute a dangerous source.

OILS

4.5. OILs are operational criteria intended to facilitate the prompt implementation of protective actions and other response actions on the basis of radiation monitoring or analysis results that are readily available during a nuclear or radiological emergency. If the OILs are exceeded, the appropriate protective actions and other response actions should be promptly[22] taken, unless it is assessed that they might cause more harm than good. The set of the pre-established set of OILs should include OILs for determining whether an individual should be referred for detailed dose assessment to determine if long term medical follow-up and treatment are warranted.[23]

4.6. The OILs given in this Safety Guide are expressed in terms of dose rates, count rates or activity concentration of radionuclides. The quantities to be compared with the OILs can be measured by means of instruments in the field or can be determined by means of laboratory analysis or assessment.

[21] The examples are given for commercially available pressurized water reactors and boiling water reactors, not small modular reactors.

[22] During the transport of radioactive material, dose rates measurements around a package might exceed the numerical values for OIL1 or OIL2, even in routine conditions. As mentioned in para. 2.41 of SSG-65[15] "OILs can only be used in conjunction with observables and indicators to initiate an emergency response. Exceeding an OIL should not be used as the sole basis for initiating an emergency response."

[23] Emergencies have occurred for which no criteria for long term medical follow-up and treatment had been pre-established. Criteria established after the occurrence of emergencies were often set unduly low as the level of doses received or were not set on the basis of radiation dose criteria at all. This led to the designation of groups for follow-up for which it would have been impossible, because of the inherent limitations of epidemiological studies, to detect any increase in the incidence of cancers, owing to the relatively small number of cases of radiation induced cancer to be expected.

4.7. OILs for dose rates or air concentrations in a plume resulting from an ongoing release are not provided because the example criteria are intended to be very general and practical. They are not included because: (a) in many cases the significant release will be over by the time results of environmental measurements are available; (b) it is difficult to take and analyse air concentrations in a sample in a timely manner; (c) there is a great variation in time and location of the plume concentrations at any location during a release; and (d) OILs of these types are highly dependent on the nature of the release, which makes it very difficult to develop OILs that apply to the full range of possible releases. During the period of significant release, therefore, protective actions (e.g. evacuation or sheltering, to a predetermined distance) are best taken on the basis of observable criteria. Operating organizations of facilities at which there could be emergencies that result in airborne releases of long duration should develop EALs and possibly facility specific OILs for measurements taken in a plume, for possible airborne releases from the facilities. Examples of OILs for dose rates in a release from a light water reactor resulting from core melt are provided in Ref. [31]. Additionally, OILs for air concentrations arising from resuspension are not provided because doses arising from resuspension have been considered in the deposition OILs.

4.8. Paragraph 4.28(4) of GSR Part 7 [2] requires that "arrangements shall be established to revise the default OILs in the course of an emergency, with account taken of the prevailing conditions as they evolve". A methodology and processes for the recalculation of OIL values during the emergency response phase to address the prevailing conditions should be an integral part of the protection strategies.

4.9. In revising default OIL values during an emergency, it should be ensured that the situation is well understood and that there are compelling reasons for the revision. The public and other interested parties should be informed of the reasons for any change in the OILs applied in an actual emergency.

4.10. Suggestions of OILs for use in nuclear emergencies involving a significant release of radioactive material from an LWR or its spent fuel, as well as in radiological emergencies, and the methodology suggested for their derivation are provided in Refs [4, 6].

4.11. OILs should also be used to support decision making on the decorporation of radionuclides from internally contaminated individuals. The suggested methodology for calculating OILs for in vivo and in vitro bioassay is provided in Ref. [7].

4.12. Paras 4.66, 4.75, 4.80–4.82, 4.84–4.88, 4.90 and 4.93, and the appendix of GSG-11 [12] provide recommendations and guidance on the use of OILs to support the decision making on lifting or adapting protective actions, and implementing activities that help reduce the residual dose during the transition from an emergency exposure situation to an existing exposure situation.

APPENDIX I. OPERATIONAL INTERVENTION LEVELS FOR A NUCLEAR OR RADIOLOGICAL EMERGENCY

I.1. In this appendix, examples of OILs for use to help determine protective actions and other response actions in responding to a nuclear or radiological emergency that results in contamination[24] are provided. Considerations in the derivation and revision of OILs, recommendations on their use in different groups of emergency scenario, and plain language explanations are provided. The following example default OILs are considered:

(a) OIL1 is a set level of a measurable quantity (ambient dose equivalent rate or count rate) representing ground contamination calling for urgent protective actions (e.g. evacuation) and other response actions to keep the effective dose to any person living in a contaminated area and the equivalent dose to the fetus below the generic criteria for urgent protective actions provided in Table 2.

(b) OIL2 is a set level of a measurable quantity representing ground contamination calling for early protective actions (e.g. relocation) and other response actions to keep the effective dose to any person living in a contaminated area and the equivalent dose to the fetus below the generic criteria for early protective actions provided in Table 2.

(c) OIL3 is a set level of a measurable quantity representing ground contamination calling for immediate restrictions on the consumption of local produce[25], including milk from animals grazing in the area and rainwater collected for drinking that might have been contaminated[26] to keep the effective dose to any person consuming those and the equivalent dose to the fetus below the generic criteria for taking response actions to reduce the risk of stochastic effects due to the ingestion of food, milk or drinking water provided in Table 2. When OIL3 is exceeded, the response actions warranted in a general emergency, if not already implemented based on the declaration of emergency, should be implemented regardless of the distance from the facility. As such, the distribution of commodities that may have been contaminated should also be restricted until they have been assessed.

(d) OIL4 is a set level of a measurable quantity representing skin contamination calling for performing decontamination or providing instructions for self-decontamination and for limiting inadvertent ingestion so as to achieve the following:

[24] The use of OIL1 and OIL2 for exposures from non-dispersed radioactive sources is also addressed in Table 5.

[25] Local produce is food produce in the vicinity of the source of a radioactive release that could already be, or soon become contaminated (either directly or indirectly). Therefore, OIL3 gives a very early indication of where food production in this locality needs to be restricted to prevent contaminated food from entering into the food supply.).

[26] When OIL3 is exceeded, the response actions warranted in a general emergency, if not already implemented based on the declaration of emergency, should be implemented regardless of the distance from the facility. Therefore, the distribution of commodities that may have been contaminated should also be restricted until they have been assessed.

— To keep the RBE weighted absorbed dose to 100 cm^2 of the skin dermis below the generic criterion given in Table 1;

— To keep the total effective dose to the contaminated person, and if that person is pregnant, to the fetus, below the generic criteria for urgent protective actions provided in Table 2.

Contamination levels exceeding OIL4 warrant medical screening, because the dose received by the contaminated person (and, where appropriate the fetus) might exceed the generic criteria for medical actions provided in Table 2. If the presence of radioiodine is suspected, iodine thyroid blocking (ITB) agents should be taken (if not already taken) to reduce further intake of radioiodine.

(e) OIL5 and OIL6 are set levels of concentrations in food, milk or drinking water that warrant the consideration of restrictions to prevent their consumption so as to keep the effective dose to any person consuming those and the equivalent dose to the fetus below the generic criteria for taking response actions to reduce the risk of stochastic effects due to ingestion of food, milk or drinking water provided in Table 2.

(f) OIL7[27] are set levels of activity concentrations of the marker radionuclides[28], I-131 and Cs-137, in food, milk or drinking water that warrant the consideration of restrictions to prevent their consumption in the case of a release of radioactive material from an LWR or its spent fuel[29]. OIL7 is used to keep the effective dose to any person and the equivalent dose to the fetus below the generic criteria for taking response actions to reduce the risk of stochastic effects due to the ingestion of food, milk or drinking water provided in Table 2.

(g) OIL8 is a set level of a measurable quantity (ambient dose equivalent rate) representing the activity of radioiodine deposited in the thyroid as a result of inhalation or ingestion. Monitoring results exceeding OIL8 warrant medical screening and taking iodine thyroid blocking (ITB) agents[30] (if not already taken) to reduce further uptake of radioiodine because the committed equivalent dose to the thyroid can result in exceeding the generic

[27] The use of OIL7 during an emergency occurring at a LWR or its spent fuel nuclear emergency is preferable over the use of OIL5 and OIL6 because of the limited availability of time and resources early in an emergency. Once sufficient resources and time become available, OIL5 and OIL6 may be used, if considered necessary and justified, keeping in mind that the default OIL5 and OIL6 values (a) are applicable to any type of nuclear or radiological emergency; (b) are more conservative than OIL7; and (c) require determining the activity concentrations of all radionuclides present in food, milk and drinking water.

[28] A marker radionuclide is easy to identify and is representative of all other radionuclides present, avoiding the need for costly and time intensive comprehensive isotopic analyses.

[29] Only spent fuel that is sufficiently heated (either by its own residual heat or another heat source) to reach zirconium ignition temperatures is expected to result in a significant release of radioactive material warranting response actions. This is typically spent fuel in the spent fuel pool of a nuclear power plant.

[30] It is still reasonable to administer ITB up to eight hours after the estimated onset of exposure. Commencing ITB later than 24 hours following the exposure might do more harm than benefit (by prolonging the biological half-life of radioactive iodine that has already accumulated in the thyroid) [29].

criteria for the equivalent dose to the fetus[31] warranting medical follow-up given in Table 2.

(h) OIL_C is a set level of a measurable quantity representing surface contamination on commodities other than food, milk and drinking water that warrant the consideration of restrictions on their use so as to keep the effective dose to any person using those and the equivalent dose to the fetus below the generic criteria for taking response actions to reduce the risk of stochastic effects due to use of such commodities provided in Table 2.

(i) OIL_V is a set level of measurable quantity representing the contamination on the surfaces of vehicles (interior surfaces are also to be monitored for vehicles), equipment and items from an area affected by a nuclear or radiological emergency that warrants the consideration of restrictions on their use by members of the public so as to keep the effective dose to any person using those and the equivalent dose to the fetus below the generic criteria for taking response actions to reduce the risk of stochastic effects due to use of such vehicles, equipment and items provided in Table 2.

(j) OIL_{IntTrd} is a set level of measurable quantity representing contamination in food, milk and drinking water, and surface contamination on other commodities that warrant the consideration of restrictions on their trade so as to keep the effective dose to any person using those and the equivalent dose to the fetus below the generic criteria for taking restrictions on the international trade of foodstuff and other commodities provided in Table 3.

CONSIDERATIONS IN THE DERIVATION OF OPERATIONAL INTERVENTION LEVELS

I.2. The following should be taken into consideration for the derivation of OILs at the preparedness stage:

4.13. The relevant generic criteria: The generic criteria from which the OILs are to be derived should be selected from the appropriate national generic criteria. Numerical values for generic criteria are suggested in Tables 1–3.

(a) The radionuclides that might be present: The potential health effects from radiation exposure, the response of the monitoring instruments and the selection of marker radionuclides (in case they are needed) depend on the radionuclides present. Therefore, the OILs should be calculated considering all the radionuclides expected to be present in the medium of concern and which might be significant contributors to the dose to the public or the instrument response.

[31] As indicated in footnote c of Table 2, the generic criterion of 50 mSv committed equivalent dose to the thyroid is not considered because it is intended for implementation of ITB and not for the urgent identification of those that might need medical follow-up. The controlling organ dose to the fetus for intake of iodine is the thyroid [33]. The equivalent dose to the parent's thyroid is assumed to be approximately equal to the equivalent dose to the fetal thyroid, although the equivalent dose to the fetal thyroid could vary greatly depending on the stage of pregnancy at the time of exposure [35].

(b) The members of the public who are most vulnerable to radiation exposure: All members of the public should be considered in calculating the OILs for taking response actions based on the projected dose for the representative person and the fetus.

(c) The exposure scenarios[32] and associated exposure pathways: Different exposure scenarios resulting from the presence of radioactive material should be considered together with the related exposure pathways in the derivation of the OILs.

(d) The physical, chemical and biological properties of radionuclides affecting the radiation exposure of the individuals: Any behaviour of the radionuclides, such as the change in the activity of radionuclides due to decay and weathering, resuspension, or transfer from the ground to milk or food that could have a significant impact on the dose or the OILs needs to be considered.

(e) The dose coefficients used in the calculation of effective doses and the doses to the relevant organs and tissues: Dose coefficients relate the activity or activity concentration of a certain radionuclide with the projected dose, which is needed to determine if the generic criteria might be exceeded. The dose coefficients to be used in the calculations should be selected considering the radionuclides present, the relevant dose quantity, the exposure scenarios, the exposure pathways, and the exposed individual, organ or tissue.

(f) The response of instruments to be used: OILs are operational criteria intended to be used with monitoring and measurement results provided by instruments. The instrument response will affect the default OIL values and needs to be considered in the calculations.

(g) The time and radionuclide dependent OIL functions and selection of default OIL values: OIL values depend on the mixture of radionuclides (or a single radionuclide) of concern, whose concentrations will vary over time for mixtures (due to processes such as decay). Therefore, for each OIL a set of time and mixture dependent functions should be calculated, based on which a default OIL value is chosen. Default values should be selected for time and/or mixture dependent OILs because (a) the mix can vary considerably during an emergency with time and location [20, 21, 22]; and (b) not having a default criterion for the implementation of response actions has led to confusion of decision makers and scepticism among the public in past emergencies, delaying urgently required response actions [20, 23].

[32] An exposure scenario is a postulated set of conditions, circumstances, events and behaviour of the public that characterizes the exposure situation. It is the basis for determining the potentially exposed individuals, the relevant exposure pathways and the effectiveness of the response actions.

USE OF OPERATIONAL INTERVENTION LEVELS AND RELATED OPERATIONAL CRITERIA IN A NUCLEAR OR RADIOLOGICAL EMERGENCY

I.3. To describe the use of OILs, three types of emergency scenario for a nuclear or radiological emergency resulting in contamination are considered in this Safety Guide, as follows:

(1) A severe accident at a nuclear facility in EPC I or II, or at such a facility located in another State (i.e. EPC V within the emergency planning zones and emergency planning distances of the facility, or EPC IV beyond the emergency planning distances of the facility), that are characterized by extensive on-site and off-site radiological consequences (emergency class: general emergency);

(2) A nuclear or radiological emergency at a facility in EPC I, II or III, that is characterized by on-site radiological consequences within the site area or specific location within the facility) (emergency class: site area emergency or facility emergency);

(3) A radiological emergency associated with activities and acts in EPC IV, with on-site[33] consequences occurring at any location within the State (emergency class: other nuclear or radiological emergency).

I.4. The OILs to be used to initiate protective actions and other response actions in the three types of nuclear or radiological emergency described in para. I.3 are given in Table 5.

TABLE 5. OPERATIONAL INTERVENTION LEVELS AND RELATED OPERATIONAL CRITERIA TO INITIATE SPECIFIC PROTECTIVE ACTIONS AND OTHER RESPONSE ACTIONS IN NUCLEAR AND RADIOLOGICAL EMERGENCIES

OIL	**Default OIL value**	**Monitoring type**	**Protective actions to be initiated**	**Applicability in terms of the three types of emergency scenario described in para. I.3.**			
				(1)	**(2)-N[a]**	**(2)-R[b]**	**(3)**
OIL1	**1000 µSv/h[c]**	GROUND MONITORING Ambient dose equivalent rate at 1 m above ground level [5]	Evacuation and associated response actions (see para. I.6)	■			

[33] See footnote 3 on p. 3. The radiological consequences of emergencies in the third group are assumed to be limited to the inner cordoned off area and its vicinity.

OIL	Default OIL value	Monitoring type	Protective actions to be initiated	Applicability in terms of the three types of emergency scenario described in para. I.3.			
				(1)	(2)-N[a]	(2)-R[b]	(3)
	2000 cps	Beta count rate at 2 cm from the ground or surface [5]		[d]			
	50 cps[d]	Alpha count rate at 0.5 cm from the ground or surface [5]					
OIL2[e]	**100 µSv/h**[f]	GROUND MONITORING Ambient dose equivalent rate at 1 m above ground level [5]	Relocation and associated response actions (see para. I.7 for **1st$_{grp}$**) (see para. I.18 for **2nd$_{grp}$**) (see para. I.23 for **3rd$_{grp}$**)	■	■	■	■[g]
	200 cps	Beta count rate at 2 cm from the ground or surface [5]				■	■[g]
	10 cps	Alpha count rate at 0.5 cm from the ground or surface [5]					
OIL3	**1 µSv/h**	GROUND MONITORING Ambient dose equivalent rate at 1 m above ground level [5]	Restrictions on food, milk and drinking water and associated response actions (see para. I.8 for **1st$_{grp}$**) (see para. I.24 for **3rd$_{grp}$**)	■			■
	20 cps	Beta count rate at 2 cm from the ground or surface [5]					
	2 cps	Alpha count rate at 0.5 cm from the ground or surface [5]					■
OIL4	**1 µSv/h**	SKIN MONITORING Ambient dose equivalent rate at 10 cm from the body[h] [5]	Decontamination of individuals and associated response actions (see para. I.9 for **1st$_{grp}$**)	■	■	■	■

OIL	Default OIL value	Monitoring type	Protective actions to be initiated	Applicability in terms of the three types of emergency scenario described in para. I.3.			
				(1)	(2)-N[a]	(2)-R[b]	(3)
	1000 cps	Beta count rate at 2 cm from the body [5]	(see para. I.19 for **2nd$_{grp}$**) (see para. I.25 for **3rd$_{grp}$**)	■[i]	■[i]	■	■
	50 cps	Alpha count rate at 0.5 cm from the body[j] [5]				■	■
OIL5	**5 Bq/kg**	MONITORING OF FOOD, MILK AND DRINKING WATER SAMPLES Gross activity of alpha (α) emitting radionuclides in food, milk and drinking water samples	Restrictions on food, milk and drinking water and associated response actions (see para. I.26 for **3rd$_{grp}$**)	■[k]			■
	100 Bq/kg	Gross activity of beta (β) emitting radionuclides in food, milk and drinking water samples					
OIL6	see Table 7	MONITORING OF FOOD, MILK AND DRINKING WATER SAMPLES Radionuclide specific activity concentrations in food, milk and drinking water samples	Restrictions on food, milk and drinking water and associated response actions (see para. I.26 for **3rd$_{grp}$**)	■[k]			■
OIL7[k]	**1000 Bq/kg of I-131** and **200 Bq/kg of Cs-137**	MONITORING OF FOOD, MILK AND DRINKING WATER SAMPLES Activity concentration of I-131 and Cs-137 in food, milk and drinking water samples	Restrictions on food, milk and drinking water and associated response actions (see para. I.10 for **1st$_{grp}$**)	■			
OIL8	**0.5 µSv/h**	THYROID MONITORING	Registration, medical follow-up and	■	■	■[l]	■[l]

OIL	Default OIL value	Monitoring type	Protective actions to be initiated	Applicability in terms of the three types of emergency scenario described in para. I.3.			
				(1)	(2)-N[a]	(2)-R[b]	(3)
		Ambient dose equivalent rate in front of the thyroid in contact with the skin	associated response actions (see para. I.11 for **1st$_{grp}$**) (see para. I.20 for **2nd$_{grp}$**) (see para. I.27 for **3rd$_{grp}$**)				
OIL$_C$	see appendix of GSG-11 [12]	MONITORING OF NON-FOOD COMMODITIES Ambient dose equivalent rate at 10 cm from the surface – Radionuclide specific surface activity concentrations	Restrictions on commodities other than food, milk and drinking water and associated response actions (see para. I.12 for **1st$_{grp}$**) (see para. I.28 for **3rd$_{grp}$**)	■			■
OIL$_V$	See paras I.36 and I.40	MONITORING OF VEHICLES, EQUIPMENT AND OTHER ITEMS Ambient dose equivalent rate at 10 cm from the surface[m] – Radionuclide specific surface[j] activity concentrations	Restricting the use of vehicles, equipment and items from affected areas and associated response actions (see para. I.13 for **1st$_{grp}$**) (see para. I.21 for **2nd$_{grp}$**) (see para. I.29 for **3rd$_{grp}$**)	■	■	■	■
OIL$_{IntTrd}$	The 'guideline levels' given in Ref. [24] for food (**OIL$_{IntTrdF}$[n]**)	MONITORING OF FOOD TRADED INTERNATIONALLY Radionuclide specific activity concentrations in food commodities moving in international trade	Restrictions on foodstuff intended for international trade and associated response actions (see paras I.14 and I.16 for **1st$_{grp}$**) (see paras I.30 and I.16 for **3rd$_{grp}$**)	■			■
	OIL$_{IntTrdC}$[n]	MONITORING OF NON-FOOD COMMODITIES	Restrictions on nonfood commodities intended for international trade and				

OIL	Default OIL value	Monitoring type	Protective actions to be initiated	Applicability in terms of the three types of emergency scenario described in para. I.3.			
				(1)	(2)-N[a]	(2)-R[b]	(3)
	See paras I.38 and I.40	TRADED INTERNATIONALLY Ambient dose equivalent rate at 10 cm from the surface – Radionuclide specific surface activity concentrations	associated response actions (see paras I.15 and I.16 for **1^{st}_{grp}**) (see paras I.31 and I.16 for **3^{rd}_{grp}**)				

[a] Nuclear emergencies at LWRs or their spent fuel pools; Ambient-dose-rate OIL1, OIL2 and OIL3, and OIL7 values can be derived for reactors other than LWRs by following the method provided in Ref. [4].

[b] Radiological emergencies

[c] If a person has handled a source with a dose rate equal to or exceeding 1000 μSv/h at 1 m, he or she has to undergo an immediate medical examination. This external dose rate criterion applies only to sealed dangerous sources and does not need to be revised in an emergency.

[d] OIL1 values defined as count rates are used in emergencies occurring at EPC I facilities other than the ones including nuclear reactors or spent fuel.

[e] For emergencies involving a radioactive material release from a light water reactor, OIL2 is 100 μSv/h for the first 10 days after reactor shutdown (the time after the nuclear reaction in the core was stopped) and OIL2 is 25 μSv/h later than 10 days after reactor shutdown or for the spent fuel.

[f] If a person has handled a source with a dose rate equal to or exceeding 100 μSv/h at 1 m, he or she has to undergo a medical examination and evaluation; any pregnant women who have handled such a source has to receive immediate medical evaluation and dose assessment. This external dose rate criterion applies only to sealed dangerous sources and does not need to be revised in an emergency.

[g] The approximate initial the radius of the inner cordoned are (safety perimeter) in the radiological emergencies in group 3 is determined on the basis of the observables and indicators at the site of an emergency. The size of the area may be expanded on the basis of environmental monitoring and OIL2.

[h] In nuclear emergencies occurring at LWRs or their spent fuel pools, monitoring the bare skin of the hand and face is sufficient for the public. The whole body should be monitored if localized high levels of contamination are expected.

[i] The ambient dose equivalent rate OIL4γ is sufficient and preferable to assess the levels of radioactive material on the skin for a release of radioactive material from an LWR or its spent fuel because it is less dependent on the measurement technique and instrument characteristics.

[j] Alpha monitoring of normal clothing is very unreliable.

[k] See footnote 27 on p. 18.

[l] The thyroid is monitored if intake of radioiodine by individuals is suspected.

[m] Inner and outer surfaces of vehicles are monitored.

[n] 'F' and 'C' stand for 'food' and 'non-food commodities' respectively.

Responding to a general emergency at a nuclear facility

I.5. In this type of emergency, the initial response actions are required to be implemented within pre-established emergency planning zones based on the emergency classification system (see Requirement 9 of GSR Part 7 [1]) before data from off-site radiological monitoring

become available. Once off-site monitoring results become available, OILs should be used first for expanding, if needed, and later for adjusting the initial response actions.

I.6. Within a day after the start of a significant release from the facility, areas where ground deposition levels exceed or are likely to exceed OIL1, if any, should be identified, and the following urgent protective actions and other response actions should be taken if OIL1 is exceeded:

(a) Within the first day after the beginning of the exposure[34] [5]:

— The public should be instructed to safely evacuate (only if it does not endanger those being evacuated; for example, patients in hospitals or care homes do not need to be immediately evacuated if this puts them at risk), if possible, in combination with iodine thyroid blocking (only if it does not delay the evacuation);

— If immediate evacuation is not possible or safe (e.g. for special facilities or owing to snow, floods or lack of transport), the public should be instructed to shelter, preferably in large buildings, in combination with iodine thyroid blocking until the safe evacuation is possible;

— Registration, skin monitoring and thyroid monitoring (by using OIL4 and OIL8) should be provided for the evacuees. They should be instructed to shower and change clothing if it can be done safely (e.g. they should not change or shower in cold temperatures, should not shower without clean water). Skin and thyroid monitoring should not warrant delaying other urgent response actions.

(b) Within weeks after the beginning of the exposure[34] [5]:

— The dose from all exposure pathways should be estimated for those who were in the identified areas to determine if medical follow-up is warranted in accordance with GSR Part 7 [1] (the relevant generic criteria are reproduced in Table 2).

(c) The response actions indicated for OIL3 should also be implemented.

I.7. Within weeks[35] after the start of the significant release, areas where ground deposition levels exceed OIL2 should be identified, and the following early protective actions and other response actions should be taken:

(a) The individuals living in the identified areas should be registered and safely relocated.

[34] The use of radiation monitoring data from monitoring stations might help in determining the beginning of the exposure.

[35] Areas with dose rates within a factor of two of the OIL1 value should be identified and relocated within the first days. Areas where dose rate is greater than OIL2 should be identified and relocated within one month.

(b) The dose from all exposure pathways should be estimated for those who were in the identified areas to determine if medical follow-up is warranted in accordance with GSR Part 7 [1] (the relevant generic criteria are reproduced in Table 2).

(c) The response actions indicated for OIL3 should also be implemented.

I.8. Within days of the start of the significant release, the areas where ground deposition levels exceed OIL3 should be identified, and the following urgent protective actions and other response actions should be taken, if they have not already been implemented based on the declaration of a general emergency:

(a) The areas where food and water is affected should be identifies and delineated. Immediately after the identification of the area, the following should be implemented:

— The public should be provided with instructions to stop the consumption, distribution and sale of non-essential[36] local produce, wild-grown products, milk from grazing animals, directly collected rainwater, local animals (unless fed with protected feed), and animal feed, until the activity concentrations have been assessed using OIL7. If the restricted food, milk or drinking water are essential, they should be replaced with alternative supplies;

— The public should be provided with instructions to temporarily stop the distribution of other commodities that may have been contaminated until they have been assessed.

(b) Within weeks after the beginning of the exposure[34] [5]:, the following should be implemented:

— The dose from all exposure pathways for persons who may have consumed local produce, wild-grown products, milk from grazing animals, directly collected rainwater and local animals from the area where restrictions were implemented should be estimated to determine if medical follow-up is warranted in accordance with GSR Part 7 [1] (the relevant generic criteria are reproduced in Table 2).

I.9. Skin contamination monitoring should be implemented within the first few days after the start of the exposure[34] [5]:. All persons who undergo skin monitoring should be registered, and their monitoring results should be recorded. The following urgent protective actions and other response actions should be implemented for the individuals if their monitoring results exceed OIL4:

(a) Immediately following the monitoring:

[36] Footnote b of table II.3 of GSR Part 7 [1] states: "Restricting essential food, milk or drinking water could result in dehydration, severe malnutrition or other severe health impacts; therefore, essential food, milk and drinking water is to be restricted only if alternatives are available."

— Appropriate decontamination to prevent any additional inadvertent ingestion and medical screening should be provided;

— Thyroid monitoring should be performed after decontamination, and the results compared with OIL8 (see also para. I.11);

— Individuals should be instructed to take iodine blocking agents (if not already taken and only within the first days following the release of radioactive material) to reduce further uptake of radioiodine.

(b) Within weeks after the beginning of the exposure[34]:

— The dose from all exposure pathways should be estimated for those whose skin contamination monitoring results exceed OIL4 to determine if medical follow-up is warranted in accordance with GSR Part 7 [1] (the relevant generic criteria are reproduced in Table 2).

I.10. Within weeks of the start of the exposure[34], the activity concentrations of both marker radionuclides I-131 and Cs-137 in food, milk or drinking water samples should be analysed If the activity concentrations of the marker radionuclides exceed OIL7, the following actions should be taken:

(a) Within days after obtaining the results:

— The public should be provided with instructions to stop consumption, distribution and sale of the affected food, milk or drinking water (if these actions can be implemented safely). If the restricted food, milk or drinking water are essential, they should be replaced with alternative supplies.

(b) Within weeks after obtaining the results:

— The dose from all exposure pathways for those who may have consumed food, milk or drinking water with activity concentrations exceeding OIL7 should be estimated to determine if medical follow-up is warranted in accordance with GSR Part 7 [1] (the relevant generic criteria are reproduced in Table 2).

I.11. Thyroid monitoring should be performed within the first week after a possible intake of radioiodine. The individual should be decontaminated, including the removal of any potentially contaminated clothing, before the monitoring. All persons who undergo thyroid monitoring should be registered and their monitoring results should be recorded. The following urgent protective action and other response actions should be implemented for the individuals if their monitoring results exceed OIL8:

(a) Immediately following the monitoring:

— If the presence of radioiodine is suspected, the individuals should be instructed to take iodine thyroid blocking agents (if not already took) to reduce further uptake of radioiodine;

— Medical screening should be provided.

(b) Within weeks after the beginning of the exposure[34]:

— The dose from all exposure pathways should be estimated for those whose thyroid monitoring results exceed OIL8 to determine if medical follow-up is warranted.

I.12. Within weeks, contamination monitoring should be implemented on the surfaces of commodities other than food, milk and drinking water that might be affected. If monitoring results exceed OIL_C:

(a) Within days after obtaining the results:

— The public should be provided with instructions to stop the use, distribution and sale of the affected commodities. If the restricted commodities are essential, they should be replaced with alternative supplies.

(b) Within weeks after obtaining the results:

— The dose from all exposure pathways for those who may have used the contaminated commodities with monitoring results exceeding OIL_C should be estimated to determine if medical follow-up is warranted in accordance with GSR Part 7 [1] (the relevant generic criteria are reproduced in Table 2).

I.13. Contamination monitoring of vehicles, equipment and items used in emergency response should start on the first day and be repeated regularly during their use. If monitoring results exceed OIL_V:

(a) Following the monitoring:

— The operator of the vehicle or the user of the equipment or item should be provided with instructions to isolate the vehicle or the equipment or item until a decision is made on the appropriate means for decontamination.

— If the isolated vehicle or the equipment or item is essential, it should be replaced with a suitable alternative.

(b) Within weeks after obtaining the results:

— The dose from all exposure pathways for those who may have used the contaminated vehicle or equipment or item with monitoring results exceeding OIL_V should be estimated to determine if medical follow-up is warranted in accordance with GSR Part 7 [1] (the relevant generic criteria are reproduced in Table 2).

I.14. The concentration of radionuclides in food traded internationally for which guideline levels are published by the Joint FAO/WHO Codex Alimentarius Commission [24] should be analysed. If the concentrations of those radionuclides exceed the guideline levels, the international trade of non-essential food should be restricted.

I.15. Contamination monitoring should be implemented on commodities traded internationally other than food which might be affected. If monitoring results exceed $OIL_{IntTrade,C}$ the international trade of non-essential commodities should be restricted.

I.16. Paragraph II.14 of GSR Part 7 [1] states:

> "If restricting trade in food and other commodities could result in severe health impacts or other detrimental effects in another State, then the food and other commodities that would give rise to a projected dose that exceeds the generic criteria in Table II.5 [in GSR Part 7] may be traded — if the trade is justified — until replacements are available, provided that:
>
> (a) The trade is approved with the receiving State.
>
> (b) The trade will not result in doses that exceed the generic criteria for the public given in Table II.2 and Table II.3.
>
> (c) Actions are taken to manage and control exposures during shipping.
>
> (d) Actions are taken to control the consumption of food and use of other commodities and to reduce the exposure of members of the public."

Responding to a site area emergency or facility emergency

I.17. The process of assessing the situation in and responding to an emergency of this type should involve monitoring and sampling on the site (a) to locate hotspots[37] and (b) to identify the contaminated individuals on the site.

I.18. Within a day after the start of a release from the facility, radiation monitoring should be implemented on the site to identify the hotspots where OIL2 is exceeded. Individuals who do not take part in emergency response should be evacuated from those areas. Within weeks after the exposure, the dose from all exposure pathways should be estimated for those who were at the hotspots to determine if medical follow-up is warranted in accordance with GSR Part 7 [3] (the relevant generic criteria are reproduced in Table 2).

I.19. Skin contamination monitoring should be implemented on the site within hours after exposure to radioactive material. All the individuals who undergo skin monitoring should be registered, and their monitoring results should be recorded. If the monitoring results exceed

[37] For an emergency a 'hotspot' is used to refer to an area with ground deposition of radioactive material resulting in an OIL or other predetermined criteria being exceeded.

OIL4, the protective actions and other response actions specified in paragraph I.9 (a) and (b) should be implemented (see footnote l of Table 5).

I.20. If the intake of radioiodine by individuals on the site is suspected, their thyroids should be monitored within a few days. All individuals who undergo thyroid monitoring should be registered, and their monitoring results should be recorded. If the monitoring results exceed OIL8, the protective actions and other response actions specified in paragraph I.11 should be implemented.

I.21. Contamination monitoring of vehicles, equipment and items used in emergency response that enter the site and might therefore be contaminated should be implemented when they are leaving the site. If the monitoring results exceed OIL_V, the response actions specified in paragraphs I.13 (a) and (b) should be implemented.

Responding to a radiological emergency associated with activities and acts in EPC IV

I.22. In the case of an emergency of this type, life saving and mitigatory actions should be taken at the site as soon as possible, and the site area is cordoned off (DS534 [10]) on the basis of the observables and indicators (see Appendix IV).

I.23. Within hours after the detection of emergency conditions or the arrival of the first responders at the site, the area that has been cordoned off (inner cordoned off area) should be adjusted based on the monitoring results and OIL2. Within weeks after the exposure, the dose from all exposure pathways should be estimated for those who were in the cordoned off area to determine if medical follow-up is warranted in accordance with GSR Part 7 [3] (the relevant generic criteria are reproduced in Table 2).

I.24. Within days after the detection of emergency conditions, the areas where ground deposition levels exceed OIL3 should be identified, and the protective actions and other response actions specified in paragraph I.8 should be implemented.

I.25. Skin contamination monitoring should be implemented for individuals at the site within hours after exposure to radioactive material. All individuals who undergo skin contamination monitoring should be registered, and their monitoring results should be recorded. If the monitoring results exceed OIL4, the protective actions and other response actions specified in paragraph I.9 should be implemented (see footnote l of Table 5).

I.26. Within a week after the detection of emergency conditions, the activity concentrations of radionuclides in local produce, milk or drinking water samples collected from the vicinity of the site should be analysed and the results compared against OIL5 and OIL6. If the activity concentrations of the radionuclides exceed OIL5 and OIL6:

(a) Within days after obtaining the results:

— The public should be provided with instructions to stop consumption, distribution and sale of the affected food, milk or drinking water if it can be implemented safely. If the restricted food, milk or drinking water are essential, they should be replaced with alternative supplies.

(b) Within weeks after obtaining the results:

— The dose from all exposure pathways for those who may have consumed food, milk or drinking water with activity concentrations exceeding OIL7 should be estimated to determine if medical follow-up is warranted in accordance with GSR Part 7 [1] (the relevant generic criteria are reproduced in Table 2).

I.27. If the intake of radioiodine by individuals at the site is suspected, their thyroids should be monitored within the first days. All the individuals who undergo thyroid monitoring should be registered, and their monitoring results should be recorded. If the monitoring results exceed OIL8, the protective actions and other response actions specified in paragraph I.11 should be implemented.

I.28. Within a week, contamination monitoring should be implemented on the surfaces of commodities other than food, milk and drinking water that might be affected. If monitoring results exceed OIL_C, the protective actions and other response actions specified in paragraph I.12 should be implemented.

I.29. Contamination monitoring of vehicles, equipment and items used in emergency response that enter the site and might therefore be contaminated should be implemented when they are leaving the site. If the monitoring results exceed OIL_V, the response actions specified in paragraphs I.13 (a) and (b) should be implemented.

I.30. Monitoring of traded commodities may include food moving in international trade. The regulatory body or other relevant authority shall consider the Codex Guideline Level (GL) [26]. The GL is the maximum level of a substance in a food commodity which is recommended by the Codex Alimentarius Commission to be acceptable for commodities moving in international trade. When the GL is exceeded, governments should decide whether and under what circumstances the food should be distributed within their territory or jurisdiction (see also para I.16).

I.31. Contamination monitoring should be implemented on commodities other than food which are traded internationally and which might be affected. If monitoring results exceed $OIL_{IntTrade,C}$ the international trade of non-essential commodities should be restricted (see para. I.16).

USE OF OIL5 and OIL6

I.32. OIL5 and OIL6 given in Tables 6 and 7 (see also Table 8) apply to radionuclides in food, milk and water intended for human consumption (they are applicable food as produced, i.e. Bq/kg fresh weight and not dried food nor or concentrated food). The health effects of radiation exposure (the generic criteria for taking response actions to reduce the risk of stochastic effects due to ingestion of food, milk or drinking water are provided in Table 2) were taken into consideration in their derivation. The differences in the chemical toxicities of different compounds in which radionuclides are incorporated are outside the scope of this Safety Guide[38]. All of the diet is assumed to be contaminated in the derivation of OIL6. Therefore, due consideration should be given to the circumstances where there may already be naturally occurring radionuclides in excess of the concentrations specified in OIL6 (e.g. for some invertebrate foodstuffs that do not make up a significant portion of the diet).

I.33. The process of assessing radionuclide concentrations in food, milk and water is shown in Fig. 3. First the potentially contaminated food should be screened over a wide area and analysed to determine the gross alpha and beta concentrations if this can be done more promptly than assessing the concentration of individual radionuclides. If the OIL5 (see Table 6) screening levels are not exceeded, the food, milk and water are safe for consumption during the emergency exposure situation. If an OIL5 level is exceeded, the radionuclide specific concentrations in the food, milk or water should be determined. If the OIL6 levels in Table 7 are exceeded, the protective actions and other response actions specified in paragraph I.26 should be implemented.

I.34. ^{40}K is commonly found in food and water. It does not accumulate in the body but is maintained at a constant level independent of intake[39]. The contribution of ^{40}K should therefore be subtracted, following a separate determination of total potassium content. The beta activity of the ^{40}K included in natural potassium is 27.9 Bq/g. This is the factor that should be used to calculate the beta activity due to ^{40}K [25].

[38] Nevertheless, a caveat is made about the chemical toxicity of uranium in footnote d of Table 7.

[39] In the response to the Chernobyl accident in 1986, in some cases ^{40}K was confused with ^{137}Cs and produce was discarded even though it contained virtually no radioactive caesium [34].

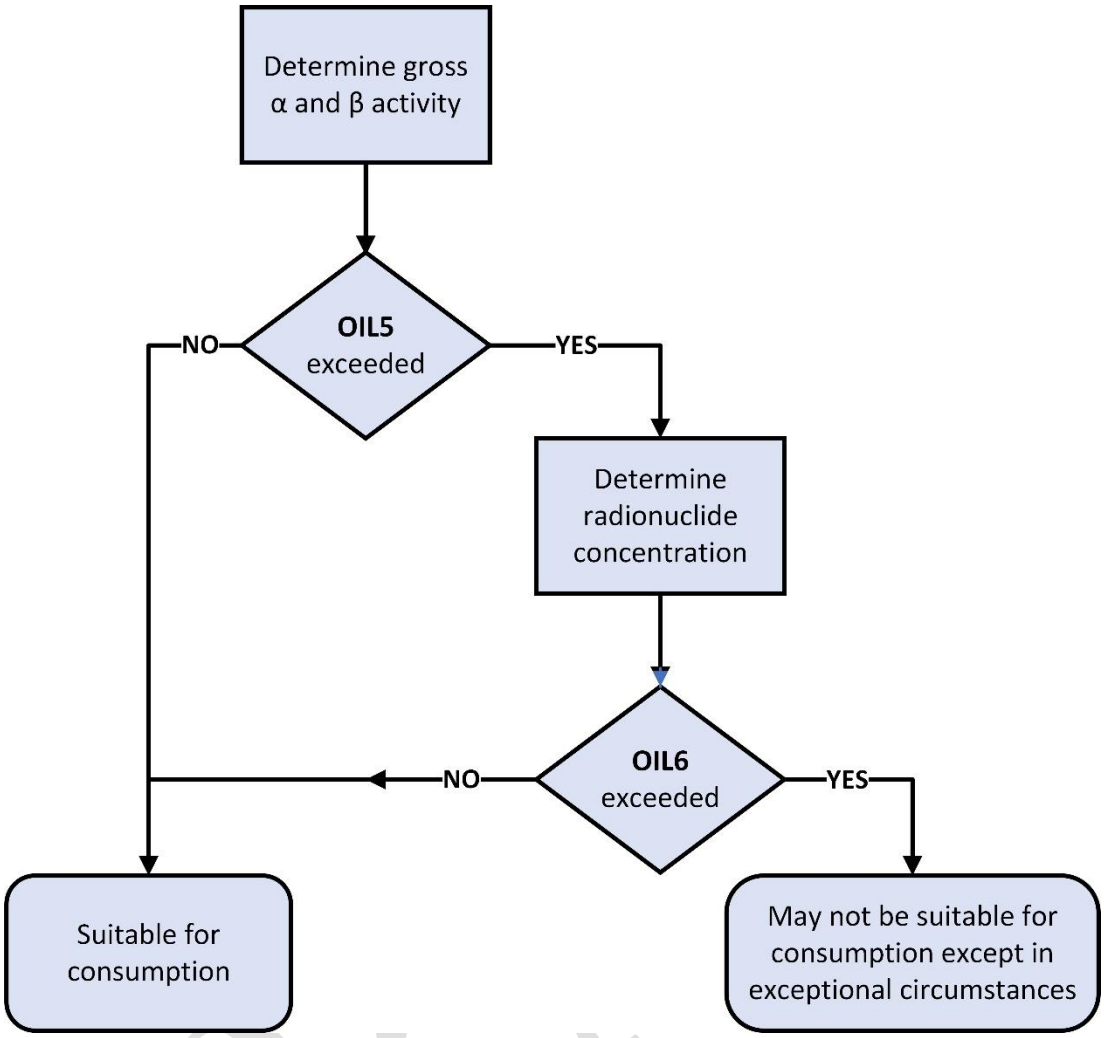


FIG. 3. Process of assessing radionuclide concentrations in food, milk and water.

TABLE 6. DEFAULT SCREENING OILs FOR FOOD, MILK AND WATER CONCENTRATIONS FROM LABORATORY ANALYSIS

OIL	OIL value	Response action if the OIL is exceeded
OIL5	Gross beta (β): 100 Bq/kg or Gross alpha (α): 5 Bq/kg	Above OIL5: Assess using OIL6 Below OIL5: Safe for consumption during the emergency phase

TABLE 7. DEFAULT RADIONUCLIDE SPECIFIC OILs FOR FOOD, MILK AND WATER CONCENTRATIONS FROM LABORATORY ANALYSIS

Radionuclide		OIL6 (Bq/kg)	Radionuclide		OIL6 (Bq/kg)
H-3		1×10^5	Cu-67		1×10^6
Be-7		9×10^5	Zn-65		2×10^3
C-11		3×10^9	Ga-67		2×10^6
C-14		1×10^4	Ga-68		2×10^8
F-18		3×10^8	Ge-68	+	5×10^3
Na-22		2×10^3	As-72		5×10^5
Na-24		4×10^6	As-73		4×10^4
Mg-28	+[a]	5×10^5	Se-75		3×10^3
Al-26		1×10^3	Rb-83		9×10^3
Si-32	+	6×10^3	Rb-86		2×10^4
P-32		2×10^4	Sr-82		6×10^3
P-33		1×10^5	Sr-85		3×10^4
S-35		1×10^4	Sr-89		4×10^2
Cl-36		4×10^3	Sr-90	+	3×10^1
K-40		NA[b, c]	Sr-91		4×10^6
K-42		4×10^6	Y-88		1×10^4
Sc-47		5×10^5	Y-90		1×10^5
V-48		3×10^4	Y-91		6×10^3
V-49		2×10^5	Zr-88		4×10^4
Cr-51		1×10^6	Zr-95	+	2×10^4
Fe-52	+	2×10^6	Zr-97	+	6×10^5
Fe-55		1×10^4	Nb-95		5×10^4
Fe-59		1×10^4	Mo-99	+	4×10^5
Co-57		2×10^4	Tc-95m	+	4×10^4
Co-60		1×10^3	Tc-96		3×10^5
Ni-63		3×10^4	Tc-99		2×10^3
Cu-64		1×10^7	Tc-99m		2×10^8

Radionuclide		OIL6 (Bq/kg)	Radionuclide		OIL6 (Bq/kg)
Ru-97		2×10^6	Cs-137	+	7×10^2
Ru-103	+	3×10^4	Ba-133		4×10^3
Ru-105		2×10^7	Ba-140	+	2×10^4
Ru-106	+	7×10^2	Ce-141		4×10^4
Rh-105		2×10^6	Ce-143		6×10^5
Pd-103	+	3×10^5	Ce-144	+	9×10^2
Pd-109	+	3×10^6	Pr-143		5×10^4
Ag-111		9×10^4	Nd-147		7×10^4
Cd-109	+	3×10^3	Pm-147		1×10^4
In-111		1×10^6	Pm-149		4×10^5
Sn-117m		9×10^4	Sm-153		6×10^5
Sb-124		6×10^3	Eu-152		3×10^3
Te-123m		7×10^3	Eu-154		2×10^3
Te-127m	+	3×10^3	Gd-148		2×10^2
Te-127		1×10^7	Gd-153		2×10^4
Te-129m	+	8×10^3	Dy-165		8×10^7
Te-131m		4×10^4	Dy-166	+	1×10^5
Te-132	+	6×10^3	Ho-166		5×10^5
I-123		6×10^6	Ho-166m		3×10^3
I-124		1×10^4	Er-169		2×10^5
I-125		2×10^2	Tm-170		6×10^3
I-129		9	Yb-169		4×10^4
I-131		3×10^2	Yb-175		5×10^5
I-133		1×10^4	Lu-177		2×10^5
I-134		4×10^7	W-188	+	6×10^3
I-135		2×10^5	Re-186		1×10^5
Cs-131		2×10^6	Re-188		8×10^5
Cs-134		6×10^2	Ir-192		1×10^4
Cs-136		5×10^4	Ir-194		8×10^5

Radionuclide		OIL6 (Bq/kg)	Radionuclide		OIL6 (Bq/kg)
Au-198		3×10^5	U-235[e]	+	1×10^2
Au-199		6×10^5	U-238[e]	+	1×10^2
Hg-203		1×10^4	Np-237	+	9×10^1
Tl-201		4×10^6	Np-239		5×10^5
Tl-204		3×10^3	Pu-238		4×10^1
Bi-207		3×10^3	Pu-239		4×10^1
Bi-212	+	8×10^7	Pu-240		4×10^1
Bi-213		1×10^8	Pu-241		2×10^3
Po-210[d]		2.0	Pu-242		4×10^1
At-211	+	3×10^5	Am-241		5×10^1
Ra-223	+	5×10^2	Am-243	+	5×10^1
Ra-224	+	2×10^2	Cm-242		6×10^2
Ra-226	+	3.0	Cm-244		8×10^1
Ac-225	+	3×10^3	Cm-248		1×10^1
Th-227	+	5×10^3	Bk-249		1×10^4
Th-228	+	8×10^1	Cf-249		3×10^1
Th-230		5×10^1	Cf-252		5×10^1
Th-232		4×10^1	Pu-239/Be-9		4×10^1
U-232[e]		3×10^1	Am-241/Be-9		5×10^1
U-234[e]		1×10^2			

[a] '+' indicates radionuclides with progeny listed in Table 8 that are assumed to be in equilibrium with the parent radionuclide and therefore do not need to be considered independently when assessing compliance with OILs.

[b] NA: not applicable.

[c] The dose from ingestion of ^{40}K is considered not to be relevant because ^{40}K does not accumulate in the body and is maintained at a constant level independent of intake.

[d] Po-210 is naturally present in enhanced levels in some foods (e.g. a median natural level of 40 Bq/kg in some seafoods) [37].

[e] Uranium is normally controlled on the basis of its chemical toxicity.

TABLE 8. EQUILIBRIUM RADIOACTIVE CHAINS

Parent radionuclide	Progeny radionuclides considered in OIL6 assessment as being in equilibrium with the parent
Mg-28	Al-28
Si-32	P-32
Fe-52	Mn-52m
Ge-68	Ga-68
Sr-90	Y-90
Zr-95	Nb-95 (2.2)
Zr-97	Nb-97m (0.95), Nb-97
Tc-95m	Tc-95 (0.041)
Mo-99	Tc-99m (0.96)
Ru-103	Rh-103m
Ru-106	Rh-106
Pd-103	Rh-103m
Pd-109	Ag-109m
Cd-109	Ag-109m
Te-127m	Te-127
Te-129m	Te-129 (0.65)
Te-132	I-132
Cs-137	Ba-137m
Ba-140	La-140 (1.2)[a]
Ce-144	Pr-144m (0.018), Pr-144
Dy-166	Ho-166 (1.5)
W-188	Re-188
Bi-212	Tl-208 (0.36), Po-212 (0.65)
At-211	Po-211 (0.58)
Ra-223	Rn-219, Po-215, Pb-211, Bi-211, Tl-207
Ra-224	Rn-220, Po-216, Pb-212, Bi-212, Tl-208 (0.36), Po-212 (0.65)
Ra-226	Rn-222, Po-218, Pb-214, Bi-214, Po-214
Ac-225	Fr-221, At-217, Bi-213, Po-213 (0.98), Pb-209, Tl-209 (0.022)

Parent radionuclide	Progeny radionuclides considered in OIL6 assessment as being in equilibrium with the parent
Th-227	Ra-223 (2.6), Rn-219 (2.6), Po-215 (2.6), Pb-211 (2.6), Bi-211 (2.6), Tl-207 (2.6)
Th-228	Ra-224, Rn-220, Po-216, Pb-212, Bi-212, Tl-208 (0.36), Po-212 (0.64)
U-232	Th-226, Ra-222, Rn-218, Po-214
U-235	Th-231
U-238	Th-234, Pa-234m
Np-237	Pa-233
Am-243	Np-239

[a] The value inside the parentheses is the activity of the daughter radionuclide, per unit of the parent, assumed to be present.

I.35. OIL6 is exceeded if the following condition is satisfied:

$$\sum_i \frac{C_{f,i}}{OIL6_i} > 1 \quad (6)$$

where

$C_{f,i}$ is the concentration of radionuclide *i* in the food, milk or water (Bq/kg);
$OIL6_i$ is the concentration of radionuclide *i* from Table 7 (Bq/kg).

METHODOLOGY FOR THE DERIVATION OF OIL_V AND $OIL_{IntTrd,C}$

I.36. A method for deriving a default OIL_V value, to be used for vehicles, equipment or items from affected areas in an emergency, for a specific radionuclide mix is given below. The relative activity of the radionuclides comprising the radionuclide mix will vary over time because of processes such as radioactive decay, resulting in a time dependent $OIL_V(t, \text{mix})$, given by:

$$OIL_V(t, \text{mix}) = \left(\sum_i \left(RA_i(t, \text{mix}) \times IR_{V,i} \right) \right) \quad (7)$$

$$\times \min \left\{ \begin{array}{c} \left(\dfrac{\mathrm{GC(vcl, eqp, itm}, E, \mathrm{1a})}{\sum_i (E_{\mathrm{vcl,eqp,itm-scenario},i}(\mathrm{1a}) \times \mathrm{RA_i}(t, \mathrm{mix})} \right), \\ \left(\dfrac{\mathrm{GC(vcl, eqp, itm}, H_{\mathrm{fetus}}, \mathrm{9mo})}{\sum_i (H_{\mathrm{fetus-\ vcl,eqp,itm-scenario},i}(\mathrm{9mo}) \times \mathrm{RA_i}(t, \mathrm{mix})} \right) \end{array} \right\} \times \mathrm{WF}$$

where

$RA_i(t, mix)$ [unitless]	is the relative activity of radionuclide *i* at time *t* for a specific radionuclide mix. It is determined by $RA_i(t, mix) = A_i(t, mix) / \Sigma_i[A_i(t, mix)]$, where $A_i(t, mix)$ [Bq] is the activity of radionuclide *i* at time *t*, for a specific radionuclide mix;
$IR_{V,i}$ [(Sv/h)/(Bq/m^2) or cps/(Bq/m^2)]	is the instrument response per unit activity of radionuclide *i* on the surfaces of vehicles, equipment or items[40];
GC(vcl, eqp, itm, *E*, 1a) = 0.01 Sv	is the generic criterion for vehicles, equipment or items based on the total effective dose to the representative person over one year (GSR Part 7 [1], reproduced in Table 2 of this Safety Guide);
GC(vcl, eqp, itm, H_{fetus}, 9mo) = 0.01 Sv	is the generic criterion for vehicles, equipment or items based on the total equivalent dose to the fetus over the period of in utero development (GSR Part 7 [1], reproduced in Table 2 of this Safety Guide);
$E_{vcl,eqp,itm-scenario,i}(1a)$ [Sv/(Bq/m^2)]	is the total effective dose to the representative person over 1 year for the 'vehicle' exposure scenario, per unit activity of radionuclide *i* on the surfaces of vehicles, equipment or items;
$H_{fetus-vcl,eqp,itm-scenario,i}$ (9mo) [Sv/(Bq/m^2)]	is the total equivalent dose to the fetus over the period of in utero development for the 'vehicle' exposure scenario, per unit activity of radionuclide *i* on the surfaces of vehicles, equipment or items;
WF [unitless]	is a weighting factor used to allow for the quantification of other considerations.

I.37. For a single radionuclide, Eq. (7) will result in a single time independent OIL_V value. For a single radionuclide mix, Eq. (7) will result in a time dependent $OIL_V(t)$ curve on the basis of which a single time independent value should be chosen. For an emergency involving a variety of radionuclide mixes (e.g. an accident at a nuclear power plant), Eq. (7) will result in a set of

[40] Depending on the type of monitoring instrument, OIL_v can be expressed in Sv/h or cps.

time dependent $OIL_V(t, \text{mix})$ curves, on the basis of which a single time independent value should be chosen.

I.38. A method for deriving a default $OIL_{IntTrdC}$ value, to be used for the international trade of non-food commodities, for a specific radionuclide mix is given below. The relative activity of the radionuclides comprising the radionuclide mix will vary over time because of processes such as radioactive decay, resulting in a time dependent $OIL_{IntTrd\text{-}C}(t, \text{mix})$, given by:

$$OIL_{IntTrdC}(t, \text{mix}) = \left(\sum_i \left(RA_i(t, \text{mix}) \times IR_{IntTrdC,i}\right)\right) \times \min\left\{\begin{array}{c}\left(\frac{GC(IntTrdC, E, 1a)}{\sum_i (E_{IntTrdC-scenario,i}(1a) \times RA_i(t, \text{mix}))}\right), \\ \left(\frac{GC(IntTrdC, H_{fetus}, 9mo)}{\sum_i (H_{fetus,IntTrdC-scenario,i}(9mo) \times RA_i(t, \text{mix}))}\right)\end{array}\right\} \times WF \quad (8)$$

where

$RA_i(t, \text{mix})$ [unitless] — is the relative activity of radionuclide *i* at time *t* for a specific radionuclide mix. It is determined by $RA_i(t, \text{mix}) = A_i(t, \text{mix}) / \Sigma_i[A_i(t, \text{mix})]$, where $A_i(t, \text{mix})$ [Bq] is the activity of radionuclide *i* at time *t*, for a specific radionuclide mix;

$IR_{IntTrdC,\ i}$ [(Sv/h)/(Bq/m^2) or cps/(Bq/m^2)] is the instrument response per unit activity of radionuclide *i* on commodity surfaces[41];

$GC(IntTrdC, E, 1a) = 0.001$ Sv — is the generic criterion for non-food commodities traded internationally based on the total effective dose to the representative person over one year (GSR Part 7 [1], reproduced in Table 3 of this Safety Guide);

$GC(IntTrdC, H_{fetus}, 9mo) = 0.001$ Sv — is the generic criterion for non-food commodities traded internationally based on the total equivalent dose to the fetus over the period of in utero development (GSR Part 7 [1], reproduced in Table 3 of this safety Guide);

$E_{IntTrdC\text{-}scenario,i}(1a)$ [Sv/(Bq/m^2)] — is the total effective dose to the representative person over 1 year for the 'international trade of non-food

[41] Depending on the type of monitoring instrument, OIL_V can be expressed in Sv/h or cps.

	commodities' exposure scenario, per unit activity of radionuclide *i* on commodity surfaces;
$H_{\text{fetus, IntTrdC-scenario},i}$ (9mo) [Sv/(Bq/m^2)]	is the total equivalent dose to the fetus over the period of in utero development for the 'international trade of non-food commodities' exposure scenario, per unit activity of radionuclide *i* on on commodity surfaces.

I.39. For a single radionuclide, Eq. (8) will result in a single time independent $OIL_{IntTrdC}$ value. For a single radionuclide mix, Eq. (8) will result in a time dependent $OIL_{IntTrdC}(t)$ curve on the basis of which a single time independent value should be chosen. For an emergency involving a variety of radionuclide mixes (e.g. an accident at a nuclear power plant), Eq. (8) will result in a set of time dependent $OIL_{IntTrdC}(t, \text{mix})$ curves, on the basis of which a single time independent value should be chosen.

I.40. The ambient dose equivalent rate should be the preferred quantity for monitoring vehicles, equipment, items, and non-food commodities during a nuclear or radiological emergency. If the radionuclide or the radionuclide mix is such that the ambient dose equivalent rate is not usable (e.g. measured values are within the gamma background levels), the beta or alpha count rates should be monitored and used instead.

PLAIN LANGUAGE EXPLANATION OF OPERATIONAL INTERVENTION LEVELS FOR A NUCLEAR OR RADIOLOGICAL EMERGENCY

I.41. Using plain language to communicate with the public and others avoids confusion and facilitates the quick and clear dissemination of information. Experience has shown that decision makers take response actions and the public follows instructions best when they understand how the actions provide for the safety of the public [23]. The default OILs are therefore supported by a plain language explanation of how criteria and associated actions provide for the safety of all members of the public. In addition, experience shows that the use of overly conservative criteria can result in the public taking actions that do more harm than good. The default OILs are developed using realistically conservative assumptions that provide reasonable assurance that all members of the public are safe.

I.42. Paragraph 2.19 of GSG-14 [13] states:

> "One function of public communication in a nuclear or radiological emergency is to convey technical information in suitable language for a general audience. Such information should be clear and comprehensible (i.e. in 'plain language'). Essential information might otherwise not be understood, committed to memory or recalled, especially during an emergency (i.e. in which it has been shown that stress and anxiety can affect comprehension)."

I.43. Paragraph 2.22 of GSG-14 [13] states:

> "The use of scientific and technical terms, and of scientific quantities and units and numerical data, should be kept to an essential minimum. Any such usage should be supported, as necessary, by plain language definitions and explanations that put the radiological health hazard in perspective."

I.44. The development of plain language explanations for the default OILs should be based on the assumption that members of the public living normally[42], including those who are more vulnerable to radiation exposure, such as children and pregnant persons, will achieve a level of protection that meets international standards, provided that in an emergency exposure situation they:

(a) Do not receive a dose to any organ approaching that resulting in severe deterministic effects. The generic criteria related to the onset of severe deterministic effects are listed in table II.1 of GSR Part 7 [1] and reproduced in Table 1 of this Safety Guide.

(b) Do not receive a dose above which the risk of stochastic health effects (e.g. cancers) is sufficiently high to justify taking protective actions during an emergency. The relevant generic criteria are presented in table II.2 of GSR Part 7 [1] and reproduced in Table 2 of this Safety Guide. Below these generic criteria, protective actions are not always justified and will be taken (if at all) on the basis of justified criteria developed, with interested parties, after careful consideration of the conditions, including the impact of any protective action.

I.45. The plain language explanations provided below may be used in communication with the public. These explanations are for people who need to follow certain protective actions and other response actions based on the use of OILs.

OIL1 plain language explanation

I.46. Remaining in the area may not be safe. Those living in the area have to *[insert appropriate recommended actions for OIL1]* to reduce the risk of health effects due to radiation.

OIL2 plain language explanation

I.47. Remaining in the area for a short time is possible if the following recommended actions are taken, but staying for longer periods may not be safe. Those living in the area have to relocate and *[insert appropriate recommended actions for OIL2].*

I.48. The recommended actions take into account people who are most vulnerable to radiation exposure (e.g. pregnant women and children). They also consider all the ways people can be

[42] Carrying out normal activities, such as children playing on the ground and people working outside.

exposed to radiation because of radioactive material deposited on the ground through pathways including inhalation of dust and inadvertent ingestion of dirt (e.g. from dirty hands). For some types of radioactive material, this advice may be overly cautious, but it is considered prudent until further analysis is performed. The relocation is likely to be temporary.

OIL3 plain language explanation

I.49. The consumption of local produce (e.g. vegetables), milk from grazing animals, and rainwater may need to be stopped until they have been declared safe. However, if this could result in severe malnutrition or dehydration because replacement food, milk or water is not available, these items may be consumed for a short time until replacements are available. The use and distribution of non-food commodities in the area that might be contaminated may also need to be restricted until they have been assessed.

I.50. The recommended actions take into account the most vulnerable members of the public (e.g. pregnant women and children). It is assumed that all the locally produced food and milk is contaminated and this will not change because of preparation of food (e.g. peeling, washing) before consumption. This does not mean that the food or milk produced in the area is not safe; however, it is prudent not to consume local non-essential food until further analysis has been performed.

OIL4 plain language explanation

I.51. If above OIL4, individuals will be registered, their monitoring results will be recorded and they may be contacted for additional medical screening if required. Any person who might have radioactive contamination on the skin or clothing has to take action to prevent inadvertent ingestion of radioactive material (which may not be visible). Appropriate actions include washing hands before drinking, eating or smoking, and keeping the hands away from the mouth until they have been washed. Further actions include changing clothes as soon as possible and showering before putting on clean ones. The removed clothing has to be put in a closed plastic bag until it can be dealt with (instructions from the relevant public authorities have to be followed for dealing with those clothes). These recommendations also apply to those people who may have been monitored. The recommended actions take into account the most vulnerable members of the public (e.g. pregnant women and children). It is assumed that people might eat with contaminated hands and thereby might ingest radioactive material. Timely monitoring and immediate decontamination by experts may not always be possible, and contamination levels may be very difficult to detect under emergency conditions. Nevertheless, potentially contaminated persons can take the effective actions mentioned above to protect themselves.

OIL5 plain language explanation

I.52. Below OIL5: Locally produced food, milk and water have been screened, and all members of the public, including infants, children and pregnant persons, can safely drink the milk and water and eat the food.

I.53. Above OIL5: The screening levels in locally produced food, milk and water have been exceeded. This does not mean that the food, milk or water is not safe to consume. The food, milk or water will be analysed further to make the final decision on their restriction. Await further details before consuming. However, if restriction of consumption is likely to result in severe malnutrition or dehydration due to the lack of replacement food, milk or water, then these items may be consumed for a short time until replacements are available or additional analysis confirms restriction is no longer necessary.

OIL6 plain language explanation

I.54. Below OIL6: Locally produced food, milk and water have been analysed, and all members of the public, including infants, children and pregnant persons, can safely drink the milk and water and eat the food.

I.55. Above OIL6: Locally produced food, milk and water have been analysed, and the measurements indicate that the consumption, distribution and sale of the affected food, milk or drinking water have to be restricted. However, if restriction of consumption is likely to result in severe malnutrition or dehydration due to the lack of replacement food, milk or water, then these items may be consumed for a short time until replacements are available.

I.56. The recommended actions consider the most vulnerable members of the public (e.g. pregnant women and children), and it is assumed that all of the food, milk and water is contaminated. It is also assumed that this will not change due to preparation of the food (e.g. peeling, washing) before consumption. Exceeding the criteria therefore might not mean that the food, water or milk is unsuitable for consumption but might indicate that further investigation, including consideration of actual consumption rates and additional screening, is needed.

OIL7 plain language explanation

I.57. Below OIL7: Locally produced food, milk and water have been analysed, and all members of the public, including infants, children and pregnant persons, can safely drink the milk and water and eat the food.

I.58. Above OIL7: Locally produced food, milk and water have been analysed, and the measurements indicate that the consumption, distribution and sale of the affected food, milk or drinking water have to be restricted. However, if restriction of consumption is likely to result in severe malnutrition or dehydration due to the lack of replacement food, milk or water, then these items may be consumed for a short time until replacements are available.

I.59. The recommended actions consider the most vulnerable members of the public (e.g. pregnant women and children), and it is assumed that half of the food, milk and water is contaminated. It is also assumed that this will change due to preparation of the food (e.g. peeling, washing) before consumption. Exceeding the criteria therefore might not mean that the food, water or milk is unsuitable for consumption but might indicate that further investigation of the local diet and additional screening are needed.

OIL8 plain language explanation

I.60. Below OIL8: There is no accumulation of radioiodine in the thyroid that warrants any medical follow-up. Nevertheless, the individuals monitored will be registered, and their monitoring results will be kept for the record.

I.61. Above OIL8: The individuals monitored will be registered, and their monitoring results will be recorded. They will be provided with iodine tablets, as necessary to reduce further uptake of radioiodine. They will be provided with medical screening. Their dose will be estimated (within a few weeks) and then individuals will be informed whether medical follow-up is warranted.

I.62. The recommended actions consider the most vulnerable members of the public (e.g. pregnant women and children).

OIL_C plain language explanation

I.63. Below OIL_C: *[Insert the list of non-food commodities of concern]* have been monitored. Their use is safe for all members of the public, including infants, children, and pregnant persons.

I.64. Above OIL_C: *[Insert the list of non-food commodities of concern]* have been monitored. Their use, distribution and sale have to be restricted.

I.65. The recommended actions consider the most vulnerable members of the public (e.g. pregnant women and children).

OIL_V plain language explanation

I.66. Below OIL_V: Vehicles, equipment and items have been monitored. Their use is safe for all members of the public, including infants, children, and pregnant persons.

I.67. Above OIL_V: Certain vehicles, equipment and items have been monitored and their use has to be restricted, provided that restriction does not interfere with the response to the emergency. If so, they can be used for a short time until replacements are available.

OIL_{IntTrd} plain language explanation

I.68. Below OIL_{IntTrd}: Commodities to be internationally traded have been analysed. Their use is safe for all members of the public, including infants, children, and pregnant persons.

I.69. Above OIL_{IntTrd}: The following food and non-food commodities to be internationally traded have been analysed *[insert list]*. Their trade has to be restricted provided that such restriction does not result in severe health impacts. If so, they can still be traded until replacements are available.

I.70. The analysis for OIL_{IntTrd} considers the most vulnerable members of the public (e.g. pregnant women and children).

REVISION OF OPERATIONAL INTERVENTION LEVELS FOR A NUCLEAR OR RADIOLOGICAL EMERGENCY

I.71. States may want to revise the default OIL values provided in this Safety Guide to consider different underlying assumptions or another methodological approach than the ones used by the IAEA [4, 6]. These changes should be justified and clearly explained to interested parties during the preparedness stage. Changes to the default OIL values given in this Safety Guide should be made by experts with experience in dose assessment and emergency preparedness and response, as well as a clear understanding of the methodology for deriving the OILs. References [4, 6] provide the methodology used by the IAEA, which can be employed as a basis for revision.

I.72. Operational criteria (such as OILs) should only be changed during an emergency if there is clear evidence that the revised criteria will be justified (i.e. do more good than harm), considering both radiological and non-radiological consequences, and when the situation is clearly understood (e.g. exposure scenarios including public behaviour and mixture of radionuclides present are well characterized). Failure to do so may lead to confusion and scepticism on the part of decision makers and the public, potentially resulting in unwarranted actions being taken. The means and authority for exceeding or modifying operational criteria during an emergency should be identified during the preparedness stage.

I.73. The generic considerations that should be taken into account to ensure that the revised OIL values are built on a defensible basis are provided in Table 9.

TABLE 9. GENERAL CONSIDERATIONS FOR REVISING THE DEFAULT OIL VALUES [4]

Changes in the:	**Considerations**[a]
Objective of the OILs	▪ Does the new objective allow prompt and effective implementation of emergency response actions on the basis of monitoring results readily available during a nuclear or radiological emergency? ▪ Does the new objective allow avoiding a discernible increase in the incidence of radiation induced health effects?

	▪ Does the new objective allow avoiding the delay of decision making due to limited availability of information (as expected in the urgent response phase of an emergency)? ▪ Does the new objective allow avoiding response actions that would result in more harm than good because of an overly conservative approach?
Generic criteria	▪ Have dosimetric criteria (as described in GSR Part 7 [1]) been used that provide a solid foundation for the implementation of response actions? ▪ Do the new dosimetric criteria ensure that there will be no discernible increase in radiation induced health effects? ▪ Are the new dosimetric criteria reasonable, i.e. do they provide a solid basis for a justified and optimized protection strategy? ▪ Do the new dosimetric criteria consider individual organ doses and resulting health effects, and not only the effective dose?
Radionuclide mix (radionuclides present)	▪ Have all radionuclide mixes which are expected to be released or have been released, and which may be of significant impact, been considered? ▪ Have all possible releases of radioactive material that may result from a nuclear[b] or radiological[c] emergency been considered? ▪ Has consideration been given to the fact that the measured radionuclide mix following a release of radioactive material will change depending on location and time?
Individuals being exposed	▪ Have all members of the public that might be exposed (including those most sensitive to radiation) been considered? ▪ Has it been clearly stated that all members of the public (including those most sensitive to radiation) have been considered?
Exposure scenarios and pathways	▪ Have all relevant exposure scenarios been considered? ▪ Have all relevant exposure pathways been considered? ▪ Have the behaviour of the public and other factors affecting public exposure been considered for the different scenarios and pathways?
Behaviour of the radionuclides	▪ Have all relevant aspects of radionuclide behaviour (such as weathering, decay, resuspension, transfer from the ground to vegetables and pasture) been considered that may have a significant impact on the dose or the OILs?
Dose coefficients	▪ Have dose coefficients been developed (or considered) for each radionuclide, dose quantity, exposure pathway, exposure scenario and for all exposed individuals? ▪ Have the relevant effective dose, equivalent dose and RBE weighted absorbed dose coefficients been considered?
Instrument response	▪ Are the OILs applicable to the instruments being used? ▪ Are the instruments appropriate for the intended measurement?

OIL(t,mix) functions and default OIL value	▪ Have time and mix dependent OIL(t,mix) functions been developed for all considered radionuclide mixes? ▪ Has a reasonably conservative and justified default OIL value been chosen considering the overall protection strategy and operational requirements?
Response actions	▪ Do the response actions take into account the overall protection strategy, the contribution from the different exposure pathways for the specific exposure scenario, how the response action would contribute to reducing the dose and whether the response action is feasible and justified?
Communicating the changes to the OILs to decision makers and public information officers	▪ Have preparations been made for communicating the basis of the changes to the OILs and the associated response actions to decision makers and the public?
Other	▪ Is the approach reasonably conservative, i.e. do the use of revised OILs and the associated response actions ensure that the public is protected effectively from the radiological health hazard? ▪ Are the response actions justified and optimized within the overall protection strategy?
	▪

[a] The answer to all questions needs to be 'yes' to justify the revised OILs.

[b] The radionuclide mixes resulting from beyond design basis accidents are to be considered.

[c] For many radiological emergencies only one radionuclide may be of concern.

APPENDIX II. DEVELOPMENT AND USE OF EMERGENCY ACTION LEVELS FOR LIGHT WATER REACTORS

II.1. Paragraph 5.14 of GSR Part 7 [1] states:

> "The operating organization of a facility or activity in category I, II, III or IV shall make arrangements for promptly classifying, on the basis of the hazard assessment, a nuclear or radiological emergency warranting protective actions and other response actions to protect workers, emergency workers, members of the public and, as relevant, patients and helpers in an emergency, in accordance with the protection strategy (see Requirement 5). This shall include a system for classifying all types of nuclear or radiological emergency".

The events considered in the classification system should not be expanded to include all reportable events but should be limited to alerts and emergencies that require immediate on-site action[43].

II.2. The following classes are defined for facilities in EPC I and II: General emergency, site area emergency, facility emergency and alert (see para. 5.14 of GSR Part 7 [1]). Declaration of an emergency in any of these emergency classes should initiate a response that is considerably beyond normal operations. Each class initiates a distinctly different level of response as shown in Fig. 4.

<table>
<tr><th>Alert</th><th>Facility emergency</th><th>Site area emergency</th><th>General emergency</th></tr>
<tr><td colspan="4">Immediate actions to analyse the situation and mitigate the consequences</td></tr>
<tr><td rowspan="3"></td><td colspan="3">Immediate actions to protect those on the site</td></tr>
<tr><td colspan="2">Prepare to take protective action off the site.</td></tr>
<tr><td>Immediate actions to protect the public off the site</td></tr>
</table>

FIG. 4. Relationship of response actions for the classification system. (Note: The actions are not presented in the sequence of implementation.)

II.3. Paragraph 5.14 (a) of GSR Part 7 [1] states:

> "*General emergency* at facilities in category I or II for an emergency that warrants taking precautionary urgent protective actions, urgent protective actions, and early

[43] Examples of events that is not to be included in the emergency classification system are: technical deficiencies exceeding the limits of in-service inspection codes; equipment failure beyond expected reliability limits; detection of major design deficiencies or of potential accident sequences outside the plant's design basis; symptoms of severe deficiencies in operator training or behaviour; breaches of technical specifications or of transport regulations; and deficiencies in safety culture.

protective actions and other response actions on the site and off the site. Upon declaration of this emergency class, appropriate actions shall promptly be taken, on the basis of the available information relating to the emergency, to mitigate the consequences of the emergency on the site and to protect people on the site and off the site."

II.4. The following are examples of situations that could lead to a general emergency:

(a) Actual or projected[44] damage to a reactor core or large amounts of recently discharged fuel, in combination with actual or projected damage to, or bypass of, other barriers or critical safety systems such that a radioactive release becomes highly probable;

(b) Detection of radiation levels off the site that warrant protective actions;

(c) A malicious act resulting in an inability to monitor or control critical safety systems that are needed to prevent a release or exposures off the site that could result in doses that warrant protective actions.

II.5. Paragraph 5.14 (b) of GSR Part 7 [1] states:

"*Site area emergency* at facilities in category I or II for an emergency that warrants taking protective actions and other response actions on the site and in the vicinity of the site. Upon declaration of this emergency class, actions shall promptly be taken: (i) to mitigate the consequences of the emergency on the site and to protect people on the site; (ii) to increase the readiness to take protective actions and other response actions off the site if this becomes necessary on the basis of observable conditions, reliable assessments and/or results of monitoring; and (iii) to conduct off-site monitoring, sampling and analysis."

II.6. The following are examples of situations that could lead to a site area emergency:

(a) A major decrease in the level of defence in depth provided for the reactor core or actively cooled fuel;

(b) A major decrease in protection against an accidental criticality;

(c) Conditions such that any additional failures could result in a general emergency;

(d) A malicious act with the potential to disrupt the performance of critical safety functions or to result in a significant release or doses that warrant protective actions.

[44] 'Projected damage' is indicated by a loss of critical safety functions necessary to protect the core or large amounts of recently discharged fuel.

II.7. Paragraph 5.14 (c) of GSR Part 7 [1] states:

"*Facility emergency* at facilities in category I, II or III for an emergency that warrants taking protective actions and other response actions at the facility and on the site but does not warrant taking protective actions off the site. Upon declaration of this emergency class, actions shall promptly be taken to mitigate the consequences of the emergency and to protect people at the facility and on the site. Emergencies in this class do not present an off-site hazard."

II.8. The following are examples of situations that could lead to a facility emergency:

(a) A fuel handling emergency including the dropping of a fuel assembly[45];

(b) An in-facility fire or other conventional emergency not affecting safety systems;

(c) A malicious or criminal activity (e.g. extortion or blackmail) leading to hazardous on-site conditions but with no potential to result in a criticality or a release off the site that would warrant protective actions;

(d) Loss of shielding or control for a large gamma emitter or for spent fuel;

(e) Rupture of a dangerous source;

(f) High doses on the site projected to approach the generic criteria for urgent protective actions;

(g) Doses exceeding established limits for occupationally exposed persons, including workers in on-site transport or handling activities, and including cases of confirmed high values measured by area or process radiation monitors or of contamination measurements;

(h) Civil disturbance (e.g. demonstrations in the vicinity of a nuclear power plant).

II.9. Paragraph 5.14 (d) of GSR Part 7 [1] states:

"*Alert at facilities* in category I, II or III for an event that warrants taking actions to assess and to mitigate the potential consequences at the facility. Upon declaration of this emergency class, actions shall promptly be taken to assess and to mitigate the potential consequences of the event and to increase the readiness of the on-site response organizations."

II.10. The classes are associated with increasing probability or confidence that conditions exist that will lead to core damage or to high doses on or off the site. Such a classification system provides the on-site personnel with the greatest opportunity to mitigate the

[45] The dropping of a fuel assembly and a fuel handling accident may be considered facility emergencies because they are not expected to give rise to doses that warrant protective actions off the site.

consequences of the event and off-site responders with the greatest opportunity to prepare to and to take effective protective actions for the public.

USE OF EMERGENCY ACTION LEVELS FOR EMERGENCY CLASSIFICATION

II.11. EALs are operational criteria used to detect and recognize an emergency and classify an emergency (see para. 4.2). The set of conditions to be considered for the development of EALs is provided in this Safety Guide to clarify the types of EALs that should be present for an LWR. Operating organizations can organize their EALs in different formats for operational use.

II.12. Plant specific EALs should cover all possible events that could result in high doses on the site or in a significant release. Sequences from plant specific probabilistic safety assessment may be used as basis to develop or test a set of plant specific EALs.

II.13. There are fundamentally two different types of EALs: symptom based and event based EALs. Symptom based EALs are facility or site specific instrument readings (e.g. reactor coolant system pressure higher than a certain level) or other observable or quantifiable thresholds (e.g. failure of emergency power supply systems as indicated by a specific parameter). Event based EALs are more subjective criteria requiring the judgement of the operating personnel. An example of an event based EAL would be ‘fire detected in an area containing vital safety systems’.

II.14. When possible, symptom based EALs should be used because they make the classification process more timely and less subject to error.

II.15. The set of conditions to considered for the development of EALs given in this Appendix is for a reactor in operating, standby or hot shutdown mode. In these modes, all the fission product barriers, instruments and safety systems are in place and operational. Plant specific EALs should also be determined for cold shutdown mode (reactor coolant system closed and reactor coolant system coolant temperature less than 100°C) and for refuelling mode. In these modes, the amount of energy in the reactor coolant system, residual heat generation and short lived fission products are greatly reduced. In addition, in these modes the reactor coolant system and containment might not be in place (e.g. the reactor pressure vessel head may have been removed), and fewer safety systems and instruments are needed to be operational.

II.16. The following recommendations apply to the process of determining site specific EALs:

(a) EALs should be organized and the site specific classification procedure should be designed for fast (to be completed in a few minutes) and easy use in an event.

(b) Care should be taken to ensure that the classification procedures are usable under accident conditions when the workload and stress are very high.

(c) The performance of the instruments in an emergency should also be considered in developing the EALs. Not all instruments are qualified for reliable operation in harsh accident conditions.

(d) The facility and site specific EALs should use the units of the instruments and the terminology used in the plant.

(e) Once the site specific EALs have been developed, they should be tested and/or validated in drills and walk-through sessions to ensure that they are usable by the assigned control room operators in emergency conditions.

(f) The final step in establishing a classification system is its review with off-site officials. The off-site officials who would be tasked with the implementation of protective actions or other response actions called for by a classification should be in agreement with the classification system.

(g) The EALs and corresponding procedures should be revised on the basis of operational experience and feedback from exercises.

ACCIDENT MANAGEMENT PROCEDURES AND EMERGENCY CLASSIFICATION

II.17. The main objectives of accident management are to stop the accident from progressing, to prevent the escalation of an event to a severe accident, to mitigate the consequences of a severe accident once it has happened and to achieve a long term safe stable state [15].

II.18. Emergency operating procedures aimed at preventing a severe accident are used by the main control room operators in events not involving a severe accident. Severe accident management guidelines are developed to deal with a severe accident and are used primarily by the operating organization's technical support centre or emergency centre to advise the main control room operators on mitigatory actions and provide information to off-site emergency response organizations.

II.19. Any conditions that would warrant the use of emergency operating procedures should be classified as constituting an emergency and should trigger a predetermined emergency response at the site. Once conditions of actual or imminent core damage exist, a transition from the emergency operating procedures to severe accident management guidelines should be implemented.

II.20. The emergency operating procedures and severe accident management guidelines should be integrated into the operating organization's emergency plan and should be coordinated with the plan to ensure a consistent and coordinated response to severe accident

conditions. It should be ensured that plant conditions in the emergency operating procedures and severe accident management guidelines provide clear inputs for navigating in the emergency classification procedure and identifying EALs relevant to the ongoing emergency.

SET OF CONDITIONS TO BE CONSIDERED IN THE DEVELOPMENT OF EMERGENCY ACTION LEVELS

II.21. More than one set of EALs may be relevant for use in an emergency, and therefore, more than one emergency class may be assessed as an output of the use of the emergency classification procedure. The most severe emergency class assessed should be declared.

II.22. The following conditions should be considered for the development of the EALs for light water reactors, and EALs corresponding to applicable emergency classes should be determined:

(a) Impairment of a critical safety function;

(i) Failure to stop nuclear reaction[46];

(ii) Insufficient core cooling[47] related to the water level in the pressure vessel;

(iii) Insufficient core cooling related to the core exit temperature[48];

(iv) Insufficient core cooling related to residual heat removal[49];

(v) For a pressurized water reactor, abnormal primary system temperature[50];

(vi) Loss of AC or DC power sources;

(vii) Loss of or degraded control of safety systems including post-accident instrumentation[51].

(b) Loss of fission product barriers: Loss of integrity of the fuel clad barrier, reactor coolant system barrier or containment barrier.

[46] 'Stop nuclear reaction' is a general term that includes 'reactor scram', which is used only for the insertion of control rods into the reactor.

[47] Insufficient core cooling is characterized by three kinds of entry conditions: vessel level, core temperature and residual heat removal capability. These conditions are valid for both pressurized water reactors and boiling water reactors, and are put before the primary system temperature, which is relevant for pressurized water reactors only.

[48] Elevated core exit temperature is a direct symptom of core cooling degradation for pressurized water reactors. Therefore, this symptom is used as an entry condition for inadequate core cooling. 650°C is a value usually used for inadequate core cooling in emergency procedures and indicates that steam – Zr reaction will start to produce hydrogen; 800°C indicates core damage that starts at core temperature about 1200°C.

[49] The operations of pumps, piping, heat exchangers, heat sinks, power supply and auxiliary fluid are considered.

[50] Temperature is to be measured in the vessel. Most pressurized water reactors have core exit thermocouples to measure temperatures in the vessel. The average of the highest four core exit thermocouple readings can be used. If there is water flow, the hot leg temperature (T_{hot}) could be used if core exit thermocouples are not available, although this indication is less prompt. For boiling water reactors there are no instruments that provide a valid reading of core temperature.

[51] Safety system control capability can be either degraded or completely lost; both cases are reflected. Unreliable functioning of several safety system instruments or alarms and unavailability of safety system instruments or controls are considered. Post-accident instrumentation provides the essential information to support safety system operation and control.

(c) Increased radiation levels;

(i) Effluent release rates greater than a specified multiple of the average annual discharge rate;

(ii) High radiation levels in the control room or other areas requiring continuous access for safety system operation and maintenance[52];

(iii) High radiation levels in areas requiring occasional occupancy to maintain or control safety systems;

(iv) Elevated containment (for boiling water reactors, dry well)[53] radiation levels[52];

(v) Unplanned increase in plant radiation levels as indicated by monitors;

(vi) High radiation levels at or[54] beyond the site boundary.

(d) Conventional emergencies, natural events, nuclear security events;

(i) Major natural events such as earthquake, tornado, flooding, high winds, hurricane, tsunami, storm surge, low water level or lightning strike;

(ii) Conventional emergencies such as fire or explosion (including turbine failure), vehicle or aircraft crash, and toxic or flammable gases including, for boiling water reactors, hydrogen in dry well[55];

(iii) Evacuation of the main control room[56];

(iv) Nuclear security event (e.g. sabotage of a nuclear facility or airborne attack);

(v) Loss of communications;

(vi) Plant shift supervisor's assessment about the emergency class.

(e) Spent fuel pool events: Abnormal spent fuel conditions (e.g. the water level of the pool).

[52] Inconsistent monitor readings could result from incomplete mixing, a failed monitor or irradiation from a contaminated system nearby. Monitors might show high, low or centre range if they fail. Readings can be confirmed using hand held monitors outside the area.

[53] For boiling water reactors, the dry well instead of the containment is more appropriate.

[54] Ambient dose equivalent rate is usually measured at the site boundary. However, if any measurement of ambient dose equivalent rate beyond the site boundary is available, it can be used for the purpose of this EAL.

[55] For boiling water reactors, hydrogen concentration in drywell could increase which can cause significant damage in case of ignition.

[56] In the case of a necessity to evacuate the main control room, the ability to control the plant is affected (the severity of the situation depends on the plant design).

APPENDIX III. OBSERVABLES AND INDICATORS FOR EMERGENCIES OCCURRING IN ACTS AND ACTIVITIES IN EMERGENCY PREPAREDNESS CATEGORY IV

III.1. Paragraph 3.18 of DS504 [10] states [DS504 is currently in draft]:"For authorized activities in emergency preparedness category IV, the response plans and procedures developed by the operating organization should describe the arrangements to organise the first response on the emergency site. These arrangements should allow the following actions to be taken, as appropriate, by the operator of the source or, if the operator is in such condition (e.g. unconscious) that unable to act, the first responders arriving first on the site:

(a) Prompt recognition of the nature and severity of the event based on predefined indicators (e.g. labels, placards, UN marking) or observables (e.g. increased dose rates, package damage)".

III.2. This Appendix provides guidance on and examples of observables of hazardous conditions and indicators of the presence of a dangerous source at the site of an emergency occurring in acts and activities in EPC IV. Examples of indicators of the presence of a dangerous source are given in Table 10 and are illustrated in Figs 5 and 6. For transport, refer to IAEA Safety Standards Series No. SSR-6 (Rev. 1), Regulations for the Safe Transport of Radioactive Material [26] and SSG-65 [15] or their latest edition when applicable).

TABLE 10. EXAMPLES OF INDICATORS OF THE PRESENCE OF A DANGEROUS SOURCE

Indicators of a dangerous source
Radiation symbols in an area or on a building (see Fig. 5)
A heavy container (i.e. indicating the presence of a large quantity of shielding) bearing a radiation symbol[a]
Transport package with labels, placards, and UN numbers [28]
Vehicle with placards and UN numbers [28]
Devices used for cancer treatment involving radioactive sources (teletherapy or brachytherapy)
Devices for irradiation used in healthcare and industry
Radiography sources
Well logging sources
Gauges containing radioactive sources used in manufacturing

Dangerous quantity of material (> D-value), as assessed by a radiological assessor

[a] Many objects contain lower activity sources that are not considered dangerous, for example portable moisture density gauges, smoke detectors, tritium signs, watches and compasses with illuminated dials.

[b] DS504 [10] provides further recommendations and Ref. [17] provide guidance in determining if a radioactive source is dangerous.

FIG. 5. Radiation symbols. The figure on the left is the trefoil radiation warning symbol. The figure on the right is the new standard ionizing radiation warning supplementary symbol.

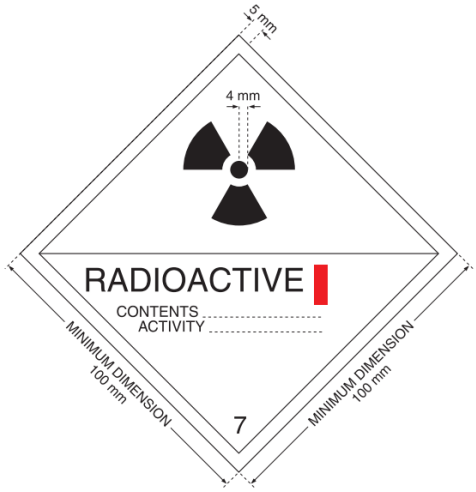


FIG. 6. An example of labels used on packages containing radioactive material and fissile material (SSR-6 (Rev. 1) [26]*)*

III.3. Recommendations on the radii of inner cordoned off areas for radiological emergencies are provided in appendix VI of DS504 [10]. These are associated with observables of hazardous conditions and reproduced in Table 11.

TABLE 11. SUGGESTED RADIUS OF THE INNER CORDONED OFF AREA (SAFETY PERIMETER) FOR A RADIOLOGICAL EMERGENCY[a] (reproduced from DS504 [10])

Situation/Observables of hazardous conditions	**Initial inner cordoned off area (safety perimeter)**
Initial determination — outside	
Unshielded or damaged potentially dangerous source	30 m radius around the source
Major spill from a potentially dangerous source	100 m radius around the source
Fire, explosion or fumes involving a dangerous source	300 m radius
Suspected bomb (possible radiological dispersal device), exploded or unexploded	400 m radius or more to protect against an explosion
Conventional (non-nuclear) explosion or a fire involving a nuclear weapon (no nuclear yield)	1000 m radius
Initial determination — inside a building	
Damage, loss of shielding or spill involving a potentially dangerous source	Affected and adjacent areas (including floors above and below)
Fire or other event involving a potentially dangerous source that can spread radioactive material throughout the building (e.g. through the ventilation system)	Entire building and appropriate outside distance as indicated above
Expansion based on radiological monitoring	
OIL2 in Table 5	Wherever these levels are measured

[a] Suggested values are based on expert judgement taking into account actual cases and experience of Member States.

REFERENCES

[1] FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS, INTERNATIONAL ATOMIC ENERGY AGENCY, INTERNATIONAL CIVIL AVIATION ORGANIZATION, INTERNATIONAL LABOUR ORGANIZATION, INTERNATIONAL MARITIME ORGANIZATION, INTERPOL, OECD NUCLEAR ENERGY AGENCY, PAN, Preparedness and Response for a Nuclear or Radiological Emergency, IAEA Safety Standards Series No. GSR Part 7, Vienna: IAEA, 2015.

[2] EUROPEAN COMMISSION, FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS, INTERNATIONAL ATOMIC ENERGY AGENCY, INTERNATIONAL LABOUR ORGANIZATION, OECD NUCLEAR ENERGY AGENCY, PAN AMERICAN HEALTH ORGANIZATION, UNITED NATIONS ENVIRONMENT PROGRAMME, WORLD , *Radiation Protection and Safety of Radiation Sources: International Basic Safety Standards, IAEA Safety Standards Series No. GSR Part 3*, Vienna: IAEA, 2014.

[3] INTERNATIONAL ATOMIC ENERGY AGENCY, *Actions to Protect the Public in an Emergency due to Severe Conditions at a Light Water Reactor, EPR-NPP Public Protective Actions 2013,* Vienna: IAEA, 2013.

[4] INTERNATIONAL ATOMIC ENERGY AGENCY, *Operational Interventaion Levels for Reactor Emergencies and Methodology for Their Derivation, EPR-NPP-OILs 2017,* Vienna: IAEA, 2017.

[5] INTERNATIONAL ATOMIC ENERGY AGENCY, *Considerations in the Development of a Protection Strategy for a Nuclear or Radiological Emergency, EPR-Protection Strategy 2020,* Vienna: IAEA, 2021.

[6] INTERNATIONAL ATOMIC ENERGY AGENCY, *Operational intervention levels for radiological emergencies, EPR-RAD OILs (under development),* Vienna: IAEA, (in preparation).

[7] INTERNATIONAL ATOMIC ENERGY AGENCY, Medical Management of Persons Internally Contaminated with Radionuclides in a Nuclear or Radiological Emergency - A Manual for Medical Personnel, EPR-Internal Contamination 2018, Vienna: IAEA, 2018.

[8] INTERNATIONAL COMMISSION ON RADIOLOGICAL PROTECTION, *The 2007 Recommendations of the International Commission on Radiological Protection, ICRP Publication 103, Ann. ICRP 37 (2-4),* Elsevier, 2007.

[9] INTERNATIONAL COMMISSION ON RADIOLOGICAL PROTECTION, Radiological protection of people and the environment in the event of a large nuclear accident: update of ICRP Publications 109 and 111. ICRP Publication 146.Ann. ICRP 49(4), New York City: Sage, 2020.

[10] INTERNATIONAL ATOMIC ENERGY AGENCY, *Arrangements for Preparedness and Response for a Nuclear or Radiological Emergency, draft General Safety Guide No. DS504,* Vienna: IAEA, (in preparation).

[11] INTERNATIONAL ATOMIC ENERGY AGENCY, *Protection Strategy for a Nuclear or Radiological Emergency draft General Safety Guide No. DS534,* Vienna: IAEA, (in preparation).

[12] INTERNATIONAL ATOMIC ENERGY AGENCY, *Arrangements for the Termination of a Nuclear or Radiological Emergency,IAEA Safety Standards Series No. GSG-11,* Vienna: IAEA, 2018.

[13] INTERNATIONAL ATOMIC ENERGY AGENCY, *Arrangements for Communication with the Public in Preparedness and Response for a Nuclear or Radiological Emergency, IAEA Safety Standards Series No. GSG-14,* Vienna: IAEA, 2020.

[14] INTERNATIONAL ATOMIC ENERGY AGENCY, *Preparedness and Response for a Nuclear or Radiological Emergency Involving the Transport of Radioactive Material, IAEA Safety Standards Series No. SSG-65,* Vienna: IAEA, 2022.

[15] INTERNATIONAL ATOMIC ENERGY AUTHORITY, *IAEA Nuclear Safety and Security Glossary, Terminology Used in Nuclear Safety, Nuclear Security, Radiation Protection and Emergency Preparedness and Response (interim edition),* Vienna: IAEA, 2022.

[16] UNITED NATIONS SCIENTIFIC COMMITTEE ON THE EFFECTS OF ATOMIC RADIATION, Source, Effects and Risks of Ionizing Radiation, Report to the General Assembly, with Scientific Annexes A and B, UNSCEAR 2012 Report to the General Assembly, New York: United Nations, 2015.

[17] INTERNATIONAL ATOMIC ENERGY AGENCY, *Dangerous Quantities of Radioactive Material, EPR-D-VALUES (2006),* Vienna: IAEA, 2006.

[18] INTERNATIONAL ATOMIC ENERGY AGENCY, INTERNATIONAL LABOUR ORGANIZATION, *Occupational Radiation Protection, IAEA Safety Standards Series No. GSG-7,* Vienna: IAEA, 2018.

[19] INTERNATIONAL ATOMIC ENERGY AGENCY, *Manual for First Responders to a Radiological Emergency, EPR-First Responders (2022),* Vienna: IAEA, (in preparation).

[20] INTERNATIONAL ATOMIC ENERGY AGENCY, Lessons Learned from the Response to Radiation Emergencies (1945–2010), EPR-Lessons Learned 2012, Vienna: IAEA, 2012.

[21] INTERNATIONAL ADVISORY COMMITTEE, The International Chernobyl Project: Technical Report, Vienna: IAEA, 1991.

[22] INTERNATIONAL ATOMIC ENERGY AGENCY, The Fukushima Daiichi Accident, 6 vols, Vienna: IAEA, 2015.

[23] T. McKENNA, E. BUGLOVA and V. KUTKOV, "Lessons learned from Chernobyl and other emergencies: Establishing international requirements and guidance," *Health Phys.*, no. 93 5, p. 527–537, 2007.

[24] CODEX ALIMENTARIUS COMMISSION, *Codex General Standard for Contaminants and Toxins in Food and Feed, Schedule 1 — Radionuclides, CODEX STAN 193-1995*, Rome: Codex Alimentarius Commission, 2006.

[25] WORLD HEALTH ORGANIZATION, Guidelines for drinking-water quality: fourth edition incorporating the first and second addenda, Geneva: WHO, 2022.

[26] INTERNATIONAL ATOMIC ENERGY AGENCY, Regulations for the Safe Transport of Radioactive Material 2018 Edition, No. SSR-6 (Rev. 1), Vienna: IAEA, 2018.

[27] INTERNATIONAL ATOMIC ENERGY AGENCY, *Development of an extended framework for emergency response criteria, IAEA-TECDOC-1432*, Vienna: IAEA, 2005.

[28] INTERNATIONAL COMMISSION ON RADIOLOGICAL PROTECTION, *Assessing Dose of the Representative Person for the Purpose of Radiation Protection of the Public and the Optimisation of Radiological Protection: Broadening the Process, Publication 101*, Oxford: Elsevier, 2006.

[29] WORLD HEALTH ORGANIZATION, *Iodine thyroid blocking: Guidelines for use in planning and responding to radiological and nuclear emergencies*, Geneva: WHO, 2017.

[30] INTERNATIONAL ATOMIC ENERGY AGENCY, *Generic Assessment Procedures for Determining Protective Actions during a Reactor Accident, IAEA-TECDOC-955*, Vienna: IAEA, 1997.

[31] INTERNATIONAL AGENCY FOR RESEARCH ON CANCER, Thyroid Health Monitoring After Nuclear Accidents, IARC Tecnical Publication No. 46, Geneva: WHO, 2018.

[32] EUROPEAN ATOMIC ENERGY COMMUNITY, FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS, INTERNATIONAL ATOMIC ENERGY AGENCY, INTERNATIONAL LABOUR ORGANIZATION, INTERNATIONAL MARITIME ORGANIZATION, OECD NUCLEAR ENERGY AGENCY, PAN AMERICAN HEALTH ORGANIZA, Fundamental Safety Principles, IAEA Safety Standards Series No. SF-1, Vienna: IAEA, 2006.

[33] INTERNATIONAL COMMISSION ON RADIOLOGICAL PROTECTION, Doses to the Embryo and Fetus from Intakes of Radionuclides by the Mother (Corrected version, May 2002) ICRP Publication 88, Oxford: Pergamon Press, 2000.

[34] INTERNATIONAL ATOMIC ENERGY AGENCY, The International Chernobyl Project: Technical Report, Vienna: IAEA, 1991.

[35] I. LIKHTAROV et al., "Estimation of the thyroid doses for Ukrainian children exposed in utero after the Chernobyl accident," *Health Phys.*, vol. 100, no. 6, p. 583–593, 2011.

[36] INTERNATIONAL COMMISSION ON RADIOLOGICAL PROTECTION, ICRP Statement on Tissue Reactions / Early and Late Effects of Radiation in Normal Tissues and Organs – Threshold Doses for Tissue Reactions in a Radiation Protection Context. ICRP Publication 118. Ann. ICRP 41(1/2), Amsterdam: Elsevier, 2012.

Annex

DOSIMETRIC QUANTITIES FOR A NUCLEAR OR RADIOLOGICAL EMERGENCY

A–1. The quantities of effective dose, equivalent dose and RBE weighted absorbed dose are used in evaluating radiation induced consequences of a nuclear or radiological emergency. They are listed together with their intended purpose in Table A–1, and illustrated in Fig. A–1.

TABLE A–1. DOSIMETRIC QUANTITIES COMMONLY USED IN EMERGENCY EXPOSURE SITUATIONS

Dosimetric quantity	Symbol	Purpose
	Dose quantities	
Absorbed dose	$D_{R,T}$	The fundamental dosimetric quantity
RBE weighted absorbed dose	AD_T	For evaluating deterministic effects induced as a result of exposure of an organ or tissue
Equivalent dose	H_T	For evaluating stochastic effects induced as a result of exposure of an organ or tissue
Effective dose	E	For evaluating detriment related to the occurrence of stochastic effects in an exposed population
	Operational dose quantities	
Personal dose equivalent	$H_P(d)$	For monitoring external exposure of an individual
Ambient dose equivalent	$H^*(d)$	For monitoring a radiation field (strongly penetrating radiation)

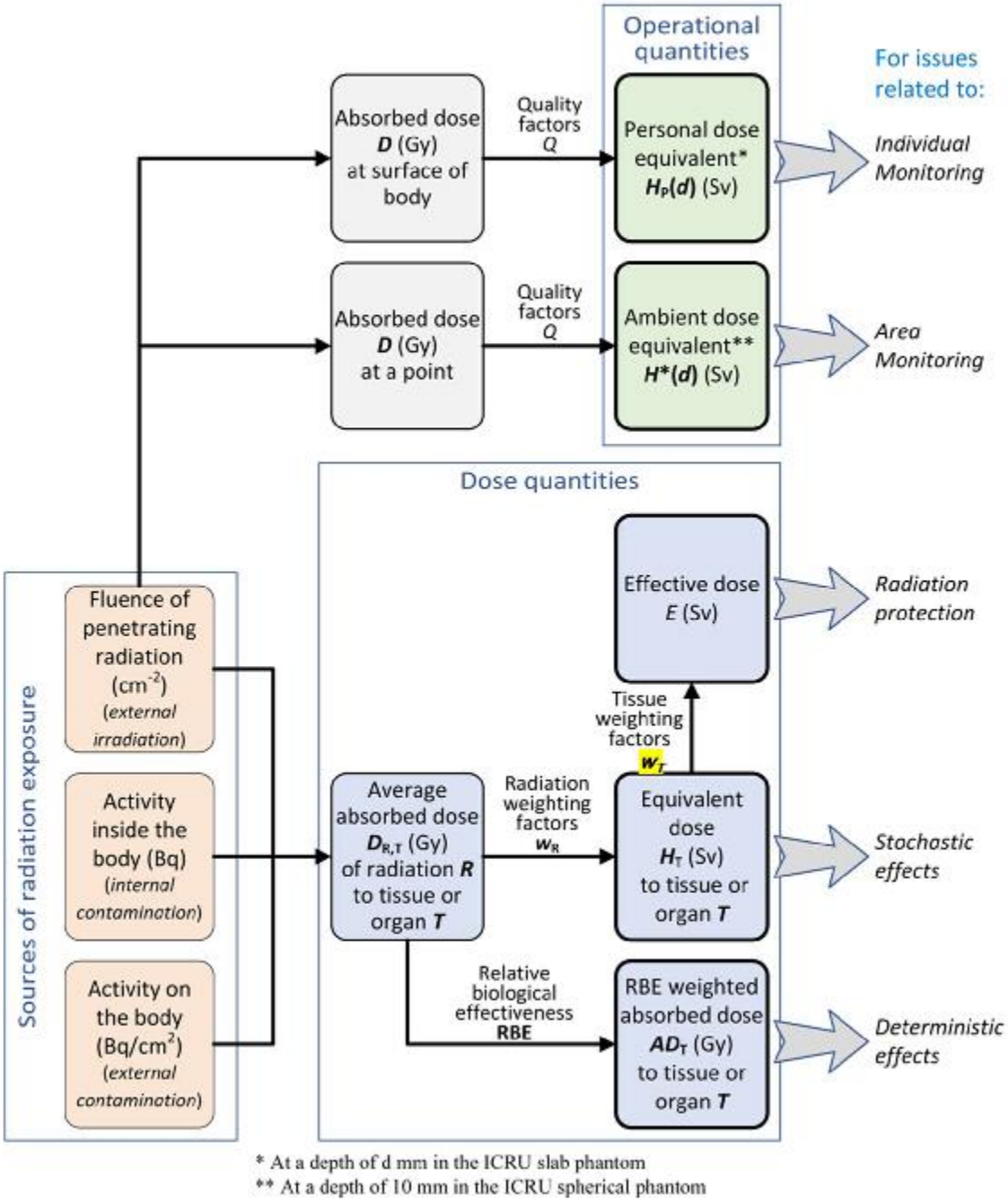


FIG. A–1. Dosimetric quantities and their application in emergency exposure situations.

A–2. Absorbed dose, D is the fundamental dose quantity, and it is defined as:

$$D = \frac{\mathrm{d}\bar{\varepsilon}}{\mathrm{d}m} \tag{1}$$

where $\mathrm{d}\bar{\varepsilon}$ is the mean energy imparted by ionizing radiation to matter in a volume element and $\mathrm{d}m$ is the mass of matter in the volume element. The SI unit for absorbed dose is joule per kilogram (J/kg), termed the gray (Gy) [A–1].

A–3. The relative biological effectiveness (RBE) weighted absorbed dose, AD_{T} is defined as:

$$AD_{\mathrm{T}} = \sum_{\mathrm{R}} D_{\mathrm{R,T}} \times RBE_{\mathrm{R,T}} \tag{2}$$

where $D_{\mathrm{R,T}}$ is the absorbed dose delivered by radiation of type R averaged over a tissue or organ T and $RBE_{\mathrm{R,T}}$ is the relative biological effectiveness [A–2] for radiation of type R in the production of severe deterministic effects in a tissue or organ T.

A–4. The value of RBE depends on the type and energy of radiation. The RBE weighted absorbed dose is used for evaluating deterministic effects induced as a result of exposure of an organ or tissue. The SI unit for RBE weighted absorbed dose is joule per kilogram (J/kg), termed the gray (Gy) (GSR Part 3 [A–3], Ref. [A–4]).

A–5. The equivalent dose, H_{T} is the dose in a tissue or organ T given by:

$$H_{\mathrm{T}} = \sum_{\mathrm{R}} D_{\mathrm{R,T}} \times w_{\mathrm{R}} \tag{3}$$

where $D_{\mathrm{R,T}}$ is the mean absorbed dose from radiation R in a tissue or organ T, and w_{R} is the radiation weighting factor [A-1]. The equivalent dose is used for assessment of the risk of incurring radiation induced cancer in an organ or tissue. It is expressed in sieverts (Sv).

A–6. The effective dose is widely used in justifying and optimizing protective actions and is expressed in sieverts (Sv) [A–1]. The effective dose (E) includes the doses due to external exposures and due to intakes (internal exposures):

$$E = \sum_{\mathrm{T}} H_{\mathrm{T}} \times w_{T} \tag{4}$$

where w_T is the tissue weighting factor [A–1].

A–7. Ambient dose equivalent is defined as the dose equivalent that would be produced by the corresponding aligned and expanded field in the ICRU sphere at a depth d on the radius vector opposing the direction of the aligned field. It is used as a directly measurable proxy (i.e. substitute) for effective dose for use in monitoring of external exposure. The recommended value of d for strongly penetrating radiation is 10 mm.

A–8. Personal dose equivalent is defined as the dose equivalent in soft tissue below a specified point on the body at an appropriate depth d. It is used as a directly measurable proxy (i.e. substitute) for equivalent dose in tissues or organs or (with d = 10 mm) for effective dose, in individual monitoring of external exposure. The recommended values of d are 10 mm for strongly penetrating radiation and 0.07 mm for weakly penetrating radiation.

A–9. Ambient dose equivalent and personal dose equivalent are operational quantities[1] based on the quantity of dose equivalent. The dose equivalent is the product of the absorbed dose at a point and the appropriate quality factor (Q_{R}) for the type of radiation giving rise to the dose [A–5]:

$$H = \sum_{\mathrm{R}} D_{\mathrm{R}} \times Q_{\mathrm{R}} \tag{5}$$

[1] The International Commission on Radiation Units and Measurements (ICRU) has reviewed the operational quantities and suggested new definitions [A–6] which have been adopted by the ICRP [A–1]. The operational quantities were renamed personal dose, H_{p}, and ambient dose, H^*. The ICRP/ICRU anthropomorphic adult reference phantoms [A–7] are used for the calculation of the personal dose and ambient dose for the better approximation of the effective dose. In 2020, the ICRU anticipated the time required for incorporation of the recommended operational quantities in the standards and legislation to be around twenty years [A–6], and the new operational quantities are not yet in use in the current dosimeters and area monitoring equipment.

REFERENCES TO ANNEX

[A–1] INTERNATIONAL COMMISSION ON RADIOLOGICAL PROTECTION, Use of Dose Quantities in Radiological Protection, ICRP Publication 147, Ann. ICRP 50(1), ICRP, 2021.

[A–2] INTERNATIONAL COMMISSION ON RADIOLOGICAL PROTECTION, Relative Biological Effectiveness (RBE), Quality Factor (Q) and Radiation Weighting Factor (wR), ICRP Publication 92, Ann. ICRP 33 4, Amsterdam: Elsevier, 2003.

[A–3] EUROPEAN COMMISSION, FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS, INTERNATIONAL ATOMIC ENERGY AGENCY, INTERNATIONAL LABOUR ORGANIZATION, OECD NUCLEAR ENERGY AGENCY, PAN AMERICAN HEALTH ORGANIZATION, UNITED NATIONS ENVIRONMENT PROGRAMME, WORLD , Radiation Protection and Safety of Radiation Sources: International Basic Safety Standards, IAEA Safety Standards Series No. GSR Part 3, Vienna: IAEA, 2014.

[A–4] INTERNATIONAL ATOMIC ENERGY AUTHORITY, IAEA Nuclear Safety and Security Glossary, Terminology Used in Nuclear Safety, Nuclear Security, Radiation Protection and Emergency Preparedness and Response (interim edition), Vienna: IAEA, 2022.

[A–5] INTERNATIONAL COMMISSION ON RADIATION UNITS AND MEASUREMENTS, Quantities and Units in Radiation Protection Dosimetry, ICRU Rep. 51, Bethesda: ICRU, 1993.

[A–6] International Commission on Radiation Units and Measurements, Operational Quantities for External Radiation Exposure. ICRU Report 95, Bethesda, MD: ICRU, 2020.

[A–7] International Commission on Radiological Protection, Adult Reference Computational Phantoms, Joint ICRP/ICRU Report. ICRP Publication 110 Ann. ICRP 39 (2), Elsevier, 2009

CONTRIBUTORS TO DRAFTING AND REVIEW

Close, L.	Radiation Protection Bureau Health Canada, Canada
Gokeri, G.	International Atomic Energy Agency
Homma, T.	Japan Atomic Energy Agency, Japan
Kouts, K.	International Atomic Energy Agency
Motomitsu. K.	Nuclear Regulation Authority, Japan
Nestoroska Madjunarova, S.	International Atomic Energy Agency
Orr, B. W.	Australian Radiation Protection and Nuclear Safety Agency, Australia
Seifert S.	Federal Office for Radiation Protection, Germany
Stephani, F.	International Atomic Energy Agency
Winkler, G.	International Atomic Energy Agency