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2013

EMERGENCY PREPAREDNESS AND RESPONSE

Actions to Protect the Public in an Emergency due to Severe Conditions at a Light Water Reactor

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ACTIONS TO PROTECT THE PUBLIC IN AN EMERGENCY DUE TO SEVERE CONDITIONS AT A LIGHT WATER REACTOR

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INTERNATIONAL ATOMIC ENERGY AGENCY
VIENNA, 2013

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FOREWORD

Under Article 5.a(ii) of the Convention on Assistance in the Case of a Nuclear Accident or Radiological Emergency (the ‘Assistance Convention’), one function of the IAEA is to collect and disseminate to States Parties and Member States information concerning methodologies, techniques and results of research relating to response to a nuclear or radiological emergency. This publication is intended to help fulfil in part these functions assigned to the IAEA in the Assistance Convention.

The aim of this publication is to provide those persons who are responsible for making and for acting on decisions in the event of an emergency at a light water reactor with an understanding of the actions that are necessary to protect the public. The publication provides a basis for developing the tools and criteria at the preparedness stage that would be needed in taking protective actions and other actions in response to such an emergency.

The publication applies the safety principles stated in IAEA Safety Standards Series No. SF-1, Fundamental Safety Principles, and it will be of assistance to Member States in meeting the requirements established in IAEA Safety Standards Series No. GS-R-2, Preparedness and Response for a Nuclear or Radiological Emergency. The application of these requirements is intended to minimize the consequences for people and the environment in any nuclear or radiological emergency. This guidance should be adapted to fit the State’s organizational arrangements, language, terminology, concept of operation and capabilities.

The IAEA General Conference, in resolution GC(55)/RES/9:

> “Emphasizes the importance for all Member States to implement emergency preparedness and response mechanisms and develop mitigation measures at a national level, consistent with the Agency’s Safety Standards, for improving emergency preparedness and response, facilitating communication in an emergency and contributing to harmonization of national criteria for protective and other actions”.

This publication is issued in the IAEA’s Emergency Preparedness and Response (EPR) Series. It takes account of the lessons learned from responses in past emergencies, including lessons from the accident at Tokyo Electric Power Company’s Fukushima Daiichi nuclear power plant in Japan in 2011, and of feedback from research, while ensuring consistency with IAEA Safety Standards Series No. GS-R-2.

The IAEA officer responsible for this publication was T. McKenna of the Incident and Emergency Centre, Department of Nuclear Safety and Security.

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1. INTRODUCTION

1.1. BACKGROUND

An emergency at a nuclear power plant that involves damage to fuel in the reactor core or in a spent fuel pool can cause deaths, severe health effects[1] and psychological effects, and can also have economic and sociological consequences affecting the public. These effects can be prevented or mitigated by the prompt implementation of protective actions and other response actions.

Radioactive material from damaged fuel released into the atmosphere will form a plume. In the most severe emergencies, this plume can possibly result in injuries and deaths within hours of a release for those located within about 2 to 5 km of the nuclear power plant if protective actions are not taken. These injuries would be the result of inhalation of, and from external exposure due to, the radioactive material in the plume, or from exposure to radiation emitted by radioactive material that is deposited on the ground. In order to be most effective in preventing these injuries, protective actions may need to be taken before arrival of the plume and thus needs to be initiated when severe conditions[2] are detected in the plant and not delayed in order to obtain environmental monitoring results. Further away from the nuclear power plant, within about 15 to 30 km, inhalation of the radioactive material in the plume could result in an increase in the cancer rates. Similarly, in order to be most effective in preventing these cancers, protective actions need to be taken before arrival of the plume and thus cannot be implemented based on environmental monitoring.

In order to be effective the protective actions need to be implemented promptly: first for those located within 3 to 5 km of the nuclear power plant, followed by those located within 15 to 30 km, when conditions are detected in the plant leading to severe damage to the fuel in the reactor core or spent fuel pool. To act promptly means to act *before* the beginning of a severe release[3]. The timing of a release is unpredictable, therefore actions to protect the public, in order to be most effective, need to be initiated immediately near the nuclear power plant when predetermined criteria are exceeded indicating that damage to the fuel in the reactor core or spent fuel pool has occurred, or will occur. The operator should have at least several hours and possibly several days warning before a severe release, thus allowing an opportunity to initiate protective actions before a release occurs.

The failure of off-site decision makers[4] to act promptly to implement urgent protective actions (e.g. evacuation or taking an iodine thyroid blocking agent) on being notified by the operators at the plant of the detection of conditions that could lead to damage to nuclear fuel could result in the occurrence of avoidable severe health effects. There would be no time for meetings to decide on what to do. Appendix I provides an analysis that demonstrates the need for prompt actions in order to prevent or mitigate severe health effects[1] among the public. However, protective actions need to be undertaken only when it is safe to do so and when they would not endanger the lives of those being evacuated[5] or relocated, including those in special facilities (e.g. patients in intensive care in hospitals or people in nursing homes).

The release could also result in deposition of radioactive material resulting in hot spots[6] where the dose to those in the area within days to weeks could exceed the international generic criteria (GC) [1] at which protective actions are justified to reduce the risk of radiation induced cancers (i.e. stochastic effects). This would principally be a concern within about 50 to 100 km of the nuclear power plant.

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[1] 'Severe health effects' are severe deterministic effects and stochastic effects, i.e. radiation induced cancers.
[2] Severe conditions are events at the nuclear power plant resulting in the classification of a General Emergency (see Section 3).
[3] A 'severe release' is an airborne release warranting urgent protective actions off the site.
[4] The off-site person(s) with the authority and responsibility to immediately, without further consultation, implement actions to protect the public.
[5] As discussed in Section 5.2, evacuations are not to be delayed on the grounds that a release is occurring provided that they can be conducted safely.

Consequently, following a release of radioactive material, monitoring needs to be performed to identify hotspots[6] that warrant evacuation within a day and relocation within a week to a month. Monitoring results will need to be compared with default operational intervention levels (OILs), which if exceeded will trigger a response action. These OILs are developed in advance at the preparedness stage, as there will be no time at the start of an emergency to develop such operational criteria.

The accidents at the nuclear power plants at Three Mile Island in the USA in 1979, Chernobyl in the USSR in 1986 and Fukushima in Japan in 2011 all showed that establishing criteria at the time of the emergency for justified protective and other response actions had been impossible as it was during a period of heightened emotions and mistrust of officials and of the scientific community. In addition, experience from these past accidents showed that decision makers were unable to act promptly to implement protective actions, because of delays caused by the lack of predetermined criteria.

Deposition of radioactive material from the plume at distances of 100 km and more from the nuclear power plant could also lead to contamination of food, milk and rainwater at levels that could result in thyroid cancers and could exceed the international generic criteria [1] for restrictions on consumption. The patterns of this deposition can be so complex that it is impossible to monitor enough of the area to effectively identify all the locations where food restrictions would be necessary. Consequently, prompt protection and restrictions for non-essential[7] local produce, wild-grown products (e.g. mushrooms and game), milk from grazing animals, rainwater,[8] animal feed[9] and commodities needs to be implemented *before* monitoring or sampling is carried out.

Psychological, economic and sociological effects have been among the most severe consequences of nuclear emergencies. In addition, in some emergencies the public, off-site officials and others[10] have taken inappropriate actions[11] that did more harm than good. This was often caused by: (a) not clearly communicating when the situation is safe and no protective or other response actions are required, (b) not placing in perspective in terms that are understandable the possible health hazard of the emergency, and (c) the concerns of others and the public not being promptly addressed. Therefore, decision makers will need to provide comprehensive reassurance to the public and others when the situation is safe and no protective actions or other response actions are required. In addition, off-site decision makers will need to be able to explain to the public and others the health hazards in the emergency in an understandable, concise and consistent way and need to be prepared to address their concerns. This requires prior preparation in order to provide a single message to put all the information that is reported during an emergency into perspective in terms of the health hazard.

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[6] See Section 6.3. for a description of hotspots.

[7] Restricting essential local produce, milk or water could result in malnutrition or other health consequences and therefore essential local produce needs to be restricted only if alternatives are available.

[8] Only consumption of non-essential drinking water that comes undiluted directly from the collection of rainwater is to be restricted. Other sources of drinking water (e.g. wells, reservoirs or rivers) will have much lower contamination levels due to dilution and will only need to be restricted if analysis of samples exceed predetermined levels.

[9] Applies only to animal feed stored outside and restrictions should not apply if alternative sources of food are not available.

[10] 'Others' refers to those undertaking their normal job following the declaration of a General Emergency (e.g. medical staff transporting or treating those from or in the affected area).

[11] Inappropriate actions include unjustified voluntarily abortions, unsafe evacuations that have caused deaths, unnecessary restrictions on imports, stigmatizing and shunning people from the affected area, refusal to treat patients from the affected area, and using inappropriate forms of iodine (such as antiseptic iodine solution) for the purpose of iodine thyroid blocking (ITB).

In summary, the objectives for the off-site decision maker in the event of an emergency involving severe damage to fuel in the core of a reactor or a spent fuel pool are to:

- Prevent injuries and deaths by initiating urgent protective actions for the public within 3 to 5 km, before a severe release, by acting promptly when conditions[12] are detected in the plant that can lead to severe damage to the fuel;

- Keep the doses to the public below the international GC at which protective actions and other response actions are justified to reduce the risk of stochastic effects (cancers) [1] and reduce economic impact by initiating the actions listed below promptly when conditions[12] are detected in the plant that can lead to severe damage to the fuel:

  - Protective actions for the public within about 15 to 30 km from the nuclear power plant; and

  - Restriction of non-essential[7] local produce, wild-grown products (e.g. mushrooms and game), milk from grazing animals, rainwater, animal feed[13] and commodities within about 100 to 300 km from the nuclear power plant;

- Keep the doses to the public below the international GC at which protective actions and other response actions are justified to reduce the risk of stochastic effects [1] by conducting monitoring out to distances of about 50 to 100 km to locate hot spots that require evacuation or relocation.

- Prevent or reduce psychological, economic and sociological effects by: (a) clearly communicating when the situation is safe and no protective or other response actions are required, (b) placing in perspective in terms that are understandable the possible health hazard of the emergency, (c) promptly addressing the concerns of the public, and (d) ensuring all traded goods meet international standards and to reassure interested parties (e.g. other States) that such controls are in place.

1.2. OBJECTIVE

This publication is intended to provide an understanding of the actions necessary to protect the public for those responsible for making and for acting on decisions in the event of an emergency involving actual or projected severe damage to the fuel in the reactor core or spent fuel pool at a light water reactor (LWR) or spent fuel pool. It provides a basis for developing the tools and criteria at the preparedness stage that would be needed in taking protective actions and other actions in response to an emergency. It could also be of direct use in the response to an emergency.

1.3. SCOPE

The publication is based on the latest IAEA safety standards [1, 2] and on lessons learned from previous emergencies, including lessons from the accident at Tokyo Electric Power Company's Fukushima Daiichi nuclear power plant in Japan in 2011 [3, 4]. It focuses on the emergency response arrangements for an emergency involving severe fuel damage to the core and/or spent fuel pool of a light water reactor (LWR). However, the tools and criteria can be adapted and applied to other reactor designs. The OILs and charts for placing the health hazard in perspective for measured quantities and doses can be used for releases from RBMK reactors, but may not be valid for CANDU (Canada Deuterium Uranium) reactors.

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[12] General Emergency conditions (see Section 3).

[13] Applies only to animal feed stored outside and restrictions if alternative sources of food are not available.

This publication applies for: (a) LWRs with power levels greater than 100 MW(th), and (b) spent fuel pools containing reactor fuel that needs to be actively cooled in order to prevent overheating and failure of the fuel. It is considered very unlikely that an emergency at a nuclear power plants with power levels below 100 MW(th) could lead to a potential release to the atmosphere warranting urgent protective actions and other protective actions off the site[14]. Therefore, nuclear power plants with a power level of less than 100 MW(th) are not considered in this publication.

1.4. STRUCTURE

After an introduction to the concept of operations, the main sections of this publication are structured to flow in the logical sequence relating to an emergency, i.e. taking actions upon detection of severe conditions at the nuclear power plant based on the predetermined emergency classification system, to the actions to be taken based on monitoring where predetermined operational intervention levels are exceeded, through to communication with the public. At the end of this publication guidance is given relating to interim and full implementation of the emergency preparedness capability. The appendices provide supporting and background information.

[14] A potential release of radioactive material to the atmosphere that could result in severe deterministic effects or eventually in a detectable increase in the incidence of radiation induced cancers in the population constitutes an emergency that would warrant urgent protective actions and other response actions off the site.

2. OVERALL CONCEPTS

2.1. EXAMPLE CONCEPT OF OPERATIONS

The concept of operations is a brief description of the response to an emergency used when planning your response. It needs to be developed at the beginning of the preparedness process to ensure that all those involved in the development of a response capability share a common vision.

This concept of operations presents an example of a response taken in the event of a severe emergency involving actual or projected severe damage to the fuel in a reactor core or spent fuel pool[15] that will meet the objectives given in Section 1.1. This concept of operations is a starting point and needs to be adapted to local conditions in order to be effective. It describes the response that is detailed in this publication. The steps in the example concept of operations are summarized in Section 2.2.

The emergency begins with the occurrence of an event (e.g. loss of a safety system) in the nuclear power plant or facility storing the spent fuel pool that will result in conditions (e.g. severe fuel damage) warranting taking urgent protective actions off-site before or shortly after a release in order to be effective in protecting the public.

Within about 15 minutes of detection of the event (or its symptoms), the nuclear power plant shift supervisor declares a General Emergency on the basis of predetermined conditions and instrument readings in the nuclear power plant. These instrument readings are called emergency action levels (EALs) and the declaration of a General Emergency triggers a coordinated response by all response organizations since each organization has predetermined the actions it is to take upon declaration of the emergency. The nuclear power plant staff also immediately take all possible on-site actions to prevent or mitigate any release and take immediate actions to protect the people on-site.

Within 30 minutes of detection of the event (or its symptoms), the shift supervisor notifies the off-site decision maker(s) responsible for the jurisdictions where urgent protective actions need to be taken promptly to reduce the risk to the public within the predetermined emergency zones and distances around the nuclear power plant, (i.e. precautionary action zone (PAZ), urgent protective action planning zone (UPZ), extended planning distance (EPD) and ingestion and commodities planning distance (ICPD)[16]). The shift supervisor recommends to the off-site decision maker(s) that they immediately start to take the predetermined urgent protective actions (e.g. evacuation, relocation, iodine thyroid blocking (ITB), food restrictions) needed to protect the public within these areas.

Within 45 minutes of detection of the event (or its symptoms), the off-site decision maker(s) starts implementation of the predetermined urgent protective actions by warning those near the nuclear power plant in the PAZ and the UPZ (e.g. with sirens and a loudspeaker to explain the siren) and informing them via media (i.e. means of public communication, including radio, television, internet web sites, newspapers and magazines and social media) of the actions to take. This is possible because provisions for prompt decision making and use of pre-recorded messages have been put in place. Within the PAZ the public needs to be instructed to immediately take ITB agent[17] and evacuate as soon as it is possible to do so safely[18]**.** Prior to evacuation the public needs to be instructed to shelter. Within the UPZ the public needs to be instructed to immediately take ITB agent and to shelter until instructed to evacuate. When there is a potential for a severe airborne release the population within the UPZ needs to be instructed to evacuate, as soon as it can be done so safely[18] without

[15] See Section 2.5 for more information).
[16] See Section 4 for more information on the emergency zones and distances.
[17] ITB agent can be immediately taken only if it has been pre-distributed in homes, schools, workplaces, hospitals and other special facilities.
[18] Safely evacuating means not endangering the lives of those being evacuated. For example, patients in hospitals or care homes do not need to be immediately evacuated if this will put them at immediate risk. Evacuation needs to be delayed until these patients can be moved safely.

within the UPZ needs to be instructed to evacuate, as soon as it can be done so safely[18] without delaying the evacuation of the PAZ. The evacuation of the UPZ may be phased in such a way that those areas at immediate risk are evacuated first (e.g. considering the projected wind direction), or in such a way that it can be implemented most effectively (e.g. optimization of the existing road network). However, ultimately the UPZ may need to be evacuated in all directions due to the wind shifts that could take place during a release or throughout the time period of a potential[19] severe release. The off-site decision maker(s) also instructs those in areas where contamination of food, water, milk or commodities could represent a risk (i.e. within the ICPD) to: (a) place grazing animals on stored (covered) feed, (b) protect drinking water supplies that directly use rainwater, (c) restrict consumption and distribution of non-essential local produce, wild-grown products (e.g. mushrooms and game), milk from grazing animals, rainwater, animal feed, and (d) restrict distribution of commodities until further assessments are performed.

Within 1 hour of detection of the event (or its symptoms), having been instructed in advance as part of the preparedness programme, the public start to promptly take the protective actions recommended.

Following a radioactive release, the areas not evacuated are promptly monitored. Based on predetermined operational criteria, called operational intervention levels (OILs[20]), areas are identified where additional protective actions and other response actions are warranted. The goal is to determine areas where the predetermined OILs are exceeded that require further:

- evacuation within a day;
- relocation within a week to a month; and
- restrictions on consumption of local produce, milk from grazing animals, rainwater and animal feed within days for those areas where ingestion will result in doses in excess of international criteria[21].

The operating organization of the nuclear power plant ensures that the people on the site, or those responding from off the site, are protected from all possible hazards. Any people who have been severely contaminated or exposed or those who have been evacuated needing medical attention (e.g. patients from nursing homes and hospitals) are taken to hospitals located outside the EPD which have been prepared to screen and treat contaminated and exposed individuals in accordance with predetermined procedures. Those transporting and treating contaminated individuals do so without hesitation because they know that they can do it safely if they use universal precautions (used to protect from infectious agents – surgical mask and gloves). Physicians treating exposed individuals consult national experts with experience in dealing with overexposures. Assistance in treating contaminated and exposed individuals can also be obtained through the IAEA or World Health Organization following Ref. [5]. Centres are established within hours outside of the UPZ to register, process, monitor and screen evacuees and to determine whether they need to receive immediate medical treatment or be registered for a later medical follow-up based on predetermined criteria. People who show symptoms of severe deterministic effects are examined and treated at predetermined and prepared hospitals located outside the EPD.

Soon after the public have been warned, the media are briefed by a single official spokesperson. Joint press briefings are held periodically with the participation of the operating organization of the nuclear power plant and local and national officials to provide a single and understandable message to the

[19] General Emergency conditions (see Section 3).
[20] See Section 6 for more information on OILs.
[21] Monitoring is used to identify where local produce, milk from grazing animals and rainwater needs to be immediately restricted. This is done to put restrictions in place for the areas where ingestion will result in doses in excess of international criteria and before results from time-consuming environmental sampling and analysis become available. However, actions to protect the ingestion pathway are not limited to where monitoring criteria are exceeded but also include a programme of food, milk and water sampling and analysis in the entire affected area, as soon as it can be established, to: (a) confirm adequacy of controls, (b) provide for additional restrictions, (c) provide for food replacements, and (d) to remove restrictions.

public and other interested parties. The briefings place information into perspective in terms of the possible health hazard and answer any concerns of the public and others. In all cases, the public and others are provided with a plain language explanation of the hazards to them, and the actions they can take to reduce those risks, as well as the actions being taken to ensure that they are safe and their interests are being protected. This applies to any event perceived as an emergency by the public or the media. The media (including internet web sites and social media) are monitored in order to identify and address inappropriate responses[22] being taken by the public and others and address new concerns that may arise.

Within hours of detection of the event (or its symptoms), the full emergency response, including all local and national response organizations, is activated and operating under a single emergency command system (ECS). For more information on the ECS see Appendix 13 of Ref. [6][23].

Within a day of detection of the event (or its symptoms), controls are implemented to ensure that all traded goods meet international standards and to reassure interested parties (e.g. other States) that such controls are in place.

Within a week implement a sampling and analysis programme to verify food, water and milk controls are adequate beyond where controls are already established and remove restrictions, as appropriate.

2.2. SUMMARY OF PROTECTIVE ACTIONS AND OTHER RESPONSE ACTIONS FOR THE EXAMPLE RESPONSE

Upon identification of conditions leading to severe fuel damage (i.e. General Emergency) take the following steps, as illustrated in FIG. 1:

Step 1. Within 15 minutes the shift supervisor declares a General Emergency on the basis of predetermined conditions and instrument readings in the nuclear power plant within the emergency classification system (EALs exceeded).

Step 2. Within 30 minutes the shift supervisor notifies[24] the off-site decision maker(s)[25] responsible for protecting the public within the PAZ, UPZ, EPD and ICPD.

Step 3. Within 45 minutes the off-site decision maker(s) starts implementing the urgent protective actions for the public, as detailed in Section 5

- instructs those within the PAZ to immediately:
  - take an ITB agent;
  - reduce inadvertent ingestion[26]; and
  - safely evacuate to beyond the UPZ [27, 28];

[22] Inappropriate actions include unjustified voluntarily abortions, unsafe evacuations that have caused deaths, unnecessary restrictions on imports, stigmatizing and shunning people from the affected area, refusal to treat patients from the affected area, and using inappropriate forms of iodine (such as antiseptic iodine solution) for the purpose of iodine thyroid blocking (ITB).

[23] The ECS is referred to as the incident command system (ICS) in Ref. [6].

[24] Needs to be accomplished by contacting a single off-site notification point so multiple calls are not needed.

[25] Including jurisdictions within the PAZ, UPZ, EPD and ICPD to include those in other States.

[26] Advise not to drink, eat or smoke and to keep hands away from the mouth until hands are washed and not to play on the ground or do other activities that could result in the creation of dust that could be ingested.

[27] If immediate evacuation is not possible (e.g. owing to snow, floods, or lack of transportation or a special facility such as a hospital), the public needs to shelter until safe evacuation is possible.

[28] 'Safely evacuating' or 'safely relocating' means not endangering the lives of those being evacuated or relocated. For example, patients in hospitals or care homes do not need to be immediately evacuated or relocated if this will put them at immediate risk. Evacuation or relocation needs to be delayed until these patients can be moved safely. Patients and those requiring specialized care should be evacuated beyond the EPD in order to

- instructs those within the UPZ to:
  - remain indoors (shelter in place) until evacuation;
  - take an ITB agent immediately;
  - reduce inadvertent ingestion[26] immediately; and
  - safely evacuate if the potential for a severe airborne release persists provided it will not delay the evacuation of the PAZ.[27, 28, 29]
- instructs those within the PAZ and UPZ who cannot evacuate immediately to:
  - take an ITB agent; and,
  - go inside (as feasible shelter in large buildings[30, 31]), shut the windows and doors, and listen to the radio or television for further instructions. Sheltering should not be implemented for a period of more than a day; and
  - prepare for evacuation to beyond the UPZ so that it can be undertaken safely[28].
- instructs those responsible for transportation systems (air, land, sea) to avoid the UPZ.
- instructs those within the EPD to take actions to reduce inadvertent ingestion[26].
- instructs those within the ICPD to:
  - place grazing animals on protected (e.g. covered) feed as appropriate and feasible;
  - protect food and drinking water sources (e.g. disconnect rainwater collection pipes);
  - stop consumption and distribution of non-essential[32] local produce, wild-grown products (e.g. mushrooms and game), milk from grazing animals, rainwater[33], animal feed[34] until concentration levels have been assessed using OIL7[35]; and
  - stop distribution of commodities until assessed.

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ensure multiple evacuations are not required. As discussed in Section 5.2, evacuations are not to be delayed on the grounds that a release is occurring.

[29] Evacuation of the UPZ may be phased in such a way that those areas at immediate risk are evacuated first (e.g. considering the projected wind direction), or in such a way to be implemented most effectively (e.g. optimization of the existing road network). However, ultimately the UPZ may need to be evacuated in all directions due to the wind shifts that could take place during a release or throughout the time period of a potential severe release.

[30] A large building is also called 'substantial' shelter.

[31] Where sheltering has been preplanned as the initial protective action (for special facilities, e.g. hospitals) arrangements need to be made in advance. (See Section 5.3).

[32] Restricting essential local produce, milk or water could result in malnutrition or other health consequences and therefore essential local produce needs to be restricted only if alternatives are available.

[33] Only consumption of non-essential drinking water that comes undiluted directly from the collection of rainwater is to be restricted. Other sources of drinking water (e.g. wells, reservoirs or rivers) will have much lower contamination levels due to dilution and will only need to be restricted if analysis of the samples exceed the OIL7 values.

[34] Applies only to animal feed stored outside and restrictions should not apply if alternative sources of food are not available.

[35] Restriction on consumption of food milk and rainwater produced in areas covered by an extensive online dose rate monitoring system could possibly be delayed until dose rates that exceed predetermined criteria are detected.

Step 4. Within 1 hour the public starts to take the recommended urgent protective actions.

Step 5. Within hours:

- a single official spokesperson briefs the media and initiates joint press briefings at a public information centre[36] with participation by the operating organization of the nuclear power plant and local and national officials;
- provide a consistent, understandable message to the public and other interested parties that presents information in perspective in terms of the health hazard and also answers any concerns; and
- monitor the actions of the public, others and the media (including web sites and social media) to identify and address inappropriate responses being taken and address new concerns that may arise.

Step 6. Within hours:

- establish centres outside the UPZ to register those who were in the PAZ and UPZ, monitor to identify those for whom skin or thyroid monitoring results exceed OIL4 or OIL8, decontaminate and perform medical screenings (in accordance with Section 2.3); and
- alert hospitals to prepare to treat contaminated[37] and exposed individuals. Physicians treating exposed individuals consult with national experts who have experience in dealing with overexposures and contaminated patients[38]. Assistance may be also obtained through the IAEA or the World Health Organization following Ref. [5].

Step 7. Within a day monitor to locate where OIL1 is exceeded and in those locations:

- safely evacuate[27, 28] those living in the area; and
- take other response actions indicated in Table 7.

Step 8. Within a day begin implementation of controls to ensure all trade meets international standards and to reassure interested parties (e.g. other States) that such controls are in place as discussed in Section 5.9.

Step 9. Within days monitor to locate where OIL3 is exceeded beyond the ICPD and in those locations[39]:

- implement additional food restrictions; and
- restrict consumption and distribution of local produce, milk, rainwater[33] animal feed[34] is indicated in Table 7.

[36] The public information centre is the location for the coordination of all official information released to the media concerning the emergency.

[37] The universal precautions against infection (gloves, mask, etc.) provide sufficient protection for those treating contaminated patients.

[38] Local physicians usually do not have the expertise needed to make such assessments.

[39] Monitoring and comparison with OIL3 values is used to identify where local produce, milk from grazing animals and rainwater needs to be immediately restricted because they clearly can exceed the OIL7 values. However, actions to protect the ingestion pathway are not limited to where the OIL3 criteria are exceeded but also include a programme of food, milk and water sampling and analysis in the entire affected area, as soon as it can be established, to determine if concentrations exceed OIL7 in order to: (a) confirm adequacy of controls, (b) provide for additional restrictions, (c) provide for food replacements, and (d) to remove restrictions.

Step 10. **Within a week** implement sampling and analysis programmes to verify food, water and milk controls are adequate to ensure concentrations are below the OIL7 values in Table 9.

Step 11. **Within a week to a month** monitor to locate where OIL2 is exceeded and in those locations:

- safely relocate[28] those living in the area; and
- take other response actions indicated in Table 7.

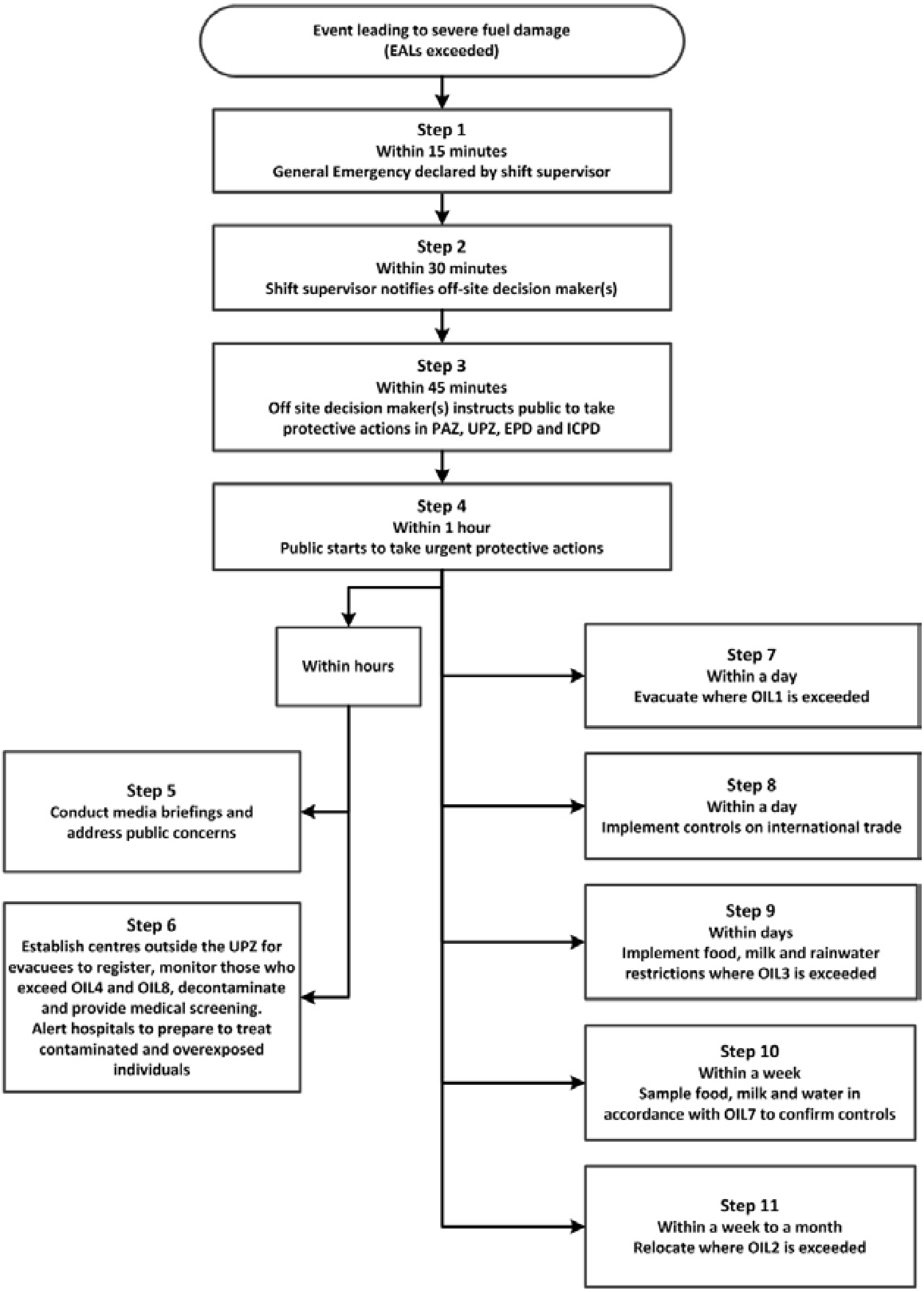


FIG. 1. Steps to take for an event that is projected to result in severe damage to the fuel in a reactor core or a spent fuel pool (General Emergency).

2.3. RESPONSE ACTIONS FOR THOSE POTENTIALLY EXPOSED

For all potentially exposed people and those evacuated or relocated:

- Register everyone, keeping families together. An example of a registration form is provided in Appendix IV.
- Immediately treat those with injuries: do not let the fear of contamination delay urgently needed medical treatment.
    - Severe medical problems (to include pre-existing medical problems that require continued treatment) need to be a priority! Provide immediate first aid, register and transport the seriously injured for further treatment.
    - It is always safe to treat an individual who may be contaminated by handling them as if they are until proven otherwise.
        - Wear gloves and wrap the patient in a sheet or blanket to contain the contamination during transportation.
        - Use universal precautions against infection (gloves, mask, etc.) which will provide sufficient protection for those treating contaminated patients.
- Send those that exhibit the symptoms of severe overexposure given in Ref. [30] for immediate examination and possible hospitalization.
- Instruct everyone to wash their hands before eating, drinking, smoking, or placing their hands near their mouths.
- Monitor skin and thyroid if monitoring capability is available:
    - Assess results of skin monitoring using OIL4 and take the indicated actions given in Table 8.
    - Assess results of thyroid monitoring using OIL8 and take the indicated actions given in Table 10.
- Instruct to decontaminate, if necessary, by removing outer clothing and washing hands and face.
- Instruct evacuees with pets to wash them once.
- If monitoring or decontamination capabilities are not immediately available, send people to an established centre beyond the UPZ (with the registration form) where it can be performed.
- If centres are not established beyond the UPZ and no capability for monitoring and decontamination is available, reassure the public that the risk to health from contamination is small and instruct those leaving that it is prudent to do the following:
    - Wash their hands before eating, drinking, smoking, or placing their hands near their mouths.
    - Shower and change clothes as soon as possible, place the removed clothing in a plastic bag until it can be dealt with.
    - Follow official instructions (e.g. from telephone hotlines, TV, radio and web sites).
- Collect the registration form from each person, making sure a means of contacting them has been provided.

2.4. TOOLS TO SUPPORT PROTECTIVE ACTION DECISION MAKING

Radioactive releases warranting protective actions off the site are unpredictable. They can occur via an unmonitored release route and can begin within minutes, but are more likely to begin at least several hours following severe damage to the fuel in the reactor core or spent fuel pool. The control room operators can project fuel damage before it occurs but cannot predict the timing or size of most severe releases[40] warranting urgent protective actions off the site. Therefore, to be most effective, urgent protective actions need to be initiated based on predetermined plant instrumentation levels or conditions (EALs) that indicate actual or projected severe damage to the fuel in the reactor core or

[40] Examples of causes of containment leakage/failure that are not predicable that can result in a severe release are: (a) hydrogen explosions, (b) overpressure, (c) by-pass, and (d) failure to isolate. The only release pathway that is predictable is intentional venting, and in most cases releases by this route would be smaller.

spent fuel pool (General Emergency, see Section 3). When these EAL levels are exceeded, the staff at the nuclear power plant will immediately notify off-site officials to trigger a coordinated response.

The control room operators cannot predict the timing, magnitude, composition, effective height and duration of most severe releases warranting urgent protective actions off the site. In addition, such a release could occur over several days resulting in very complex deposition patterns off-site. Consequently, dose projection models cannot be effectively used for making decisions concerning urgent protective actions that need to be taken before or shortly after the release in order to be most effective.

The above points are illustrated by the accidents at the Chernobyl nuclear power plant and Fukushima Daiichi nuclear power plant. For these accidents, the location, size and timing of the releases were not predicted, releases occurred over a period of days to weeks and the release rates and composition could not be assessed by the control room operators. In both cases, the release rates and mixture of the radioactive material had to be estimated based on dose rate and other environmental data following the release. Furthermore, the estimates of the size of the release continued to be revised more than one year after the accidents as more data became available [7, 8].

The experience from the Chernobyl and Fukushima emergencies is consistent with the results of severe accident analysis, which show that protective actions need to be implemented in all directions immediately when conditions in the plant indicate actual or projected damage to the fuel, since the timing, direction and duration of a release are not predictable.

Projections of wind direction may be useful in determining the areas within the PAZ or UPZ that need to be evacuated first if the population cannot be effectively evacuated in all directions simultaneously. After a release, wind directions and models may be useful in initially directing resources for off-site monitoring and sampling. However, monitoring and sampling needs to be conducted in all directions close to the nuclear power plant and not just in those areas indicated by models.

Model projections always need to be accompanied with a plain language explanation that stresses that the results are very uncertain and need to be qualified, and that the actual situation can only be assessed on the basis of monitoring results.

Dose projection models and other computer-based tools could also be used to assess environmental monitoring data in order to develop deposition and dose maps for decision-making.

Networks of automated environmental monitoring stations can also be useful in directing monitoring teams and when combined with operational intervention levels (OILs) in identifying areas warranting evacuation, relocation and food restrictions following a release.

In all cases, tools used as a basis for urgent protective actions must be integrated into decision-making systems in such a way that their use will not delay the implementation of urgent protective actions, especially for making decisions concerning those that need to be taken before or shortly after release to be most effective.

2.5. RESPONSE TO OTHER EMERGENCIES

As stated in the Scope (Section 1.3), the focus of this publication is on the emergency response arrangements for an emergency involving severe damage to the fuel in the core or spent fuel pool[41] of a LWR (events classified as a General Emergency, see Section 3). The underlying assumption of this publication, supported by research and experience, is that following severe fuel damage to the fuel in the core or spent fuel pool, severe releases can occur that warrant taking urgent protective actions promptly off-site. This is in order to prevent severe deterministic effects or reduce the risk of stochastic effects, in accordance with international guidance [1] (see Appendix I).

Releases from events not involving severe damage to the fuel in the reactor core or spent fuel pool probably can only result in doses off the site warranting protective actions due to ingestion of local produce, wild-grown products (e.g. mushrooms and game), milk from grazing animals, rainwater or other items that can be directly contaminated by a release. These events would be classified as a Site Area emergency (see Section 3).

In addition, emergencies not involving severe damage to the fuel could result in: (a) significant public concern, (b) the public taking inappropriate actions, and (c) economic consequences if protective and other response actions are not promptly taken. Events at nuclear facilities that would not result in the declaration of a Site Area Emergency (see Table 3) with little or no off-site radiological consequences may attract significant interest from the media or public that requires a prompt response to address concerns of the perceived risk.

Therefore, arrangements also need to be put in place to respond promptly to Site Area Emergencies and events that attract significant interest from the media or public. These arrangements could be built on the tools and criteria provided in this publication.

[41] General Emergences that can result in uncovering of the fuel for sufficient time to cause overheating of the fuel, resulting in significant fuel cladding failure and a release of radioactive materials (fission products) from the fuel.

3. EMERGENCY CLASSIFICATION SYSTEM

A prompt and effective response can only be implemented if everyone knows what to do when the emergency is declared. This rapid and coordinated response is accomplished through the use of an emergency classification system. It is based on increasing levels of hazard for those on and off the site of the nuclear power plant and tied to the response needed for the protection of workers, the public and others.

The IAEA international requirements [9] suggest the following emergency classes related to possible off site consequences[42]:

- An **Alert** is declared once something uncertain, or a decrease in the level of protection has been detected, but no action is needed to protect those off the site;;
- A **Site Area Emergency** is declared when the population off the site need to prepare to take protective actions and other response actions and monitoring needs to be conducted in the vicinity of the facility;
- A **General Emergency** is declared when protective actions and other response actions need to be taken immediately to protect the public off the site.

Table 1 provides a description of the classes including a list of examples of events that correspond to the appropriate classification and a plain language explanation for the public.

[42] International requirements [9] also provides for a 'Facility Emergency' which is only declared when there is a risk to those on site but no risk off the site.

TABLE 1. DESCRIPTION OF THE EMERGENCY CLASSES

Class	Description related to the protection of the public off the site	Example events resulting in this classification	Plain language explanation for the public
General Emergency	Events resulting in an actual or substantial risk of an atmospheric release requiring immediate implementation of urgent protective actions[a] and other response actions off the site within the PAZ, UPZ, EPD and ICPD.	• Actual or projected severe[b] damage of the fuel in the reactor core or the spent fuel pool[c]. • Loss of safety functions projected to result in severe damage to the fuel in the reactor core or spent fuel pool, including loss of the ability to perform the following safety functions: ○ Shut the reactor down (establish reactor criticality control); ○ Keep the core covered (cool the fuel pins); ○ Remove decay heat from the reactor and the containment; ○ Maintain vital auxiliaries (e.g. AC/DC power and control systems, and instrumentation). • Detection of actual or imminent severe damage to the fuel in the reactor core or spent fuel pool. • Inability to control safety functions needed to protect the reactor core or spent fuel pool. • Detection of radiation levels off the site indicating actual severe damage to fuel (e.g. more than 100 µSv/h).	An emergency has occurred at [*insert name of the nuclear power plant*], which means that a release of radioactive material is possible. If a release occurs, those located within an emergency zone or distance of the nuclear power plant may not be safe. You need to follow the instructions given by local officials that will provide for your protection, with priority being given to those who are most at risk. You need to immediately [*insert appropriate instructions for the recommended protective actions and other response given in Table 4*]. Local officials will communicate when the situation is safe and no protective or other response actions are required.
Site Area Emergency	Events resulting in a major decrease in the level of protection for those on the site and near the nuclear power plant requiring: (a) immediate alerting of the public to prepare to take protective actions and other response actions; (b) activation of the emergency response organizations; and (c) monitoring in the vicinity	• Conditions such that any additional failures could result in a General Emergency. • Potential to disrupt the performance of safety functions needed to protect the fuel in the spent fuel pool. • Releases from events[d] not involving severe damage to the fuel in the reactor core or spent fuel pool that warrant taking protective actions (e.g. ingestion restrictions based on monitoring and sampling off the site).	An emergency has occurred at [*insert name of the nuclear power plant*], which at this time does not represent a risk to your safety; however, it is prudent for you to prepare to [*insert appropriate instructions for the recommended protective actions and other response given in Table 4*] if it becomes necessary to ensure your safety. The following actions [*insert action being taken, e.g. closing local schools*] are being taken as precautionary measures. Local officials will communicate when the situation is safe and no protective or other response actions are required. We are now assessing the situation and you may need to take further actions once the assessment is completed.

Class	Description related to the protection of the public off the site	Example events resulting in this classification	Plain language explanation for the public
	of the facility. Protective actions may need to be taken off the site following a release based on monitoring and sampling where operation intervention levels are exceeded following a release for some Site Area Emergencies.		
Alert	Events involving an uncertain or significant decrease in the level of protection of the public off the site.	• Abnormal conditions that warrant obtaining immediate additional assistance for the on-site operations staff. • Abnormal conditions that warrant increased preparedness on the part of off-site officials.	An emergency has occurred at [*insert name of the nuclear power plant*], which is being assessed and dealt with by the operating staff onsite. It does not represent a risk to those off-site and no protective or other response actions are required. However, the level of protection may have decreased for those on site. Off-site officials are increasing their preparedness in case events do warrant protection of the public off the site.

[a] A protective action that, in the event of an emergency, needs to be taken promptly in order to be effective. For more information on protective and other response actions see Section 5.
[b] Damage to fuel in the reactor core or spent fuel pool that can result in release warranting urgent protective action and other response actions off the site.
[c] Containing fuel requiring active cooling.
[d] For example, a release of reactor coolant (e.g. steam generator tube rupture) with leaking fuel.

Only a Site Area Emergency and General Emergency warrant an off-site response to alert the public or to implement protective actions and other response actions. A Site Area Emergency means that any additional failures at the nuclear power plant will result in severe damage to the fuel in the reactor core or in the spent fuel pool. Therefore, upon declaration of a Site Area Emergency it is prudent to advise the public to prepare to take protective actions and other response actions, to activate emergency response organizations and conduct radiological monitoring in the vicinity of the nuclear power plant. The declaration of a General Emergency means that either: (a) events have occurred at the nuclear power plant that will lead to severe damage to the fuel in the reactor core or the spent fuel pool, or (b) severe damage to the fuel has been detected. Therefore, the declaration of a General Emergency triggers immediate implementation of urgent protective actions and other response actions to protect the public.

An emergency is declared when an emergency action level (EAL) is exceeded. An EAL is a predetermined observable criterion, which if met, triggers the appropriate classification of the emergency and corresponding response actions. EALs are based on the information that is observable by the control room operators and is indicative of the possibility of damage to the fuel in the reactor core or in the spent fuel pool.

FIG. *2* depicts an example of a sequence of events causing EALs to be exceeded, triggering the declaration of a General Emergency and resulting in a release warranting protective actions off the site. The figure shows that there is likely to be several points (from failure of the nuclear power plant safety systems to actual fuel damage) in the progression of events when one of the EALs for the declaration of a General Emergency is exceeded before a release takes place.

In this example, there is an unexpected event (labelled 1 in FIG. 2), which in this example is a pipe rupture resulting in the loss of water required to cool the core that automatically triggers safety systems designed to protect the core by injection of water to replace what is being lost. If these nuclear power plant safety systems are able to cope with the event there is no risk for the off-site population, and consequently there is no need to declare a General Emergency. If the safety systems fail to cope, which in this example is failure to inject sufficient water into the vessel to keep the core covered (labelled 2 in FIG. 2), EALs will be exceeded, and the shift supervisor will declare a General Emergency and notify off-site decision makers with the purpose of immediately implementing urgent protective actions for the public. Minutes to hours after the failure of the safety systems needed to keep the core cool, the fuel in the core will heat up rapidly damaging it and causing it to melt (labelled 3 in FIG. 2), which will also result in other EALs being exceeded and will provide another opportunity to declare a General Emergency before a release takes place warranting protective actions off the site. When the fuel in the core is damaged a large amount of radioactive material will be released from the fuel, which could be released to the atmosphere if the containment fails. The containment could fail at any time and it is impossible to predict when this will happen. Thus, following damage to the fuel in the core, there is always the possibility of an unpredictable release to the atmosphere (labelled 4 in FIG. 2) that can result in severe health effects.

As stated previously in Section 2.4, it is important to note that the timing, size and duration of most of the severe releases[43] warranting urgent protective actions off the site cannot be predicted by the control room operators. In addition, even after a release occurs the control room operators cannot be expected to know the size or duration of the release, because most releases warranting protective actions off the site will be by routes (e.g. leaking from unidentified location in the containment) that cannot be monitored by the control room. Containment failure is possible but not expected during the first hours after the time of the event warranting the declaration of a General Emergency, but if there is a release that can result in severe health effects off the site it will be unpredictable.

[43] Examples of causes of containment leakage/failure that are not predicable that can result in a severe release are: (a) hydrogen explosions, (b) overpressure, (c) by-pass, and (d) failure to isolate. The only release pathway that is predictable is intentional venting, and in most cases releases by this route would be smaller.

The sequence of events at Fukushima Daiichi nuclear power plant in Japan [3, 4] also showed that initiating protective actions when damage to the fuel is projected provides time for their effective implementation before a release. The accident at the Fukushima Daiichi nuclear power plant began with the interruption of the off-site electrical power supply by the earthquake; the tsunami struck about half an hour later resulting in the loss of all on site power and the loss of the ability to provide cooling water to the fuel in the core of Unit 1, which would result in severe damage of the fuel within hours unless the injection of cooling water is restored. The nuclear power plant staff recognized the inability to provide cooling water to the core in Unit 1, so they promptly notified the Japanese government that the situation was a State of Nuclear Emergency[44] [3].

About 2 hours after the loss of the ability to provide cooling water to the core of Unit 1, the water in the vessel holding the fuel fell below the top [10] of the fuel and the fuel began to heat up rapidly, within hours causing the fuel to melt and resulting in the release of a large amount of radioactive material into the containment and at this point a release resulting in health effects offsite was possible. Severe core damage occurred days later in Units 2 and 3. The evacuation of the population near the nuclear power plant was started within about 6 hours of the time the tsunami struck and completed before the release began.

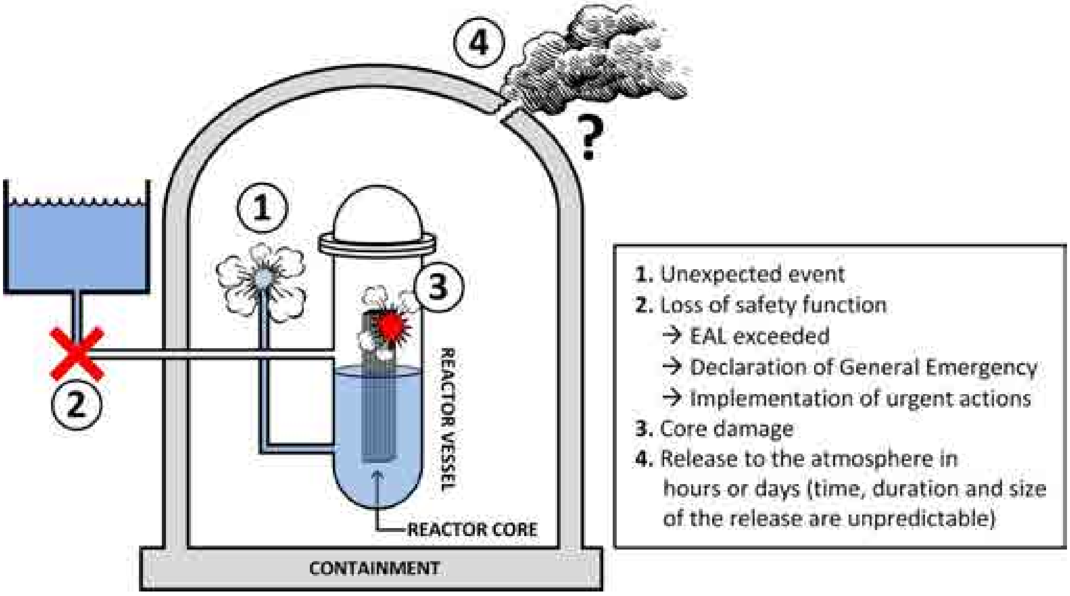


FIG. 2. Sequence of events leading to a release of radioactive material to the atmosphere warranting protective actions off the site.

Those responsible for emergency preparedness and response arrangements should not assume that a General Emergency will be preceded by an Alert or Site Area Emergency. The response arrangements need to be designed to be implemented immediately upon declaration of a General Emergency[45]. An emergency warranting urgent protective actions off the site would most probably start as a General Emergency.

The control room operators monitor the status of the systems needed to protect the reactor core and spent fuel pool. They can declare a General Emergency and thus initiate an immediate and coordinated response, in the majority of cases, before a release. The shift supervisor at the nuclear power plant needs to be responsible for declaring the emergency because this is the only person with sufficient information and understanding of the situation to make such a declaration. In order to promptly classify and declare an emergency, the shift supervisor needs to have the responsibility,

[44] This would have been declared a General Emergency under the IAEA emergency classification system [1] because such a situation may result in severe damage of the fuel.
[45] The off-site decision maker(s) should not assume they will have time to activate the response organizations before the public needs to be alerted.

authority, procedures, training and criteria for doing so. For the emergency classification system to work effectively, the off-site decision makers need to understand its basis and be willing to act immediately upon notification of the declaration of a General Emergency by the shift supervisor. Refs. [1, 11] provide additional guidance on the emergency classification system.

4. OFF-SITE EMERGENCY ZONES AND DISTANCES

In addition to an emergency classification system, off-site emergency zones and distances around the nuclear power plant need to be identified in advance during the preparedness stage. This is to ensure that effective protective actions and other response actions can be promptly implemented to protect the public that are consistent with the hazard. Four areas need to be defined:

- Precautionary action zone (PAZ);
- Urgent protective action planning zone (UPZ);
- Extended planning distance (EPD); and
- Ingestion and commodities planning distance (ICPD).

The emergency zones and distances are described in Table 2 and the suggested sizes for the zones and distances are given in Table 3. The size and boundaries of the zones and distances need to be site specific and due to the large variations in site and nuclear power plant characteristics it is beyond the scope of this publication to provide a single set of specific distances that would be most effective for all nuclear power plants. Therefore, the sizes of the zones and distances given in Table 3 are to be considered as a first approximation that needs to be adjusted to specific plant designs, emergency scenarios and local conditions.

The sizes of the zones and distances can be established based on specific analysis of the nuclear power plant, as long as releases that are representative of those expected for an emergency involving severe damage to reactor fuel are considered, as illustrated in Appendix I. The emergency zones (PAZ and UPZ) are areas where comprehensive arrangements are put in place at the preparedness stage to promptly, upon declaration of a General Emergency, implement urgent protective and other response actions as summarized in Table 4. The emergency distances (EPD and ICPD) are to be established at the preparedness stage for the identification of areas in which actions may need to be taken during the response but for which only limited arrangements are put in place in advance. These emergency zones and distances are illustrated in FIG. 3 and FIG. 4. It is important to note that they do not stop at national boundaries. The suggested sizes in Table 3 represent a judgement of the distance within which making advanced arrangements is reasonable in order to ensure an effective response. For the emergencies with the most severe potential consequences postulated, protective actions might need to be taken beyond the size suggested. The basis for the suggested sizes is discussed in Appendix I.

The PAZ and UPZ sizes are described in terms of the radius of a circle around the nuclear power plant. However, the actual boundaries of the zones need to be defined by local landmarks (e.g. roads, administrative boundaries, rivers) so that the public and those responding to the emergency can easily identify them, as shown in FIG. 3 and FIG. 4. The boundary of the PAZ and UPZ needs to be established to ensure the most effective evacuation. For example, if the area within 5 km of the nuclear power plant can be evacuated faster if a town is excluded, then the boundary of the PAZ needs to be established to exclude the town, as shown in FIG. 5.

TABLE 2. DESCRIPTION OF EMERGENCY ZONES AND DISTANCES

Emergency zones and distances	Description
Precautionary action zone (PAZ)	An area where comprehensive arrangements are made at the preparedness stage to notify the public and have the public start to take urgent protective actions and other response actions listed in Table 4 within one hour of the declaration of a General Emergency by the shift supervisor of the nuclear power plant. The goal is to initiate protective actions and other response actions before the start of a release warranting protective actions off the site[a], in order to prevent severe deterministic effects. The boundary of the PAZ needs to be established to minimize evacuation times and evacuation of the PAZ to beyond the UPZ is given priority over evacuation of the UPZ. In addition, provisions are made within this zone for the protection of personnel staffing special facilities such as hospitals, nursing homes and prisons that cannot be immediately evacuated.
Urgent protective action planning zone (UPZ)	An area where comprehensive arrangements are made at the preparedness stage to notify the public and have the public start to take the urgent protective actions and other response actions listed in Table 4 within about one hour of the declaration of a General Emergency by the shift supervisor. The goal is to initiate protective actions and other response actions before or shortly after the start of a release warranting protective actions off the site[a], but in such a way as not to delay the implementation of the urgent protective actions and other response actions within the PAZ. In addition, provisions are made within this zone for the protection of personnel staffing special facilities such as hospitals, nursing homes and prisons that cannot be immediately evacuated.
Extended planning distance (EPD)	The distance to which arrangements are made at the preparedness stage so that upon declaration of a General Emergency: (a) instructions will be provided to reduce inadvertent ingestion; and (b) dose rate monitoring of deposition conducted to locate hotspots following a release which could require evacuation within a day and relocation within a week to a month. Evacuation of patients and those requiring specialized care would be to locations outside of the EPD to ensure that further evacuations would not be required after a release.
Ingestion and commodities planning distance (ICPD)	The distance to which arrangements are made at the preparedness stage so that upon declaration of a General Emergency instructions will be provided to: (a) place grazing animals on protected (e.g. covered) feed, (b) protect drinking water supplies that directly use rainwater (e.g. to disconnect rainwater collection pipes), (c) restrict consumption of non-essential local produce, wild-grown products (e.g. mushrooms and game), milk from grazing animals, rainwater and animal feed, and (d) stop distribution of commodities until further assessments are performed. The ingestion and commodities planning distance is also the distance within which arrangements are made at the preparedness stage to collect and analyse, during the emergency, samples of local produce, wild-grown products (e.g. mushrooms and game), milk from grazing animals, rainwater, animal feed and commodities to confirm the adequacy of controls.

[a] As discussed in Section 5.2, evacuations should not be delayed because a release is under way if it can be conducted safely.

TABLE 3. SUGGESTED SIZES FOR EMERGENCY ZONES AND DISTANCES

Emergency zones and distances	Suggested maximum radius (km)[a, b]	
	≥ 1000 MW(th)	100[c] to 1000 MW(th)
Precautionary action zone (PAZ)[d]	3 to 5	
Urgent protective action planning zone (UPZ)[d]	15 to 30	
Extended planning distance (EPD)	100	50
Ingestion and commodities planning distance (ICPD)	300	100

[a] The suggested maximum radii are based on judgments made after reviewing the references and calculations that are described in Appendix I. The calculations were performed assuming releases considered to be representative of those expected for an emergency involving severe damage to reactor fuel. The sizes of the zones and distances provided in Table 3 are a first approximation. The sizes can be established based on specific analysis of the nuclear power plant and local conditions, as long as releases that are representative of those expected for an emergency involving severe damage to reactor fuel are considered, as illustrated in Appendix I.

[b] The radius from the nuclear power plant of a circle encompassing the outer boundary of the area. A range is provided to allow flexibility; however, boundaries that are more than a factor of two less than or greater than the recommended range need to be avoided because that could reduce the effectiveness of the associated protective and other response actions as discussed in Appendix I.

[c] It is considered very unlikely that nuclear power plants with power levels below 100 MW(th) could give rise to a release of fission products causing exposures off the site with doses leading to severe deterministic effects. Therefore, emergency zones recommended for nuclear power plants with a power level of less than 100 MW(th) are not suggested in this publication.

[d] The actual boundary of the zones does not need to be a circle but needs to be defined by local landmarks (e.g. roads, political boundaries, rivers) to allow easy identification by the public and those responding to an emergency.

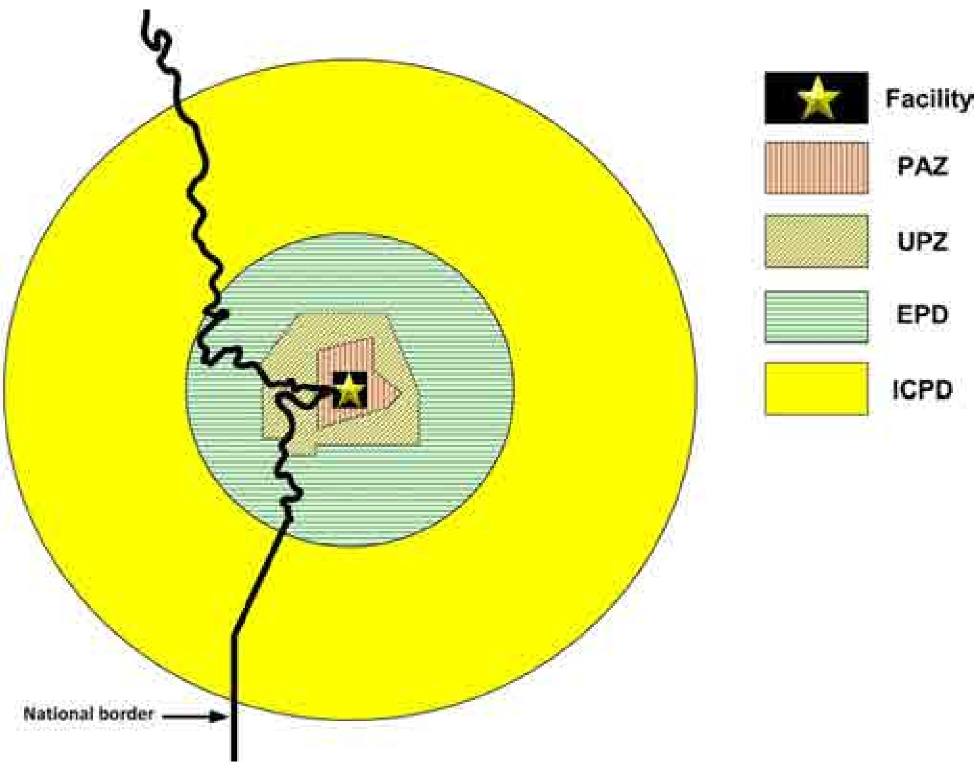


FIG. 3. Emergency zones and distances.

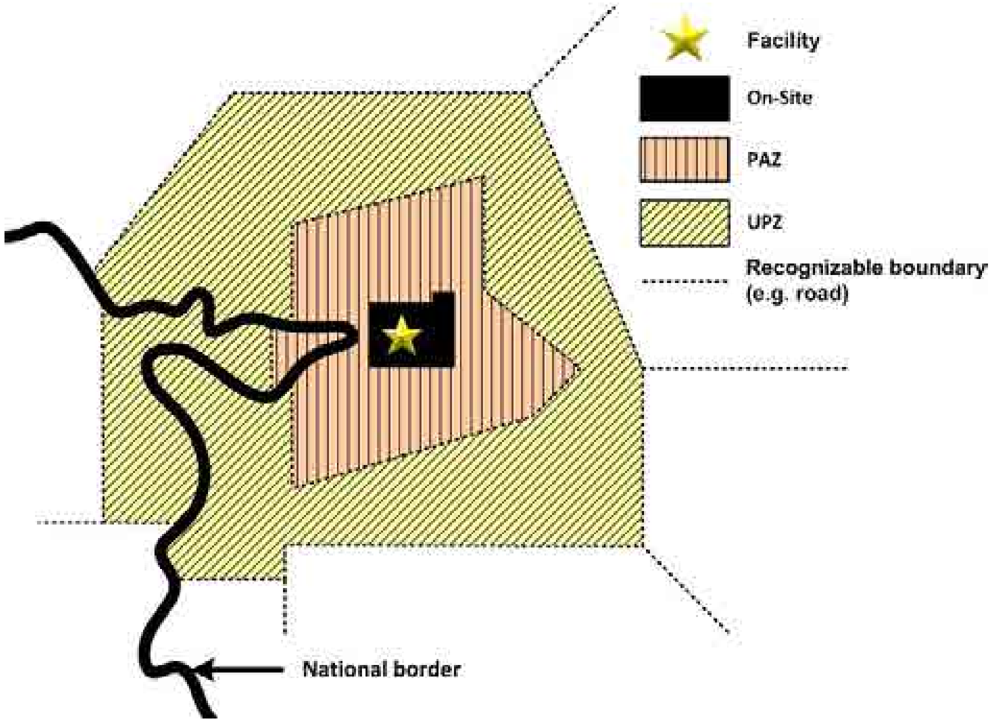


FIG. 4. Example of establishing boundaries for PAZ and UPZ.

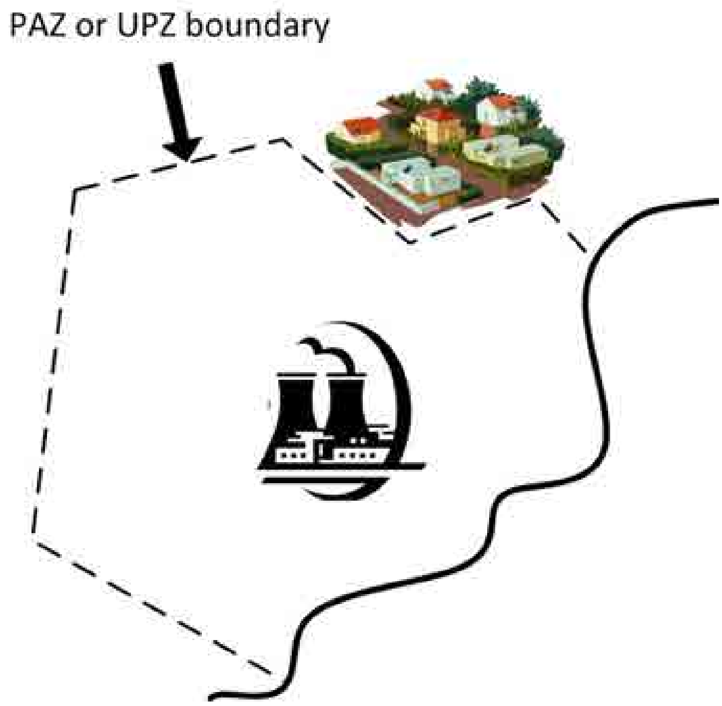


FIG. 5. Example of a PAZ or UPZ with the boundary excluding a town to enable a fast evacuation.

5. URGENT PROTECTIVE ACTIONS AND EARLY PROTECTIVE ACTIONS AND OTHER RESPONSE ACTIONS

Two categories of protective actions and other response actions off the site may be taken in response to an emergency arising from damage to a reactor core or spent fuel pool:

- Urgent protective actions and other response actions need to be taken promptly (normally within hours) in order to be effective; their effectiveness will be markedly reduced if they are delayed. Urgent protective actions and other response actions include ITB, evacuation, short term sheltering, actions to reduce inadvertent ingestion, decontamination of individuals, prevention of ingestion of potentially contaminated food, milk or water, and identification of those needing a medical examination.
- Early protective actions and other response actions can be implemented within days to weeks and still be effective. The most common early protective actions and other response actions are relocation, longer term restrictions on consuming contaminated food, and registration of those who need to receive a medical screening.

These actions can be initiated in two ways. The first is to initiate implementation of actions within the predetermined emergency zones and distances upon the declaration of a General Emergency (see Table 4) and the second is to initiate implementation of actions after a release as the result of monitoring, comparison of results with predetermined OILs and identification of areas where OILs are being exceeded (see Section 6).

TABLE 4. URGENT PROTECTIVE ACTIONS AND OTHER RESPONSE ACTIONS FOR THE PUBLIC IN A GENERAL EMERGENCY

- Instruct those within the PAZ to immediately take an ITB[a] agent, reduce inadvertent ingestion[b], and safely evacuate[c] to beyond the UPZ.
- Instruct those within the UPZ to:
  - immediately remain indoors (shelter in place) until evacuation, take an ITB[a] agent and reduce inadvertent ingestion[b];
  - if there is a potential[d] for a severe airborne release, instruct the population to safely[c, e] evacuate beyond the UPZ as soon as possible without delaying evacuation of the public within the PAZ[f]
- Instruct those within the PAZ and UPZ who cannot be safely[c] evacuated to take an ITB agent immediately, to go inside (as feasible, to shelter in large buildings[g, h]), to shut the windows and doors, and to listen to the radio, television or to check online for further instructions.
- Instruct transportation systems (air, land, sea) to avoid the PAZ and UPZ.
- Instruct those within the EPD to reduce inadvertent ingestion[b] until the deposition levels are assessed.
- Within the ICPD issue instructions to:
  - place animals on protected (e.g. covered) feed as appropriate and feasible;
  - protect food and drinking water sources (e.g. disconnect rainwater collection pipes);
  - stop distribution and consumption of non-essential local produce[i], wild-grown products (e.g. mushrooms and game), milk from grazing animals, rainwater and animal feed until concentration levels have been assessed using OIL7;
  - stop distribution of commodities until they have been assessed; and
  - implement controls to ensure all trade meets international standards and to reassure interested parties (e.g. other States) that such controls are in place (see Section 5.9).
- Provide registration and monitoring to see if OIL4 or OIL8 have been exceeded, decontamination and medical screening consistent with the recommendations given in Section 2.3 and estimate the dose to those who were in the PAZ and UPZ to determine if a medical examination or counselling and follow-up are warranted.

[a] If this will not delay evacuation.
[b] Advise not to drink, eat or smoke and to keep hands away from the mouth until hands are washed and not to play on the ground or do other activities that could result in the creation of dust that could be ingested.
[c] ‘Safely evacuating’ means not endangering the lives of those being evacuated. Patients and those requiring specialized care should be evacuated beyond the EPD in order to ensure multiple evacuations are not required. As discussed in Section 5.2, evacuations are not to be delayed on the grounds that a release is occurring.
[d] General Emergency conditions (see Section 3).
[e] If immediate evacuation is not possible (e.g. owing to snow, floods, or lack of transportation or a special facility such as a hospital), the public need to shelter in large buildings if feasible — only for a short period — until safe evacuation is possible.
[f] The evacuation of the PAZ has priority over the evacuation of the UPZ. If necessary, evacuation of the UPZ needs to be delayed until it will not interfere with the evacuation of the PAZ. Evacuation of the UPZ may be phased in such a way that those areas at immediate risk are evacuated first (e.g. considering the projected wind direction), or in such a way to be implemented most effectively (e.g. optimization of the existing road network). However, ultimately the UPZ may need to be evacuated in all directions due to the wind shifts that could take place during a release or throughout the time period of a potential severe release.
[g] The personnel staffing special facilities (i.e. facilities where residents cannot be moved immediately (e.g. hospitals, nursing homes, prisons), facilities needed to support the response (e.g. communications facilities), or facilities where there is a need for protection to avoid other dangers (e.g. chemical facilities)), as part of the emergency preparedness process needs to be designated and protected as emergency workers (e.g. provisions for monitoring and guidance values (see Table 4 of Ref. [1]).
[h] Arrangements for the monitoring of dose rates inside of special facilities (e.g. hospitals) where it has been predetermined that sheltering will be an initial protective action need to be made in advance when putting in place emergency plan arrangements.
[i] Local produce is food that is grown in open spaces that may be directly affected by the release and that is consumed within weeks (e.g. leafy vegetables).

5.1. IODINE THYROID BLOCKING (ITB)

Large amounts of radioactive iodine can be released when the fuel in the reactor core or fuel recently removed from the core overheats. The people evacuating from the PAZ or UPZ or sheltering within those zones *during* a release can inhale enough radioactive iodine to damage the thyroid and greatly increase the chance of developing radiation induced thyroid cancer. In addition, severe health effects[46] may occur in a fetus from the dose to the fetal thyroid, due to the iodine concentrating in the thyroid gland (the fetal thyroid is active after about 10 weeks of gestation).

The uptake by the thyroid gland of radioiodine from inhalation can be reduced by taking stable (non-radioactive) iodine. This is called iodine thyroid blocking (ITB) or stable iodine prophylaxis because the stable iodine saturates the thyroid, greatly reducing the absorption of the radioactive iodine. To be effective, the stable iodine needs to be taken before or shortly after intake (i.e. within 2 hours of inhalation or ingestion of the radioactive iodine) [12]. As discussed in Appendix I, the dose from inhalation of radioactive iodine by those in the PAZ and UPZ can be sufficient to result in severe deterministic effects in the thyroid and fetus, and sheltering or evacuation performed after the start of a release may not provide sufficient protection to prevent these effects. Therefore, in order to reduce the possibility of these effects, it is necessary for the ITB agent to be pre-distributed so that it can be immediately taken by those in homes, schools, workplaces, hospitals and other special facilities within the PAZ and UPZ with instructions for use, so that it can be taken immediately upon declaration of a General Emergency (detection of conditions in the nuclear power plant indicating that a release is possible). Pre-distribution is necessary because it may not be possible to distribute the ITB agent during an emergency in the time required for it to be effectively applied. This is because the timing of a release of radioactive materials is unpredictable, a release can occur any time after core damage.

The WHO recommends [13] that in the absence of any explicit instructions to the contrary by public health authorities, only one dose of ITB agent should be taken. A single dose of ITB agent is usually sufficient for adequate protection for 24 hours. In the event of prolonged or repeated exposure, public health authorities may advise taking ITB more than once. Under such circumstances, neonates (< 1 month) and pregnant or breastfeeding women should not be given repeated doses of ITB agent.

Therefore, multiple applications of ITB agent may not be a substitute for evacuation for a prolonged exposure situation (longer than 24 hours). The ITB agent is taken primarily to provide protection while arrangements are put in place to implement a safe evacuation.

ITB is both safe and effective if the stable iodine is provided in the correct dosages. The guidance of the World Health Organization [13] needs to be followed in this regard.

5.2. EVACUATION

Evacuation, conducted before a release, can prevent exposure from all possible pathways. Evacuation also moves people away from the area of the emergency so that they are no longer an immediate concern for those managing the response.

As discussed in Appendix I, evacuation within the PAZ starting before a release combined with ITB is the preferred protective action in the event of an emergency involving severe damage to the fuel for all reactors with power levels greater than 100 MW(th). This is needed to prevent severe deterministic effects and to prevent doses exceeding the international generic criteria [1] calling for urgent protective or other response actions to be taken.

For reactors with power levels greater than 1000 MW(th), evacuation within the UPZ is needed in order to prevent doses exceeding the international generic criteria [1] calling for urgent protective or other response actions to be taken.

[46] Severe health effects' are severe deterministic effects and stochastic effects, i.e. radiation induced cancers.

Appendix I also shows that large building sheltering can prevent lethal doses and also provides a substantial reduction in all doses; therefore, if evacuation is delayed or immediate evacuation is not possible (e.g. due to snow, floods, lack of transport or in case of special facilities, such as hospitals), the public need to shelter in large buildings if feasible until safe evacuation is possible.

Evacuation of patients and those requiring specialized care from the PAZ and UPZ would be to locations outside of the EPD to ensure that further evacuations would not be required after a release.

Concerns have been raised over the possibility of traffic congestion or 'shadow evacuations'[47] causing a delay in an evacuation of the PAZ. For this reason, a phased evacuation (i.e. evacuating the PAZ to outside the UPZ first, followed by evacuation of the UPZ) is recommended.

Evacuation at speeds greater than walking speed (about 5 km/h), even in the plume (i.e. during a release), is more effective than sheltering [14, 15, 16] and since the release can occur over a number of days, evacuations do not need to be delayed because a release is underway if it can be conducted safely.

Evacuations are safe and occur frequently in response to emergencies involving natural and human made hazards. Experience has shown that local officials can promptly evacuate an area effectively with no advance planning [17]. However, evacuation can be dangerous for special populations (e.g. hospital patients), if it is not properly planned [18].

Those being evacuated need to take an ITB agent, if it can be done without delaying the evacuation, in order to provide protection from inhalation of the passing plume.

5.3. SHELTERING

In this publication two different types of sheltering are discussed:

- Sheltering 'in place', where people in a potential risk area are instructed to 'go inside, shut the windows and doors, and listen to the radio or television for further instructions'.
- Sheltering in large buildings (also called substantial shelter [19]), away from windows with the outside ventilation shut off.

Sheltering is a short term measure and can only be used for a few days. Sheltering is typically used as a temporary measure whenever immediate and safe evacuation is not possible (e.g. for special facilities[48] that are dangerous to evacuate immediately, and whenever conditions make immediate evacuation impossible or hazardous (e.g. in severe weather)). Sheltering should not be used for more than a day unless arrangements have been made in advance for: (a) meeting the needs of those sheltering (e.g. for food, water, sanitation, power, medical assistance, etc.), (b) keeping those who are sheltering informed, and (c) provisions should be made to monitor doses to ensure the effectiveness of sheltering for locations where sheltering is the action taken. Sheltering, by itself, is never considered adequate protection against a release from a damaged reactor core or spent fuel pool (as illustrated in Appendix I), and needs to be undertaken in conjunction with ITB if possible. Therefore, as discussed in Section 5.1, the use of sheltering needs to be limited by the fact that taking an ITB agent by the public for more than a day may not be appropriate.

The effectiveness of sheltering depends on the construction of the building being used for shelter and its ability to provide effective protection for all of the important exposure pathways[49]. As discussed in Appendix I, sheltering 'in place' in a typical home and large building sheltering may not provide adequate protection from a release warranting protective actions off the site within the PAZ or UPZ.

[47] 'Shadow evacuation' is unofficial spontaneous evacuation undertaken by members of the public who are located outside the area where evacuations are officially recommended.

[48] Special facilities include telecommunications centres that need to be staffed in order to maintain telecommunications, chemical plants that cannot be evacuated until certain actions have been taken to prevent fire or explosions and hospitals with patients that cannot be immediately evacuated and prisons.

[49] Exposure pathways are the different routes, or pathways, by which people can be exposed to radiation.

However, large building sheltering can prevent lethal doses and also provides a substantial reduction in all doses; therefore, if safe evacuation is not immediately possible, large building shelter needs to be used if possible.

In addition, for special facilities where sheltering is the predetermined urgent protective action, the staff that are to remain sheltered in the facilities need to be trained and equipped as emergency workers during the emergency preparedness process or provisions in place to brief them of this advice during the emergency. The staff need to be able to monitor the dose rate to confirm the effectiveness of the protection for the staff and the public that is being provided.

Appendix I provides further information on why ITB agent also needs to be taken whenever anyone is sheltering.

5.4. RELOCATION

Relocation is the non-urgent removal of people in order to avoid longer term exposure from radioactive material deposited on the ground. Areas requiring relocation are typically identified based on monitoring that indicates where dose rates may be greater than the OIL2 values. Relocation may also be required if people are living in areas where essential food and water is contaminated in excess of the OIL7 values and replacement food or water cannot be provided.

For an emergency relating to a release from a reactor core or spent fuel, areas within the EPD may require relocation due to hotspots. Deposition patterns can be very complex and strategies to deal with this complexity need to be developed as discussed in Sections 6.3.

Relocation is a non-urgent protective action and therefore, time is available (a week to a month) – to allow those being relocated to take deliberate actions to address personal needs, such as: providing for household pets, gathering important possessions, securing property, or providing for farm animals. There will also be some time for off-site officials to make provisions for housing and care for those being relocated; however, relocation does need to be done within days to a month to be effective in reducing the dose to the population. This is because: (a) exposure resulting in severe health effects can be received within days in those areas with dose rates within a factor of two of the OIL1 values warranting evacuation and (b) a large portion of the dose warranting relocation may be received during the first month where the OIL2 values are exceeded.

5.5. PREVENTION OF INADVERTENT INGESTION

Radioactive material released from the damaged fuel in the core or spent fuel pool can be deposited on the ground or other surfaces (e.g. cars). Inadvertent ingestion of this deposited radioactive material, such as from eating with dirty hands, can be a significant source of exposure for those living in the PAZ, UPZ and EPD in the first few days following a release warranting protective actions off the site. Therefore, people in the PAZ, UPZ and EPD need to be instructed to take the following actions to prevent or reduce the dose from inadvertent ingestion: (a) not to drink, eat or smoke and to keep their hands away from their mouth until their hands are washed, (b) not to let children play on the ground, and (c) not to conduct activities that could result in the creation of dust that could be ingested.

5.6. DECONTAMINATION OF INDIVIDUALS

Deposition of radioactive material on the skin sufficient to cause severe deterministic effects (e.g. burns) is only possible on the site. The people within the PAZ or UPZ could receive significant exposure from inadvertent ingestion from radioactive material on their skin from the passing radioactive plume or by contact with material deposited on the ground or on other objects. Therefore, IAEA guidance [1] states that whenever individuals may be contaminated they need to be instructed to keep their hands away from their mouth (prevent inadvertent ingestion) and to shower and change their clothing as soon as possible. If no capability for monitoring and decontamination is available, reassure the public that the risk to health from contamination is small. The presence of radioactive material on the skin can also have adverse psychological and economic effects. Large numbers of people from the affected area can be expected to demand to be monitored for reassurance that they were not contaminated. Levels of radioactive material on the skin that exceed OIL4 may indicate that the person has inadvertently ingested or inhaled enough radioactive material to result in doses warranting a medical follow-up. See Section 5.8 for further information.

In several past emergencies [20, 21], potentially contaminated people have been stigmatized and shunned, and medical staff have refused to treat them. However, as discussed in Section 2.3, those transporting and/ or treating contaminated individuals can do so safely if they use universal precautions against infection (gloves, mask, etc.) which will provide sufficient protection.

Simply removing outer clothing and washing the bare skin (hands and face) will greatly reduce levels of radioactive material present. In emergencies affecting many people, initial decontamination measures need to be limited to these basic measures, and only limited (i.e. easy and simple) efforts need to be made to control the waste arising from the decontamination.

During an evacuation, it is likely that those from the affected area will also take their pets; therefore, consideration needs to be given for the animal's decontamination. It is recommended that this is undertaken by the owners who need to be advised that pets need to be washed once.

5.7. FOOD, MILK AND DRINKING WATER RESTRICTIONS

The accident at the Chernobyl nuclear power plant, as discussed in Appendix I, showed that following a release resulting from fuel damage warranting protective actions off the site, consumption of vegetables grown in the open space (local produce, to include wild-grown products (e.g. mushrooms and game), milk from animals grazing on contaminated grass, and rainwater consumption are one of the largest contributors of dose. Consumption of rainwater and local produce can be a concern within hours of a release and consumption of milk within about two days. Both the accidents at Chernobyl and Fukushima also showed the need to communicate the controls that are in place for the purpose of reassuring the public and interested parties (e.g. other States).

As discussed in Section 6.3, for a radioactive release in an emergency the patterns of the deposition are very complex and will be constantly changing if there is an ongoing release. Even the relatively small ongoing releases expected to occur over a period of days or weeks may result in hotspots that could cause contamination of food, milk, rainwater and animal feed that is greater than the international generic criteria calling for restrictions of consumption or distribution [1]. These complex and changing deposition patterns make it impossible to promptly identify the areas warranting a restriction of consumption based on monitoring and sampling alone. As a consequence, upon declaration of a General Emergency there needs to be provisions within the ICPD to immediately:

- protect food and water by instructing the public to protect sources of drinking water that use rainwater (e.g. to disconnect rainwater collection pipes) and to protect sources of food that may become contaminated, for example, by placing grazing animals on protected (e.g. covered) feed, if possible;
- restrict consumption and distribution of non-essential local produce, wild-grown products (e.g. mushrooms and game), milk, rainwater and animal feed following a release until it is sampled and assessed;
- take actions to prevent contaminated food (for both human and animal consumption) from entering the distribution system; and
- reassure the public and interested parties (e.g. other States) that such controls are in place.

After the start of a release, comparison of dose rates from ground deposition with OIL3 values (see Table 7) need to be used to promptly identify further areas that warrant restrictions on locally produced food, milk , rainwater, animal feed and commodities without waiting for the results of time consuming laboratory analysis. In addition, a system of sampling and laboratory analysis needs to be implemented to ensure the adequacy of controls using the OIL values of radionuclide concentrations established during the preparedness phase for emergencies, such as OIL7 values given in Table 9.

Monitoring and comparison with OIL3 values is used to identify where local produce, milk from grazing animals and rainwater needs to be immediately restricted because they clearly can exceed the OIL7 values. However, actions to protect the ingestion pathway are not limited to where the OIL3 criteria are exceeded but also include a programme of food, milk and water sampling and analysis in the entire affected area, as soon as it can be established, to determine if concentrations exceed OIL7 in order to: (a) confirm adequacy of controls, (b) provide for additional restrictions, (c) provide for food replacements, and (d) to remove restrictions.

Restrictions are not to be applied if they could result in malnutrition or other health consequences.

5.8. IDENTIFICATION AND MEDICAL MANAGEMENT OF EXPOSED PEOPLE

5.8.1. Severe health effects

Two types of possible radiation induced health effects are referred to as severe health effects throughout this publication. They are:

- severe deterministic effects; and
- stochastic effects (i.e. radiation induced cancers).

Severe deterministic effects are those deterministic effects which can be fatal or reduce the quality of life [9]. Deterministic effects occur after exposures above a dose threshold, and the magnitude of the effect increases with an increase in the dose. These effects typically occur within days or months of exposure. The dose at which an individual would suffer the effect can vary with age and health of the exposed individual, and the time over which the dose was received; the outcome of the exposure can vary with medical treatment received.

The severe deterministic effects that are most likely to occur in an emergency involving a release due to damaged fuel in a reactor core or spent fuel pool are the following:

- Severe beta radiation burns to the skin or soft tissue as a result of radioactive material (e.g. iodine) on or near the skin (e.g. on clothes or in contaminated water). These burns would be expected to occur only for those on the site. Beta burns contributed to the fatal injuries of on-site responders during the Chernobyl accident.
- Fatalities as a result of high levels of whole body overexposure are possible for those within about the first 3 to 5 km off the site (i.e. within the PAZ) for the worst postulated release.
- Non-fatal severe effects to the fetus, thyroid and the reproductive organs can occur among those within about the first 10 to 30 km (i.e. within the PAZ and UPZ). The severe effects to the fetus and the thyroid are principally due to inhaling radioactive iodine.

Stochastic effects (radiation induced cancers) are assumed, to have no dose threshold, and the probability (not the severity) of occurrence increases with higher radiation doses. However, there will be a dose below which any excess radiation induced cancers cannot be detected [22, 23, 24] as further discussed in Appendix III. Radiation induced thyroid cancer is the greatest concern among other possible radiation induced cancers following a release from a reactor core or spent fuel pool. This is because large amounts of radioactive iodine may be released. The iodine may be inhaled, ingested by drinking contaminated rainwater and milk from animals grazing on contaminated pasture, or by eating contaminated local produce. Once inhaled or ingested, the radioactive iodine concentrates in the thyroid resulting in very high doses to the organ (for more information see Section 5.1).

There was a clearly detectable increase in the number of radiation induced thyroid cancers following the Chernobyl accident among the population group aged 0–18 years old (in 1986) living at distances beyond 300 km [25] away from the accident site. These cancers were due principally to doses received from drinking milk from cows grazing on pasture contaminated with radioactive iodine. Radiation induced thyroid cancers started to appear in 1990, four years following the Chernobyl accident [25, 26]. However, these cancers are usually not life threatening if detected and treated early. This is the reason why those who may have inhaled iodine during the release or may have ingested food, milk or rainwater contaminated by radioactive iodine need to be registered and have their dose estimated to determine whether a medical follow-up is warranted[50].

A detectable increase in the incidence of any other radiation induced cancers (e.g. leukaemia) among the public after a release from a damaged reactor core or spent fuel pool warranting protective actions off the site is very unlikely and would require that many people receive doses sufficient to result in severe deterministic effects [22, 23, 24]. To date, only a detectable increase in radiation induced thyroid cancers amongst the population group aged 0–18 years old (in 1986) living in the areas of Belarus, Russia and Ukraine affected by the Chernobyl accident has been clearly established. There is no scientific evidence of an increase in the incidence of other radiation induced cancers among the public or in incidence of non-malignant disorders that could be related to radiation exposure from the Chernobyl accident [27, 28, 29].

Appendix III discusses radiation induced health effects further and provides the threshold dose at which severe deterministic effects can occur and the international generic criteria at which actions are justified in order to prevent, detect or effectively treat stochastic effects (radiation induced cancers).

5.8.2. Immediate medical examination, consultation and treatment

Hospitals should be instructed on how to treat possibly contaminated patients (i.e. taking universal precautions against infection will provide sufficient protection). Only those people with sufficient whole body radiation exposure to exhibit the symptoms described in Ref. [30] warrant an immediate (priority) medical examination and hospitalization as required for consultation for the treatment and management of severe deterministic effects.

5.8.3. Medical follow-up

In order to determine who needs to receive later medical follow-up and to provide a basis for informed counselling of pregnant women and others, the doses to those categories of people listed in Table 5 need to be estimated.

[50] Registration for the purposes of dose estimation to determine whether medical follow-up is warranted needs to start 1–2 years after the emergency to ensure that the data collected can be used to indicate the background incidence rate of cancers.

TABLE 5. IDENTIFYING INDIVIDUALS FOR MEDICAL FOLLOW UP

<table>
<tr><th>Who</th><th>Comments</th></tr>
<tr><td>Those within the PAZ and UPZ during or following release</td><td rowspan="2">Need to provide information on their location and activities during the emergency. Also need to have skin and thyroid monitored.</td></tr>
<tr><td>Those in areas where OIL1 or OIL2 were exceeded (see Table 7).</td></tr>
<tr><td>Those with concentration of radioactive material on the skin exceeding OIL4 (see Table 8)</td><td>Skin contamination above OIL4 could indicate that the person has inhaled or inadvertently ingested enough radioactive material to warrant a medical follow-up.</td></tr>
<tr><td>Those with a dose rate from the thyroid exceeding OIL8 (see Table 10)</td><td>Monitoring of the thyroid and skin needs to be performed later than 1 day and sooner than 6 days after the exposure.</td></tr>
<tr><td>Those who may have consumed contaminated food, milk or water with concentrations exceeding OIL7 (see Table 9)</td><td></td></tr>
<tr><td>Concerned pregnant women</td><td>As discussed below, the risk to their fetus is small, but it can only be assessed by an expert on the health effects of radiation exposure (not local physicians).</td></tr>
</table>

Within weeks, a programme to estimate the dose and resulting health risk for all those people affected needs to be under way to identify any additional people who may require long term medical follow-up, based on the generic criteria given in Ref. [1]. Priority is to be given to making the dose estimates for pregnant women. The process of estimating the dose is beyond the scope of this publication, but assistance in performing such estimations can be obtained through the IAEA following Ref. [5].

Expert advice and counselling needs to be provided to everyone who is examined, been registered for a medical follow-up, who has concerns about the impact of the emergency on their health, or that of their children or fetus. There are only a limited number of experts in diagnosing and treating the health effects of radiation exposure in the world. Medical examinations, treatment (see Ref. [30]), and counselling needs to be done only after consultation with experts (such assistance can be obtained through the IAEA or World Health Organization, following Ref. [5]).

All pregnant women within the PAZ and UPZ, who were in areas where OIL1 or OIL2 was exceeded, had their thyroid or skin monitored or who have concerns, needs to be registered and told that; (a) the risk to their fetus is small, but it can only be assessed by an expert on the health effects of radiation exposure (not their local physician) and (b) that their risk will be evaluated, and an official will contact them to discuss the results and answer their questions.

In several past emergencies [20], medical staff have refused to treat potentially contaminated patients because they did not understand how to protect themselves from contamination. Provisions need to be in place to provide advice to medical facilities in the vicinity that might treat potentially contaminated patients that universal precautions against infection (gloves, mask, etc.) will provide sufficient protection when treating potentially contaminated patients.

5.9. PROTECTION OF INTERNATIONAL TRADE AND COMMERCIAL INTERESTS

Emergencies have caused adverse economic consequences. National and international customers need to be reassured that exports from the affected region are being carefully controlled to ensure that they are not contaminated (i.e. do not exceed international criteria for trade). Economic consequences have occurred when the possibility of contamination of exports is mentioned, even though no major release occurred. Therefore, it is necessary for arrangements to be in place to ensure that all tradable goods meet international standards and to reassure the public and interested parties (such as importing States) of this. Experience has shown that establishing a testing and certification system can mitigate the economic impact on international trade. Therefore, provisions need to be in place to restrict the distribution of commodities within the ICPD until certification can be used to verify that products from the affected area are safe and do not exceed internationally agreed criteria for trade, while products from unaffected areas can be verified with a certificate of origin. Refs. [2, 31] provide guidance on international trade.

5.10. STOPPING OR RELAXING RESPONSE ACTIONS

Protective actions and other response actions need to be stopped or relaxed, as appropriate, after consideration of, or confirmation of the following conditions:

- No further major releases are possible (e.g. the emergency would no longer be classified as a Site Area or General Emergency);
- Monitoring has been completed;
- Sampling and analysis of potentially contaminated food, milk and water have been completed;
- Protective actions and other response actions consistent with the OILs are no longer needed;
- Relaxing of response actions will do more good than harm;
- Interested parties have been consulted; and
- The public has been informed and understands the reason for the change.

After the emergency is declared to be over, further actions need to be taken based on criteria developed after careful assessment of local conditions, in consultation with interested parties to ensure any the further actions do more good than harm when the impact of the action on the public is considered.

6. MONITORING AND COMPARISON WITH OPERATIONAL INTERVENTION LEVELS

Following a release of radioactive material from the reactor core or spent fuel pool, additional decisions on protective actions and other response actions will need to be taken based on environmental measurements. International guidance [1] has established generic criteria that are doses at which taking protective or other response actions are justified. The generic criteria are established at levels where:

- urgent and early response actions are justified in order to prevent severe deterministic effects and to reduce the risk of stochastic effects (radiation induced cancers) in the population;
- longer term medical actions are warranted to detect and to effectively treat radiation induced health effects.

However, generic criteria cannot be used directly in an emergency, because they are in terms of dose and not in terms of quantities that are measurable in an emergency, such as dose rate. Therefore, predetermined default operational triggers, called operational intervention levels (OILs) have been developed for quantities that are measured by a field monitoring instrument or determined by laboratory analysis. Predetermined default OILs are used to trigger particular protective actions and other response actions consistent with the generic criteria. In an emergency, predetermined OILs are used immediately and directly (without further assessment) to determine the appropriate protective actions and other response actions.

This section provides OILs for assessing release from an LWR or RBMK. OILs are provided for ground deposition (OIL1, OIL2, OIL3), deposition of radioactive material on the skin (OIL4), dose rate above the thyroid from iodine intake (OIL8), as well as food, milk, and water concentrations (OIL7) after a release from a damaged reactor core or spent fuel pool warranting protective and other response actions off the site. Appendix II provides a summary of the basis for the OIL1, OIL2, OIL3, OIL4, OIL7 and OIL8 values. Note that OIL5 and OIL6 are used for other purposes not relevant for a release from a reactor core or spent fuel pool.

If the generic criteria in the State are different than those given in Ref. [1], then the OILs may need to be revised, but this needs to be done before an emergency as part of the preparedness process. As discussed in Appendix II, the OILs are probably adequate for all mixtures of radioactive material released from emergencies involving damage to the fuel in the reactor core or spent fuel pool. The OILs could be revised for specific mixtures of radionuclides however, procedures for doing this are beyond the scope of this document. If requested, the IAEA could provide support in calculating OILs based on actual mixtures during an emergency. Care must be taken not to revise OILs during an emergency unless: (a) conditions are stable and the mixtures of radionuclides are well understood; (b) application of the revised OILs will result in significantly different protective actions and other response actions being taken; and (c) the need for the revisions are clearly explained to the public.

Experience has shown that off-site decision makers take actions and the public follow their instructions best when they both understand how the actions increase the safety of the public. Therefore, a plain language explanation of how the criteria and associated protective actions and other response actions provide for the safety of all members of the public is presented for each OIL in Section 6.2.

6.1. OPERATIONAL INTERVENTION LEVELS

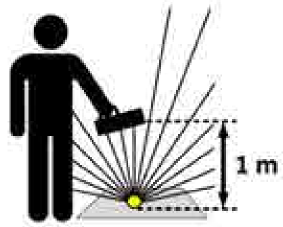
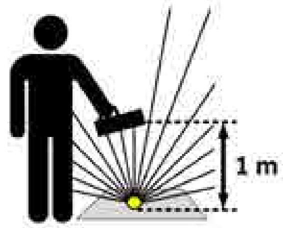
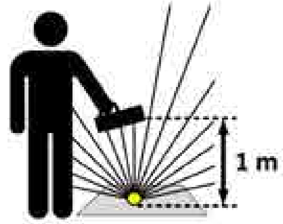
6.1.1. OIL1, OIL2 and OIL3 for ground deposition dose rates

OIL1, OIL2 and OIL3 for ground deposition dose rates (µSv/h at 1 m above ground level) are used to determine where ground deposition levels warrant evacuation, relocation or restrictions on consumption or distribution of local produce, wild-grown products (e.g. mushrooms and game), milk from animals grazing in the area, rainwater, animal feed, or commodities that may have been contaminated as shown in Table 6. The OIL1, OIL2 and OIL3 values are provided in Table 7.

TABLE 6. COMPLETION TIME AND PURPOSE FOR MONITORING OF OIL1, OIL2 AND OIL3

OILs	**Time for completion**	**Purpose**
OIL1	Within a day	Identify where evacuation is required beyond the areas evacuated when a General Emergency is declared.
OIL2	Within a week	Identify and relocate areas with dose rates that are within a factor of two of the OIL1 values.
	Within a month	Identify and relocate areas where the dose rate is greater than the OIL2 values.
OIL3	Within days	Identify where additional food, rainwater or commodity restrictions are warranted beyond the areas established (e.g. ICPD) when a General Emergency is declared.

TABLE 7. DEFAULT OIL1, OIL2 AND OIL3 FOR GROUND DEPOSITION DOSE RATES

These default OILs are for a release from a light water reactor or RBMK core or spent fuel pool. The dose rate at 1 m above ground level needs to be measured in an area with low or no vegetation and away from roads, trees and buildings.	
Default OIL	**Actions if exceeded**
OIL1 **Dose rate at 1 m above ground level**  **1000 µSv/h**	**Immediately[a]:** – Instruct the public to take ITB agent[b]; – Safely evacuate[c, d]; – Reduce inadvertent ingestion[e]; – Stop consumption and distribution of all local produce[f], wild-grown products (e.g. mushrooms and game), milk from animals grazing in the area, rainwater[g] and animal feed; – Stop distribution of commodities until they have been assessed; – Provide registration, monitoring, decontamination and medical screening consistent with Section 2.3 for those in the area. **Within days:** – Estimate the dose to those who were in the area to determine if a medical examination or counselling and follow up is warranted in accordance with Ref. [30].
OIL2 **Dose rate at 1 m above ground level**  ≤ 10 days after shutdown of the reactor[h]: **100 µSv/h** > 10 days after shutdown of the reactor [h, i]: **25 µSv/h**	**Immediately[a]:** – Instruct the public to prepare to relocate while taking actions to reduce inadvertent ingestion[e]; – Stop distribution and consumption of local produce[f]; wild-grown products (e.g. mushrooms and game), milk from animals grazing in the area and rainwater[g]. **Within a week to a month[j]:** – Register those in the area; – Safely relocate[c] those living in the area. Relocation needs to begin with those in the areas of highest potential exposure (see – Table 6); – Estimate the dose to those who were in the area to determine if a medical examination or counselling and follow-up are warranted in accordance with Ref. [30].
OIL3 **Dose rate at 1 m above ground level**  **1 µSv/h[l]**	**Immediately[a]:** – Stop distribution and consumption of non-essential[k] local produce[f], wild-grown products (e.g. mushrooms and game), milk from animals grazing in the area, rainwater[g] and animal feed until concentration levels have been assessed using OIL7; – Stop distribution of commodities until they have been assessed. **Within days:** – Replace essential[k] local produce, milk and rainwater as soon as possible or relocate the people if replacements are not available; – Register and estimate the dose of those who may have consumed local produce, milk, rainwater[g] from the area where restrictions were implemented to determine if medical counselling and follow-up is warranted in accordance with Ref. [30].

[a] If not already completed based on conditions at the nuclear power plant (i.e. General Emergency) before any monitoring has been carried out.
[b] Only if this will not delay evacuation.

[c] 'Safely evacuating' means not endangering the lives of those being evacuated. For example, patients in hospitals or care homes do not need to be immediately evacuated or relocated if this will put them at immediate risk. Evacuation or relocation needs to be delayed until these patients can be moved safely.

[d] If immediate evacuation is not possible (e.g. owing to snow, floods, lack of transport or for special facilities such as hospitals), the public need to shelter in large buildings if feasible —for a short period only — until safe evacuation is possible.

[e] Advise not to drink, eat or smoke and to keep hands away from the mouth until hands are washed and not to let children play on the ground or do other activities that could result in the creation of dust that could be ingested.

[f] Local produce is food that is grown in open spaces that may be directly contaminated by the release and that is consumed within weeks (e.g. leafy vegetables).

[g] Only consumption of non-essential drinking water that comes undiluted directly from the collection of rainwater is to be restricted. Other sources of drinking water (e.g. wells, reservoirs or rivers) will have much lower contamination levels due to dilution and will only need to be restricted if analysis of the samples exceed the OIL7 values.

[h] Time after shutdown is the time between when the measurement is made from the time when the nuclear reaction in the core was stopped. For further information on the two values given for OIL2 see Appendix II.

[i] This is therefore applicable for all releases from a spent fuel pool.

[j] Within a week, to identify those areas with dose rates that are within a factor of two of the OIL1 values and within a month to identify all the areas where the dose rate is greater than the OIL2 values.

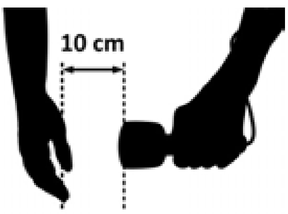
[k] Restricting essential local produce, milk or water could result in malnutrition or other health consequences and therefore essential local produce needs to be restricted only if alternatives are available.

[l] Above the background dose rate.

6.1.2. OIL4 for skin dose rate

The OIL4 value (µSv/h at 10 cm) given in Table 8 can be used to assess whether the levels of radioactive material on the skin warrant a medical examination or other response actions.

TABLE 8. DEFAULT OIL4 FOR SKIN DOSE RATES

<table>
<tr><td colspan="2">This default OIL is for a release from a light water reactor or RBMK core or spent fuel pool.
The dose rate needs to be measured at 10 cm from the bare skin of the hand or face and conducted in an area with a background dose rate of less than 0.5 µSv/h.</td></tr>
<tr><td>Default OIL4</td><td>Actions for those being monitored</td></tr>
<tr><td>Dose rate at 10 cm from skin


1 µSv/h[b]</td><td>Immediately:
– Instruct them to take ITB agent if not already taken;
– Instruct them to reduce inadvertent ingestion[a];
– Register all those monitored and record the dose rate; and
– If OIL4 is exceeded, decontaminate them and provide them with medical screening consistent with Section 2.3.
– Reassure those treating and/ or transporting contaminated individuals they can so safely if they use universal precautions against infection (gloves, mask, etc.).

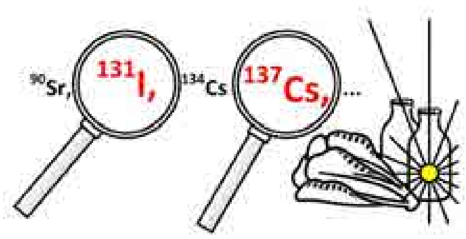
Within days:
– Estimate the dose to those for which OIL4 is exceeded to determine if a medical examination or counselling and follow up is warranted in accordance with Ref. [30].</td></tr>
</table>

[a] Advise not to drink, eat or smoke and to keep hands away from the mouth until hands are washed.
[b] Above the background dose rate.

6.1.3. OIL7 for marker radionuclides ^{131}I and ^{137}Cs concentrations in food, milk and drinking water

OIL7 values in Table 9 are expressed as concentrations (Bq/kg) of the two marker radionuclides ^{131}I and ^{137}Cs and are used as indicators to determine if food, milk and water are safe for consumption or not. ^{131}I and ^{137}Cs are marker radionuclides (isotopes). A marker radionuclide is easier to identify during sample analysis and is representative of all the other radionuclides present and is used to determine if protective actions and other response actions are needed without performing a comprehensive isotopic analysis.

TABLE 9. DEFAULT OIL7 FOR CONCENTRATIONS OF MARKERS I-131 AND Cs-137 IN FOOD, MILK AND DRINKING WATER

<table>
<tr><td colspan="3">These default OILs are for a release from a light water reactor or RBMK core or spent fuel pool.
The concentration of both of these radionuclides needs to be determined and the OIL is exceeded if either of the ^{131}I or ^{137}Cs values is exceeded. It is important to note that all other radionuclides likely to be present in the environment after the release from the reactor core or spent fuel pool are considered in the derivation of the OIL7 values.</td></tr>
<tr><td colspan="2">Default OIL7[a, b]</td><td>Actions if either value is exceeded</td></tr>
<tr><td colspan="2">Radionuclide concentrations in food, milk and drinking water

</td><td rowspan="2">– Stop consumption of non-essential[c] food, milk or water;
– Replace essential[c] food, milk and drinking water as soon as possible or relocate the public if replacements are not available; and
– Estimate the dose of those who may have consumed food, milk or drinking water with concentrations greater than OIL7 to determine if a medical follow up is warranted in accordance with Ref. [30].</td></tr>
<tr><td>1000 Bq/kg
of I-131</td><td>200 Bq/kg
of Cs-137</td></tr>
</table>

[a] The analysis of milk needs to be done recognizing that the concentration of ^{131}I and ^{137}Cs in milk will not reach maximum levels until two or more days after grazing of cows on contaminated pasture.
[b] ^{131}I and ^{137}Cs serve as marker radionuclides (isotopes) so that the concentration of all the radionuclides present in the environment after the release from a reactor core or spent fuel pool do not need to be determined. The calculation of OIL7 for the marker radionuclides includes the contribution of the other radionuclides (fission products) expected to be present after a release from severe fuel damage. Ref. [1] provides a method for assessing the dose considering explicitly all the radionuclides present.
[c] Restricting food, milk and drinking water could result in malnutrition or other health consequences and therefore food, milk and drinking water needs to be restricted only if alternatives are available.

6.1.4. OIL8 for dose rate from the thyroid

OIL8 values for dose rate (μSv/h) from the thyroid in Table 10 are used to assess whether the amount of radioiodine in a person's thyroid warrants a medical examination and other response actions.

TABLE 10. DEFAULT OIL8 FOR DOSE RATE FROM THE THYROID

<table>
<tr><td colspan="3">This default OIL is for dose rate from the thyroid and needs to be measured: (a) after the person has been decontaminated and contaminated outer clothing removed, (b) 1–6 days after possible intake of radioiodine, (c) made with a probe with an effective area ≤ 15 cm², (d) by placing the monitoring probe in contact with the skin in front of the thyroid, and (e) conducted in a location with a background dose rate of less than 0.2 µSv/h.</td></tr>
<tr><td colspan="2">OIL8[a]</td><td>Actions for those being monitored</td></tr>
<tr><td colspan="2">Above background dose rate in contact with the skin in front of the thyroid
1 to 6 days after exposure

</td><td rowspan="2">Immediately:
– Instruct them to take ITB agent if not already taken;
– Instruct them to reduce inadvertent ingestion[b];
– Register all those monitored and record the thyroid dose rate; and
– If OIL8 is exceeded provide them with medical screening consistent with Section 2.3.
Within days:
– Estimate the dose to those whose thyroid dose rate was greater than OIL8 to determine if a medical examination or counselling, and follow up is warranted in accordance with Ref. [30].</td></tr>
<tr><td>0.5 µSv/h[c]
Age ≤ 7 years</td><td>2 µSv/h[c]
Age > 7 years</td></tr>
</table>

[a] Position of gamma dose rate monitor detector is over the thyroid close to or in contact with the skin.
[b] Advise not to drink, eat or smoke and to keep hands away from the mouth until hands are washed. This needs to be done if contamination is possible, regardless of whether or not the OIL value is exceeded.
[c] Above the background dose rate.

6.2. PLAIN LANGUAGE EXPLANATIONS FOR OILS

Experience has shown that decision makers take actions and the public follow their instructions best when they both understand how the actions increase the safety of the public [32].

A plain language explanation of how the criteria and associated actions provide for the safety of all members of the public is presented for each of the OILs below. These plain language explanations can be used by off-site decision makers to communicate to the public what actions are being implemented and their basis. Section 7 of this publication provides charts that can be used to place the health hazard into perspective based on measured quantities and dose estimates.

6.2.1. Plain language explanation for OIL1

Remaining in an area where OIL1 is exceeded may not be safe. Those living in the area need to immediately [*insert appropriate local instructions needed to address the recommended actions for OIL1 from Table 7*] to reduce the risk of radiation induced health effects.

Individuals who were in an area where OIL1 was exceeded need to ensure they are registered for a medical screening to determine if any further actions are needed. Remember, the health effects resulting from radiation exposure are unlikely and can only be assessed properly by experts. Others, such as local physicians, usually do not have the expertise needed to make such assessments.

OIL1 was developed for the protection of someone living in the area affected by a release from a reactor core or spent fuel pool. These recommended actions need to be taken in order to protect all members of the public, including those most vulnerable to radiation exposure (e.g. children and pregnant women). This OIL takes into consideration all the ways a person can be exposed to radiation from radioactive material deposited on the ground, including inhalation of dust and inadvertent ingestion of dirt (e.g. from dirty hands). However, it is assumed that the person is not eating or drinking contaminated food or water because urgent protective actions (e.g. evacuation) have been implemented.

Chart 1 in Section 7 can be used to place the health hazard in perspective from living in an affected area based on the dose rate measured above the ground.

6.2.2. Plain language explanation for OIL2

Remaining in an area where OIL2 is exceeded for [*insert time up to a week*], until arrangements are made for your relocation, is safe if the following recommended actions are taken [*insert appropriate local instructions needed to address recommended actions for OIL2 from Table 7*].

Individuals who were in an area where OIL2 was exceeded need to ensure they are registered for a medical screening to determine if any further actions are needed. Remember, the health effects resulting from radiation exposure can only be assessed properly by experts. Others, such as local physicians, usually do not have the expertise needed to make such assessments.

OIL2 was developed for the protection of someone living in the area impacted by a release from a reactor core or spent fuel pool for up to a week while making preparations to relocate. These recommended actions need to be taken in order to protect all members of the public, including those most vulnerable to radiation exposure (e.g. children and pregnant women). This OIL takes into consideration all the ways a person can be exposed to radiation from radioactive material deposited on the ground, including inhalation of dust and inadvertent ingestion of dirt (e.g. from dirty hands). However, remaining in an area where OIL2 has not been exceeded is safe, provided that the person is not eating or drinking food, milk or water with concentrations greater than the OIL7 values.

Chart 1 in Section 7 can be used to place the health hazard in perspective from living in an affected area based on the dose rate measured above the ground.

6.2.3. Plain language explanation for OIL3

OIL3 was developed for the protection of someone consuming local produce (e.g. vegetables), milk from grazing animals and rainwater that may have been produced in an area affected by a release from a reactor core or spent fuel pool.

The local produce, milk or rainwater from the area where OIL3 is exceeded may be safe; however, it is prudent not to consume them until further analysis has been performed.

This OIL assumed that half of the food, milk and rainwater consumed by those most vulnerable to radiation exposure (e.g. children and pregnant women) was produced in the affected area and that little is done (e.g. not washing the food) to reduce the concentration levels before consumption. If alternatives are available in the areas where OIL3 is exceeded, stop consuming local produce (e.g. leafy vegetables), milk from grazing animals and rainwater until they have been screened and declared safe. The OILs are established at levels well below those at which any radiation induced health effects would be expected; therefore, if restriction of consumption is likely to result in severe malnutrition or dehydration because replacements are not available, food, milk, or rainwater from areas with concentration levels above the OIL3 value may be consumed, as directed by local officials, until replacements are available.

6.2.4. Plain language explanation for OIL4

A person with a concentration of radioactive material on the skin greater than OIL4 needs to [*insert appropriate local instructions needed to address the recommended actions for OIL4 from Table 8*] and be registered for a medical screening to determine if any further actions are needed. This does not mean that the person will suffer any effects, but that it is prudent to conduct further medical examinations.

Remember, health effects resulting from radiation exposure can only be assessed properly by experts. Others, such as local physicians, usually do not have the expertise needed to make such assessments.

The risk from radioactive material on the skin is small and comes primarily from unintentionally (inadvertently) eating radioactive material that has gotten on the hands. Individuals who may have radioactive material on them because they were near the nuclear power plant or came from an evacuated area need to take the following basic precautions: (a) keep their hands away from their mouth until they have been washed, and, (b) remove their outer clothing and shower as soon as possible and then dress in clean clothing. The removed clothing needs to be stored in a closed bag until it can be dealt with under the direction of local officials.

Below the OIL4 values, the associated levels of radioactive material on the skin are not a significant health risk; however, washing hands, showering and changing clothing as soon as possible is always prudent.

Chart 2 in Section 7 can be used to place the health hazard from radioactive material on the skin in perspective based on the dose rate.

6.2.5. Plain language explanation for OIL7

Exceeding OIL7 does not mean that the food, milk or water is unsafe; however, it is prudent not to consume them until further analysis has been performed.

These OIL values are for the worst possible case where all food, milk and water consumed by those most vulnerable to radiation exposure (e.g. children and pregnant women), that little is done (e.g. washing) to reduce the concentration of radioactive material before consumption. If alternatives are available when OIL7 is exceeded, stop consuming the food, milk or water until they have been screened and declared safe. The OILs are established at levels well below those at which any radiation induced health effects would be expected; therefore, if restriction of consumption is likely to result in severe malnutrition or dehydration because replacements are not available, food, milk or water with concentration levels above the OIL7 value may be consumed, as directed by local officials, until replacements are available.

Food, milk and water with concentrations below OIL7 can be safely consumed by all members of the public, including children and pregnant women. This OIL was developed to protect all members of the public, including those most vulnerable to radiation exposure (e.g. children and pregnant women).

Charts 3 and 4 in Section 7 can be used to place the health hazard from consumption in perspective based on the concentrations in the food, milk or water.

6.2.6. Plain language explanation for OIL8

A thyroid dose rate above the OIL8 indicates that the person have inhaled or ingested enough radioactive iodine to require a medical screening. Individuals whose thyroid dose rate is greater than the OIL8 need to be registered for a medical screening to determine whether any further actions are needed. This does not mean that the person will suffer any adverse effects, but that it is prudent to conduct further medical examinations.

Remember, health effects resulting from radiation exposure can only be assessed properly by experts. Others, such as local physicians, usually do not have the expertise needed to make such assessments.

6.3. CONTAMINATION AND HOTSPOTS

The use of the terms ‘contamination’ and ‘hotspot’ has been a source of considerable confusion and public concern. This has been of particular concern when hotspots and areas of contamination were shown on maps used to describe the impact of the emergency on the public and decision makers. In many cases, very low levels of radiation were shown that would not cause any health effects and would therefore not warrant any response actions; however, this was not clearly explained to the public and decision makers.

6.3.1. Contamination

Contamination is defined as ‘Radioactive substances on surfaces, or within solids, liquids or gases (including the human body), where their presence is unintended or undesirable’ [33]. However, we all have radioactive material in and on our bodies that is unintended as a result of the accident at the Chernobyl nuclear power plant and the nuclear weapon tests, but we would not consider ourselves contaminated. Therefore, use of the term ‘contaminated’ often causes undue concern amongst the public, even if the levels do not require any sort of response.

> *In an emergency something or someone is to be referred to as contaminated only if the amount of radioactive material on or in an object or person is greater than a predefined criterion, such as an OIL, which requires an action such as relocation, decontamination or restrictions on exports.*

6.3.2. Hotspots

Following a release of radioactive material, the site levels of deposition can vary considerably resulting in areas with higher concentrations of radioactive material or dose rates than those nearby. These higher concentrations are often called hotspots, which causes undue concern amongst the public. However, this variation in itself does not indicate that there is a radiation health concern and does not indicate that any response is needed unless an OIL is exceeded.

> *In an emergency a hotspot only needs to be used to refer to an area with ground deposition of radioactive material resulting in an OIL or other predetermined criteria being exceeded.*

6.3.3. Deposition patterns

The pattern of deposition of radioactive material can be very complex and non-homogeneous over large and small areas, as shown in FIG. 6 [8] and FIG. 7 [27] for the Chernobyl accident.

The deposition patterns following the release from the accident at the Fukushima Daiichi nuclear power plant were also complex as illustrated in FIG. 8 [34]. This figure shows the ^{137}Cs deposition after the releases. FIG. 8 also shows the local wind direction at the Fukushima Daiichi nuclear power plant out to the sea (marked with a "?" in FIG. 8) during part of the release. As already discussed in Section 2.4, if this had been a nuclear power plant located inland there would have been deposition in all directions and not only downwind, therefore requiring the implementation of protective actions or other response actions in all directions.

Rainwater can cause the concentration of radioactive material in local areas such as ditches, under trees or along the drip zones of houses (i.e. under the edges of roofs), as illustrated in FIG. 9, resulting in considerable differences in the dose rate and concentrations of radioactive material over short distances such as a few meters.

Hotspots requiring relocation of the public in accordance with the international generic criteria [1] can occur at distances of more than 50 km from the nuclear power plant (within the distance recommended for the EPD) as discussed in Appendix I and illustrated in FIG. 6 and FIG. 7. It is important to note that 20 % of the dose from deposition received over the period of a year following a release is received within the first month; therefore, off-site decision makers need to be able to locate hotspots and relocate people living there quickly (see Table 7 for the required OILs).

Deposition from the plume may also result in the radioactive material in local produce, milk from grazing animals and rainwater. Consumption of these products could possibly result in doses among those living at distances greater than 100 km from the nuclear power plant, leading to a detectable increase in the radiation induced thyroid cancer rate [25]. As shown in FIG. 7, consumption could also possibly result in doses exceeding the international generic criteria [1] calling for restrictions of food consumption at distances beyond 300 km from the nuclear power plant (within the distance suggested for the ICPD). As discussed Section 5.7, consumption of rainwater or local produce can be a concern within hours of a release and consumption of milk within about two days.

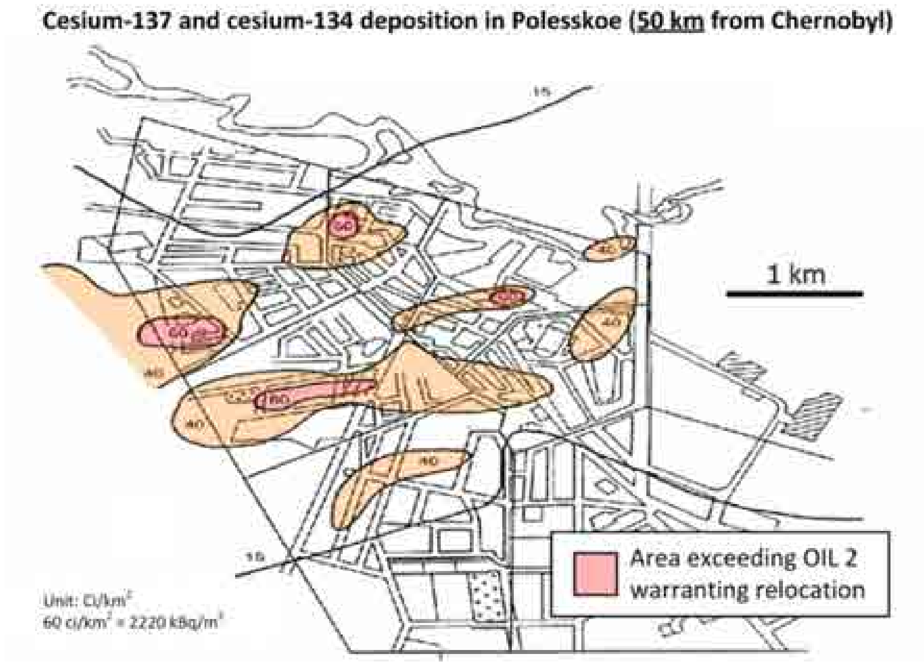


FIG. 6. Hotspots more than 50 km from the Chernobyl nuclear power plant required relocation.

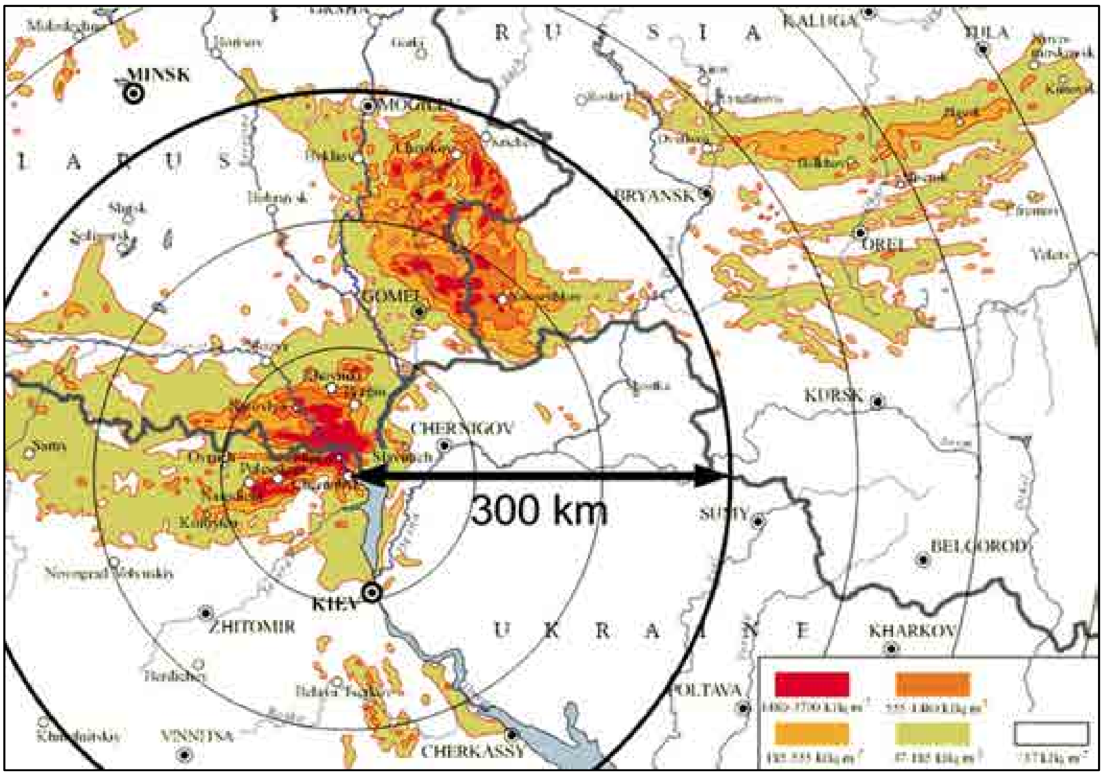


FIG. 7. Deposition of ^{137}Cs following the Chernobyl accident. In accordance with international generic criteria the red areas may warrant relocation and all the coloured areas may warrant restriction of consumption and distribution of local produce, wild-grown products (e.g. mushrooms and game), milk from grazing animals, rainwater or animal feed.

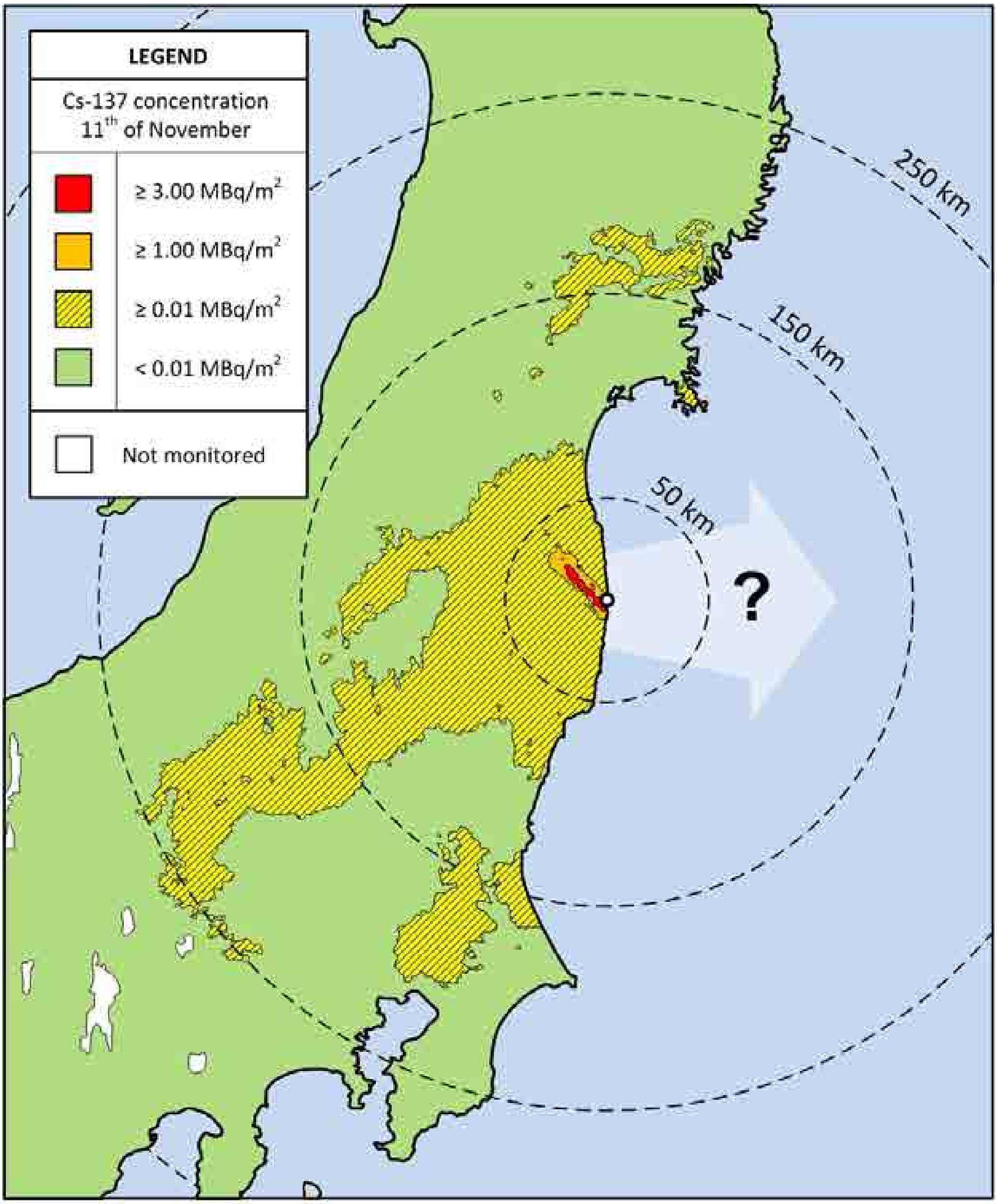


FIG. 8. Deposition of ^{137}Cs after the release from the Fukushima Daiichi nuclear power plant.

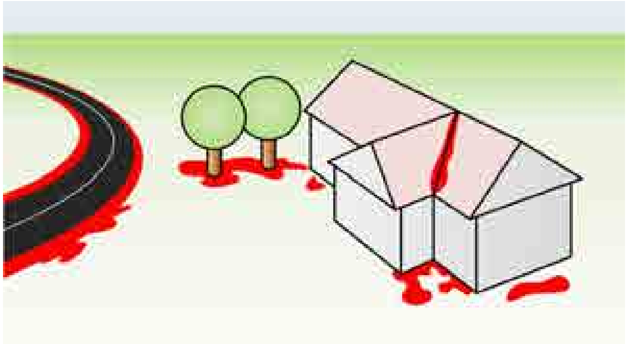


FIG. 9. Local hotspots indicated in red.

FIG. *7* [27] shows that areas exceeding OIL3 values warranting food restrictions occurred over a complex area out to a distance of more than 300 km due to the release from the accident at the Chernobyl nuclear power plant. The patterns of this deposition (hotspots) are so complex that it is impossible to monitor enough of the area in order to effectively identify all the locations for which food restrictions apply. Consequently, non-essential local produce, wild-grown products (e.g. mushrooms and game), milk or rainwater within the ICPD needs to be restricted upon declaration of a General Emergency (i.e. before monitoring or sampling is carried out) and until it is assessed and found to be safe for consumption. Failure to implement these controls within a few days of a release could result in eventual radiation induced thyroid cancers, particularly among children, such as those which occurred after the accident at the Chernobyl nuclear power plant [25, 26, 28].

6.4. DETERMINING WHERE GROUND DEPOSITION OILS ARE EXCEEDED

Arrangements need to be in place to take protective actions and other response actions promptly based on field monitoring data. However, early in an emergency there will only be limited monitoring data which may be confusing and inconsistent. This is due to the considerable variation in the dose rates, as well as variations in the monitoring team measurements. Even highly professional teams can be expected to report different dose rates and concentration levels when monitoring in the same areas. This will be particularly problematic early on in the emergency when decisions need to be made quickly in order to be effective. Therefore, arrangements need to be in place to enable decisions to be made promptly, based on early, limited and possibly inconsistent monitoring data.

A possible strategy for doing this is illustrated in FIG. 10. In this example there was a General Emergency and the population within the PAZ and UPZ were evacuated. A release has occurred and a monitoring team is deployed to determine if additional protective actions are needed beyond the UPZ. FIG. 10 shows in orange the areas of deposition of radioactive material that warrants evacuation, however it will take weeks for environmental monitoring to identify in detail all these areas.

The monitoring team has taken the route depicted in black in FIG. 10. Only a few of the monitoring team's measurements exceed the OIL1 levels (those shown as blue stars on the route taken by the monitoring team). These levels of dose rate indicate evacuation is warranted. However, as can be seen in the figure, most of the areas with deposition levels warranting evacuation were not identified by this monitoring team. The decision maker recommends that those living within the entire administrative area (light blue areas in FIG. 10) where there were measurements that exceed OIL1 be evacuated. This decision was made in recognition that:

- the pattern of deposition could be very complex;
- those living where OIL1 is exceeded are a considerable risk and need to evacuate promptly; and
- it will take days to weeks of monitoring to locate with accuracy all the areas that need to be evacuated.

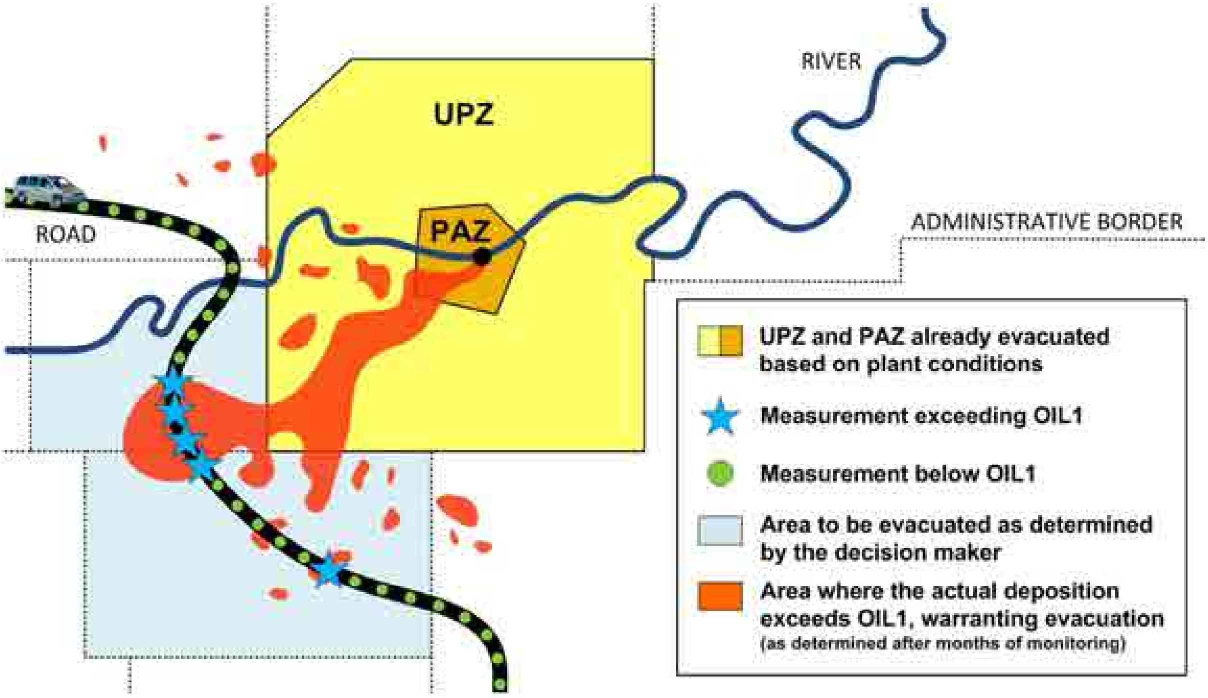


FIG. 10. Illustration of the application of OIL1 when limited data are available.

When determining if and where protective actions and other response actions need to be taken, decision makers need to consider the characteristics of the measurements and the natural and social environment of the area, such as the following:

- the number of readings exceeding the OIL, both in the same location and in the vicinity;
- the magnitude of the reading and if it is just over the OIL or greatly in excess;
- the reliability of the measurement (Have confirmatory measurements been performed?);
- the population in the area, since if there is no population nearby there is less need to make a quick decision;
- the consequence for no action (or action). For example immediate action is warranted where urgent actions need to be taken (where OIL1 or OIL3 may be exceeded) but there could be days for further assessments to confirm the areas where early actions need to be taken (where OIL2 may be exceeded).
- the use of the land and whether there are farms in the locality;
- conditions that may make implementation of protective actions hazardous (e.g. restricting essential food or water, movement of patients without proper preparations, evacuation or sheltering under hazardous conditions);
- social conditions;
- the ability to define the area in a way understandable to the public; and
- administrative and jurisdiction boundaries.

6.5. DISPLAYING MONITORING RESULTS ON MAPS

Past emergencies have proven that displaying monitoring and sampling results on a map is important for the effective communication with the public and decision makers. However, displaying results that are below those requiring a response action (i.e. that do not exceed an OIL) has led to confusion and anxiety amongst the public, and in some cases resulted in the public taking actions that do more harm than good; such as unnecessary relocation and stigmatization towards those from the affected area. It is recommended when displaying monitoring and sampling results that the map shows only where OILs have been exceeded and clearly indicates any protective actions and other response actions within these areas that need to be taken. It also needs to be communicated to the public when protective actions and other response actions are not required; therefore the map needs to include where OILs are not exceeded as illustrated in FIG. 11. This figure is an example of a map displaying monitoring results of the dose rate from deposition. The following needs to be included when displaying monitoring results on maps:

- Colour coding that corresponds to the particular OIL that is exceeded indicating where an action is warranted as illustrated in FIG. 11 and FIG. 12;
- The date of measurement and unit of measurement (e.g. μSv/h or Bq/kg); and
- Notes or cautions concerning the results as illustrated in FIG. 13.

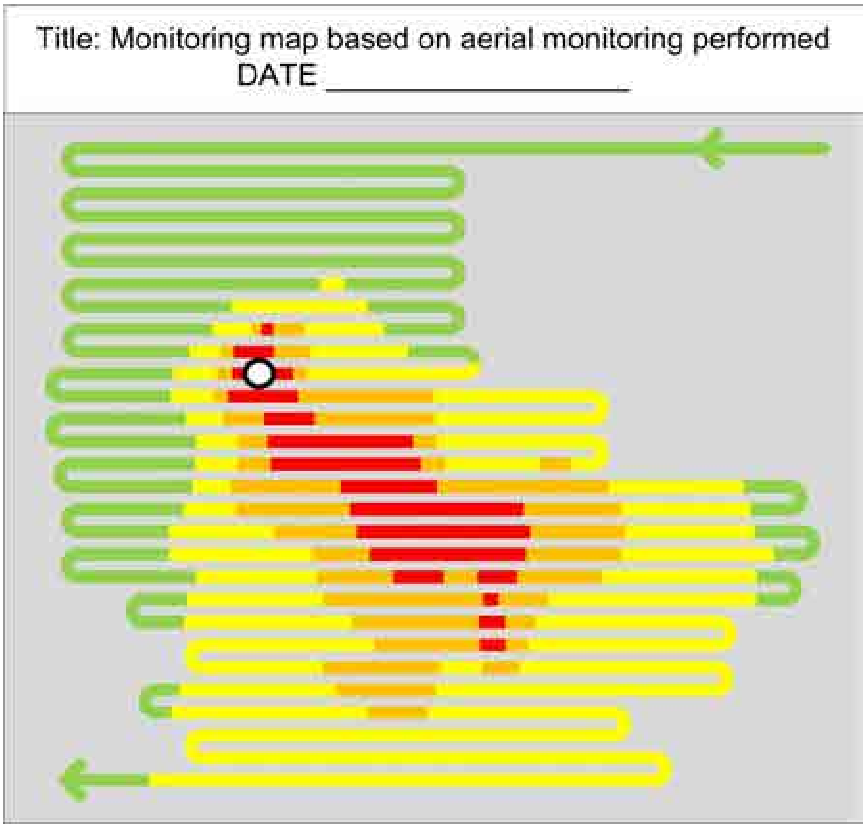


FIG. 11. Example of ground dose rate map measured by aerial survey.

EXAMPLE LEGEND FOR GROUND DOSE RATE MAP		
OIL exceeded	**Dose rate at 1m above ground level**	**Immediately required protective actions[a]**
🟥 **OIL1**	**≥ 1000 µSv/h**	▪ Instruct the public to take ITB agent; ▪ Safely evacuate; ▪ Reduce inadvertent ingestion; ▪ Stop consumption and distribution of all local produce, forest products (e.g. mushrooms), milk from grazing animals, rainwater, animal feed; and ▪ Stop distribution of commodities. ▪ Provide registration, monitoring, decontamination and medical screening for those in the area.
🟧 **OIL2**	**≥ 25 µSv/h** (for t > 10 days[b]) **≥ 100 µSv/h** (for t ≤ 10 days[b])	▪ Instruct the public to prepare to relocate[c] while taking actions to reduce inadvertent ingestion; ▪ Stop distribution and consumption of local produce, milk from animals grazing in the area and rainwater; and ▪ Stop distribution of commodities.
🟨 **OIL3**	**≥ 1 µSv/h**	▪ Stop distribution and consumption of non-essential local produce, wild-grown products (e.g. mushrooms and game), milk from grazing animals, rainwater, animal feed until the concentration of radioactive material has been assessed using OIL7; and ▪ Stop distribution of commodities.
🟩 **NONE**	**< 1 µSv/h**	None, but further actions may be needed in this area based on later monitoring and sampling.

[a] For further details on protective actions consult Table 7.
[b] Time interval between the shutdown of the reactor and the performance of monitoring.
[c] To be followed by relocation within days in accordance with Table 7.

FIG. 12. Example legend for ground dose rate map.

EXAMPLE NOTES/CAUTIONS (check those that apply) GROUND DOSE RATE MAP
☐ The map is based on limited monitoring data and will be refined as further data is received.
☐ The map is based on airborne monitoring which averages the (doses rates /concentration) over an area of about ___m² and areas with (dose rates / concentrations) where additional protective actions or other response actions need to be taken (OIL exceeded) may be missed.
☐ Possible radiation induced health effects from being in the area cannot be based solely on the dose rate from the deposition. All possible exposure pathways must be considered to include inhalation during plume passage and ingestion.
☐ For further information visit (web site) ____________________________________
☐ ____

FIG. 13. Example notes / cautions for maps displaying monitoring results.

7. COMMUNICATION WITH THE PUBLIC AND DECISION MAKERS

7.1. INFORMATION FOR THE PUBLIC AND DECISION MAKERS

The media will learn of an emergency immediately and with cellular phones, internet and social networking information will spread quickly, shaping the public perception of what is occurring. In past emergencies, having several sources of official information caused confusion, as it is difficult to ensure that all of the sources provide a consistent message when events and concerns are rapidly changing, and when the media are able to present statements from different sources immediately. Therefore, it is important to have a single source of official information providing answers and responding to these issues.

Within an hour or two of a General Emergency being declared a consistent, understandable message needs to be communicated to the public. This requires the establishment of a joint public information centre at which a single official spokesperson briefs the public via the media. The public information centre will be located in a secure area in the vicinity of the area of the emergency and will coordinate all official information released to the media concerning the emergency [35]. In addition, measured quantities and calculated doses need to be explained in terms of the possible health hazard as discussed below in Section 7.2. The decision maker also needs to be prepared to answer questions and concerns from the public such as those listed in Appendix V.

7.2. HELPING THE PUBLIC AND DECISION MAKERS UNDERSTAND WHAT IS SAFE

Nuclear or radiological emergencies will have detrimental social, psychological, economic effects on the public. In addition, there have been cases of decision makers, members of the public and others (e.g. medical staff) taking inappropriate and damaging actions that result in injuries or increased risks to health that were not justified based on the radiation hazard. These non-radiological effects can be the most severe consequences of the emergency, occurring even if there is no release of radioactive material. This was often the result of conflicting and confusing information being provided by official sources and the failure to answer the following questions in a simple, consistent and understandable way:

- Am I safe?
- What do I do to be safe?
- How are my interests being protected (e.g. in relation to imports of goods)?

The difficulty in answering these questions is compounded by ‘experts’ providing their own assessments in the media, many of which are wrong or confusing. The assessments and explanations include numerous technical units and quantities, which are often used incorrectly.

7.2.1. Why is a definition of safe important?

Failure to clearly communicate to the public, decision makers and others when it is safe (to include all members of the public — with a particular focus on the groups most sensitive to radiation such as children and pregnant women) and when no protective actions or other response actions are required, or communicating what protective actions and other response actions are needed to be taken to keep the public safe, may result in the public taking actions that do more harm than good in the belief that they are protecting themselves and their families.

After the accident at the Chernobyl nuclear power plant, members of the public living in an area that was safe did not have this message communicated to them effectively. Because of their doubt about whether they were safe or not, pregnant women sought advice and counsel from their local physicians who were not experts in the health effects resulting from radiation exposure and consequently these women had concerns for the possible radiation induced health effects to their fetus, which were not warranted based on the radiation risks. Other examples of inappropriate actions include rejecting products from the area, causing deaths due to unsafe evacuations [10] (e.g. intensive care patients in hospitals), medical staff refusing to treat those from the affected area [21], unwarranted relocations, taking inappropriate forms of ITB, evacuations that were not recommended which interfere with evacuations of those at risk ('shadow evacuations': see Section 5.2), and the demanding of medical examinations when it is not warranted (e.g. the 'worried well'[51]) that interferes with the treatment of those who are most at risk.

Providing an answer to the public's principal concern ('Am I safe?') and communicating it to the public, decision makers and others is needed to prevent actions being taken that do more harm than good and is only possible if a definition of safe has been established. The purpose of establishing a definition of safe is to:

- Answer the public's principal concern during an emergency ('Am I safe?'); and
- Prevent inappropriate actions being taken by the public, decision makers and others that are not justified based on the radiation risk.

7.2.2. Defining what is safe and placing the radiological health hazard in perspective

The definition of safe is understood as meeting international safety standards for which no protective or other response actions need to be taken. As discussed in Appendix III, international guidance [1] has established generic criteria that are calculated doses at which taking protective actions and other response actions are justified to minimize severe deterministic effects or reduce the risk of stochastic effects. Therefore, any measured quantity or calculated doses that indicate that the person most sensitive to radiation (e.g. children or pregnant women) may have received a dose, or are projected to receive a dose, which exceeds a generic criteria for a particular exposure scenario are considered unsafe. The generic criteria are established at levels where:

- urgent and early response actions are justified in order to minimize severe deterministic effects and reduce the risk of stochastic effects (radiation induced cancers) in the population; and
- longer term medical actions are warranted to detect and to effectively treat radiation induced health effects.

Below these generic criteria there will not be any severe deterministic effects or an observable increase in the incidence of cancer, even in a very large exposed group. Furthermore, the risk of cancers and other health effects is too low to justify taking any action, such as a medical screening [1].

In emergencies various measured quantities such as dose rate (e.g. expressed in sieverts per hour, Sv/h), food concentrations (e.g. expressed in becquerels per kilogram, Bq/kg) or calculated doses (e.g. expressed in Sieverts, Sv) are reported and often used to describe the situation to the public and decision makers. In many of these cases, the quantities and doses are: (a) used incorrectly (e.g. use of effective dose to assess health effects, not considering the members of the public most sensitive to radiation or all exposure pathways) and (b) are not put into perspective in terms of the possible health hazard.

A system has been created in order to place the radiological health hazard in perspective for a measured quantity or calculated dose in a simple and understandable format, as shown in *FIG. 14* and explained in Table 11. This system defines what is safe and also indicates whether there are possible health concerns and when the situation is dangerous to health. When using the system, the specific conditions (e.g. living on contaminated ground) and public behaviour (e.g. consumption of food, milk or water with concentrations in excess of the OIL7 values is prevented) for which it applies (e.g. exposure scenarios when living in an affected area) need to be clearly indicated.

[51] The 'worried well' are members of the public who have not been exposed or injured but are seriously concerned about their possible radiation exposure or contamination.

This publication includes three Sections to address this problem and to improve communication with the public, decision makers and others:

- Section 7.3 provides charts that relate measured operational quantities in an emergency to the health hazard system given in FIG. 14;
- Section 7.4 provides a means to evaluate assessments and identify common errors made when placing health hazards in perspective; and
- Section 7.5 provides a means to assess and relate calculated doses to the health hazard system given in FIG. 14.

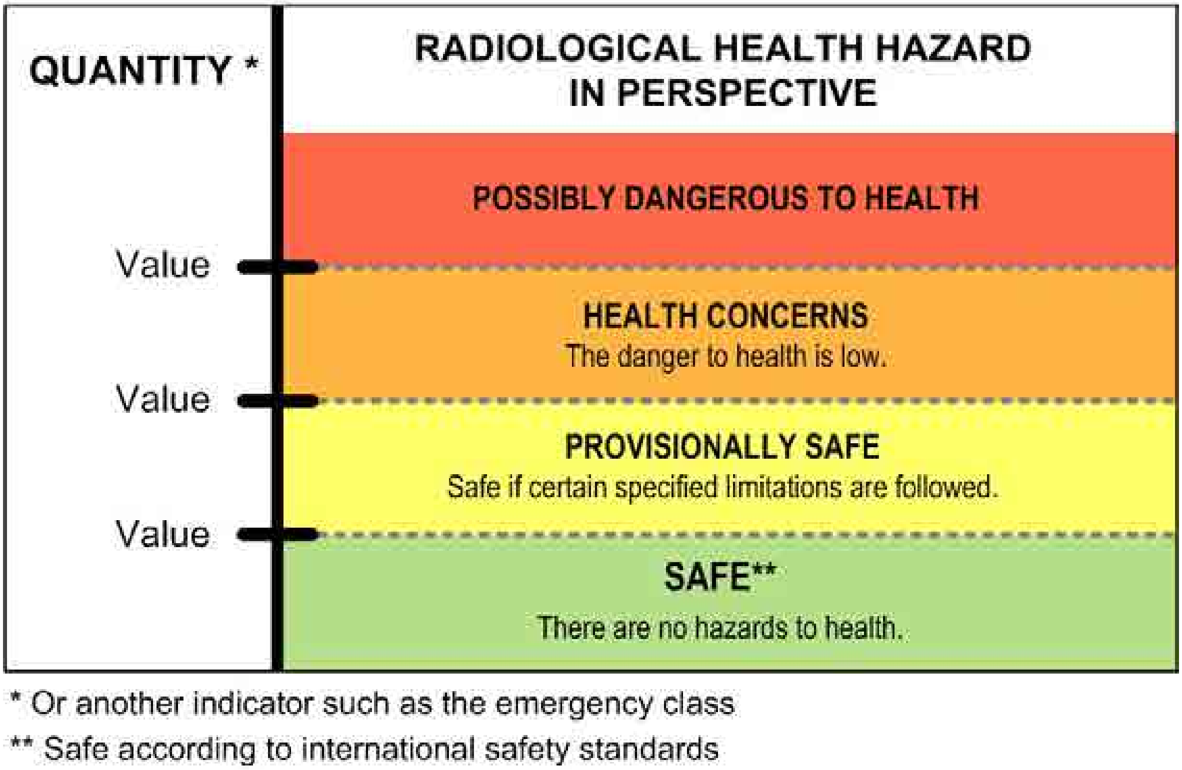


FIG. 14. System for placing in perspective the radiological health hazard associated with specified conditions and public behaviour during a nuclear or radiological emergency for communication with the public and decision makers.

TABLE 11. DESCRIPTION OF THE SYSTEM FOR PUTTING IN PERSPECTIVE THE RADIOLOGICAL HAZARD TO HEALTH ASSOCIATED WITH SPECIFIED CONDITIONS AND PUBLIC BEHAVIOUR FOR A NUCLEAR OR RADIOLOGICAL EMERGENCY

Health hazard perspective	Explanation
Possibly dangerous to health (red)	There is a possibility of radiation induced health effects that are life threatening or can result in a permanent injury that reduces the quality of life (severe deterministic effects). At this level there is also the small possibility of an observable increase in the incidence of cancer due to radiation induced cases, if the number of exposed people is more than a few hundred.
Health concerns (orange)	The danger to health is very low. However, there is a possibility of doses exceeding the international criteria [1] that call for taking protective actions and other response actions to include medical screening in order to further assess: (a) the small possible risk to pregnant women (fetus), and (b) the small possible increase in the risk of radiation induced cancers.
Provisionally safe (yellow)	All members of the public are safe including the most sensitive (i.e. children and pregnant women) and there are no hazards to health due to radiation exposure if the specified limitations are followed, such as remaining in the area is limited to a specific amount of time and/or specified protective actions are taken (e.g. reduce ingestion of radioactive material).
Safe (green)	All members of the public are safe including the most sensitive (i.e. children and pregnant women) as international GC [1, 2] are met. The doses for the specified conditions and public behaviour (exposure scenario) are less than the GC [1, 2] at which protective actions and other response actions are justified to minimize severe deterministic effects or to reduce the risk of stochastic effects. Below this level there will not be any severe deterministic effects or an observable increase in the incidence of cancer, even in a very large exposed group. Furthermore, the risk of radiation induced cancers is too low to justify taking any action, such as a medical screening [1, 2].

7.3. MEASURED OPERATIONAL QUANTITIES IN PERSPECTIVE

7.3.1. Relating measured operational quantities to the radiological health hazard

Measured quantities cannot be related to the health hazard to the public due to a radiation exposure (*FIG. 14* and Table 11) without answering the following questions:

- What was measured?
- Who was exposed?
- How were they exposed?
- What is the risk in terms of the health effects?

For potential radioactive releases from a LWR or RBMK core or spent fuel pool, these questions can be answered in advance because the characteristics of the releases and the various exposure pathways are understood. Therefore, the various measured operational quantities can be related to the possible radiation induced health effects by the process shown in FIG. 15. In order to simplify this process for application in an emergency, each step specified in FIG. 15 has been performed with reasonably conservative assumptions. The overall results are presented in Charts 1–4. Therefore, Charts 1–4 are ‘shortcuts’ that allow the steps depicted in FIG. 15 to be skipped.

However, it is important to note that if the measured quantity used for placing health hazards in perspective is based on only a limited number of measurements then this qualification needs to be explained to the public and to decision makers.

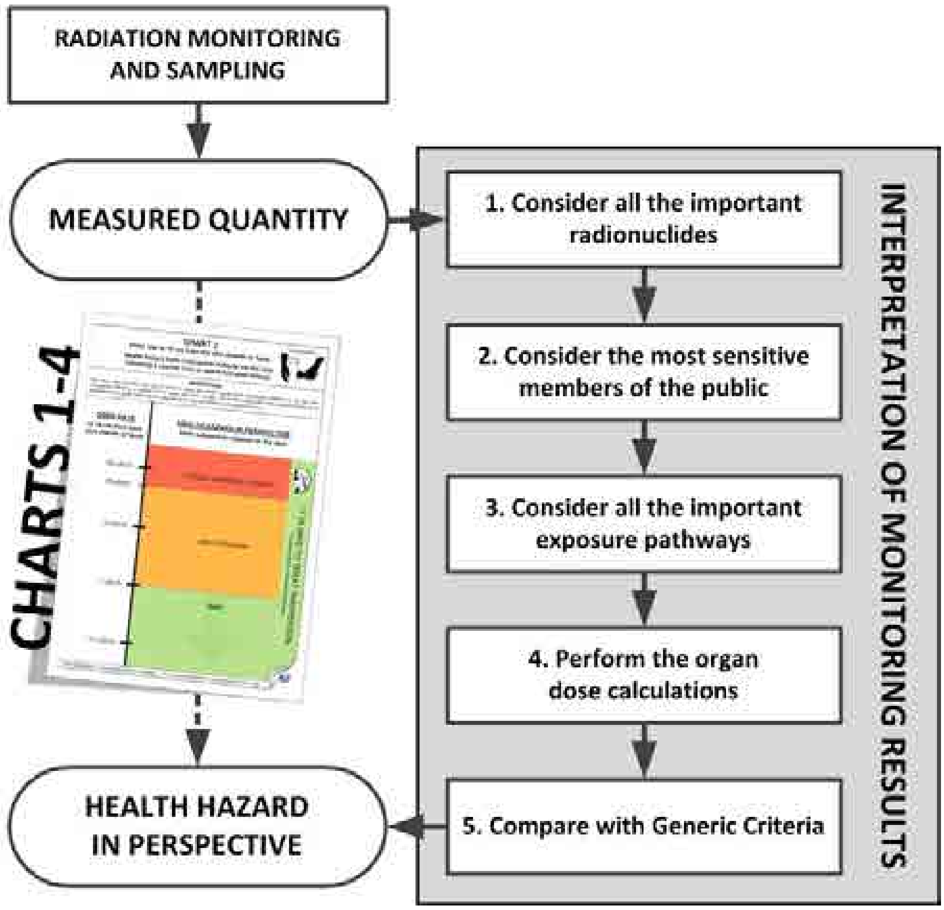


FIG. 15. Steps required for placing the radiological health hazard in perspective based on measured operational quantities.

7.3.2. Charts to place the radiological health hazard in perspective based on measured operational quantities

Charts 1–4 were developed by taking into consideration all radionuclides expected to be present after a release from a reactor core or spent fuel pool and all the exposure pathways expected to be relevant. The measured quantities are used as key indicators representative for the exposure scenario and resulting health hazard. For example, when a concentration of ^{137}Cs in food, milk or water is shown on the chart, not only are the health hazards related to ^{137}Cs considered, but also the health hazards related to the exposure of all the radioactive materials expected to be present following a release from a reactor core or spent fuel pool, such as ^{131}I, ^{134}Cs, ^{140}Ba, ^{90}Sr and ^{106}Ru, are considered. Similarly, when a dose rate measurement from deposition is shown on the chart, not only is the external exposure to radiation considered, but all exposure pathways expected to be relevant (e.g. inadvertent ingestion) are included.

The possible radiation induced health effects can only be determined following a careful assessment of the individual. The charts provided in this section are not intended to replace individualized assessments, medical screenings or examinations; instead, the purpose of the charts is to:

- Help the public, decision makers and others understand what protective actions and other response actions are appropriate or inappropriate for ensuring the safety of everyone.
- Help to identify those members of the public who might need a medical screening, examination or further assessment, in order to determine possible radiation induced health effects during the first critical weeks and months, when timely decision making is crucial for an effective response to the emergency, and detailed and individualized assessments may not be possible due to limited resources and data.

The charts are based on reasonably conservative assumptions so that the actual radiation induced health effects would be expected to occur at a value higher than first indicated in the chart, including for the members of the public most sensitive to radiation. Therefore, if the charts indicate that there are health concerns or conditions that are possibly hazardous to health, the individual (where appropriate) needs to be registered, and to receive a medical examination, counselling and/ or medical follow-up.

7.3.3. Use of charts for measured operational quantities

Step 1 — Obtain at least one of the following data sets along with an explanation of the quality of the data used**:**

- dose rates representative of those in areas where people are living;
- dose rates measured from the bare skin; or
- concentrations in food, milk or water representative of what is being consumed.

Step 2 — Select the appropriate chart

Select the chart based on what quantity was measured and which exposure scenario is being considered using Table 12.

TABLE 12. APPLICABILITY OF THE MEASURED QUANTITIES CHARTS

Exposure scenarios	Measured quantity	Chart No.
Living in an affected area for 7 days, 1 month or 1 year	Dose rate [μSv/h] at 1m above ground level in inhabited areas	1
Radioactive material on the skin	Dose rate [μSv/h] at 10 cm from the bare skin	2
1 day of consumption of food, milk or drinking water considering all radionuclides released	Cs-137 [Bq/kg] marker[b] concentrations in food, milk or drinking water	3A[a]
	I-131 [Bq/kg] marker[b] concentrations in food, milk or drinking water	3B[a]
1 year of consumption of food, milk or drinking water considering all radionuclides released	Cs-137[Bq/kg] marker[b] concentrations in food, milk or drinking water	4A[a]
	I-131 [Bq/kg] marker[b] concentrations in food, milk or drinking water	4B[a]

[a.] Both the ^{131}I and ^{137}Cs marker radionuclide concentrations need to be determined and evaluated according to Charts 3 and 4.

[b.] The other radioactive material from a fission product release that would be present (e.g. Sr-90, Te-132, I-135, Cs-134...) do not need to be considered because they are considered based on their expected amounts relative to the concentrations of the marker.

Step 3 — Convert the units of the measured quantity to those in the charts

Ensure that the measured quantities are in the same units as they appear on the selected chart (μSv/h or Bq/kg). For example, 2 mSv/h needs to be converted to μSv/h as shown below:

$$2\,\frac{\text{mSv}}{\text{h}} \times 1000\,\frac{\mu\text{Sv}}{\text{mSv}} = 2000\,\frac{\mu\text{Sv}}{\text{h}}$$

Table 13 shows the conversions for the most commonly used prefixes to those used in the charts, and Table 14 shows other SI prefixes that may be used.

TABLE 13. CONVERSIONS OF THE MOST COMMON UNITS USED IN THE CHARTS

Multiply (reported unit)	**By**			**To get (unit used in charts)**
Sv/h	1 000 000	(or 10^6)	µSv/Sv	µSv/h
mSv/h	1 000	(or 10^3)	µSv/mSv	µSv/h
Bq/g	1 000	(or 10^3)	g/kg	Bq/kg
kBq/kg	1 000	(or 10^3)	Bq/kBq	Bq/kg
kBq/g	1 000 000	(or 10^6)	(Bq/kg)/(kBq/g)	Bq/kg
MBq/kg	1 000 000	(or 10^6)	Bq/MBq	Bq/kg
MBq/g	1 000 000 000	(or 10^9)	(Bq/kg)/(MBq/g)	Bq/kg

TABLE 14. SI PREFIXES TYPICALLY USED

Prefix	**Symbol**	**10^n**	**Decimal**
tera	T	10^{12}	1 000 000 000 000
giga	G	10^{9}	1 000 000 000
mega	M	10^{6}	1 000 000
kilo	k	10^{3}	1 000
–	–	10^{0}	1
milli	m	10^{-3}	0.001
micro	µ	10^{-6}	0.000 001
nano	n	10^{-9}	0.000 000 001
pico	p	10^{-12}	0.000 000 000 001

Step 4 — Explaining the charts

The front of each chart has a 'description' which summarizes what is being addressed by the chart. The back of each chart (i.e. the page following the chart) has an explanation of its purpose, the measured quantity, exposure scenario, population considered and the possible health hazard. When discussing the charts with the public the following points need to be stressed:

- If a particular radiation induced health effect is indicated it means that there is only a small chance of someone suffering the effect, it does not mean that it will definitely take place.
- The radiation induced health effects would not be expected to occur for anyone at levels below those indicated in the charts.
- An accurate assessments of the possible radiation induced health effects can only be performed after the individual's exposure is better known and can only be performed by experts in diagnoses and treatment of the radiation induced health effects.
- If the situation is possibly dangerous to health or there are health concerns, the appropriate protective actions and other response actions (e.g. medical follow-up) indicated on the charts need to be taken.
- The quality of the data being used and how representative they are needs to be explained. If future refinements of the data are expected, this needs to be stressed.

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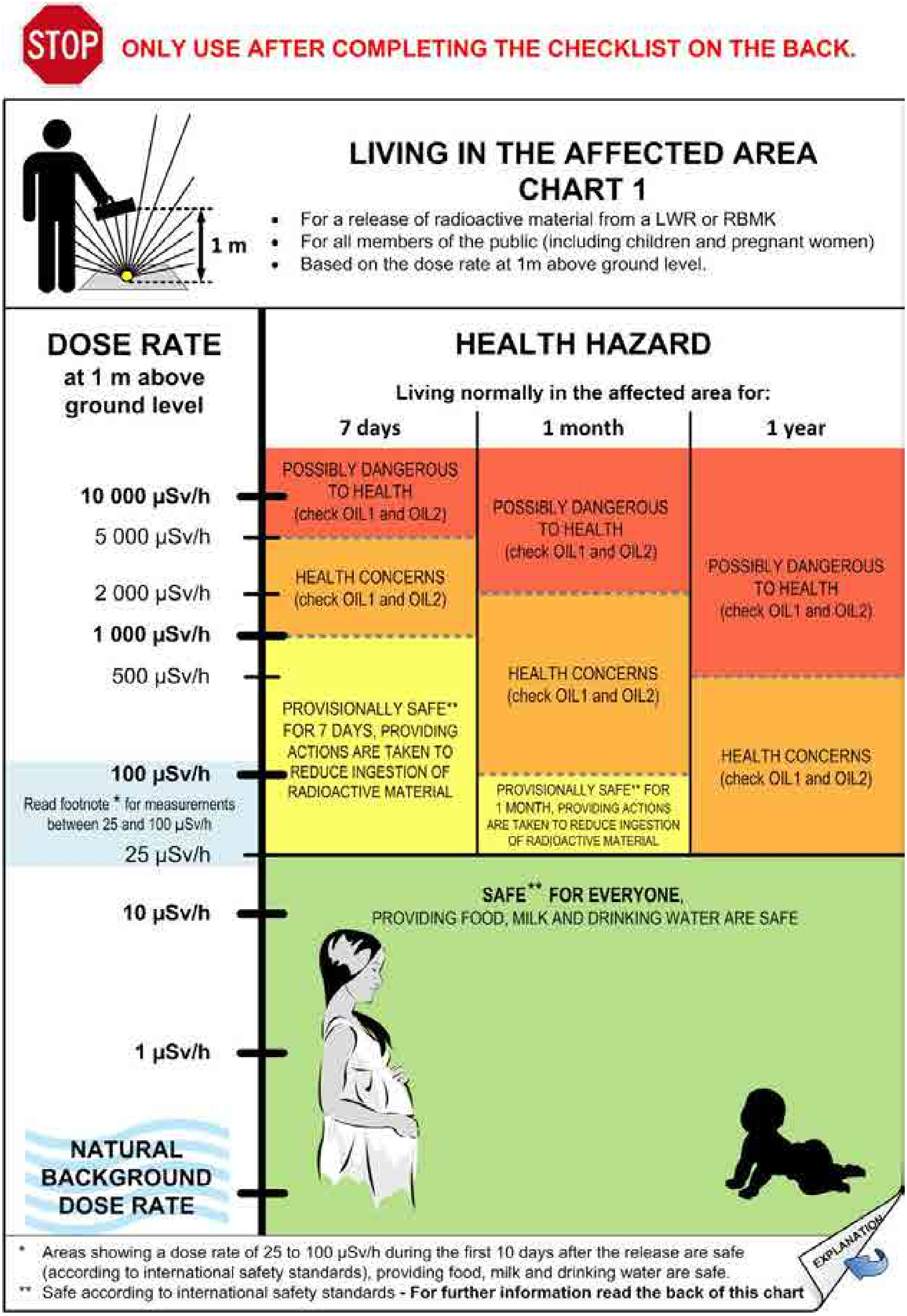


Chart 1. Health hazard from living in an affected area following a release from a reactor or spent fuel pool of a LWR or RBMK based on dose rate.

CHART 1 EXPLANATION

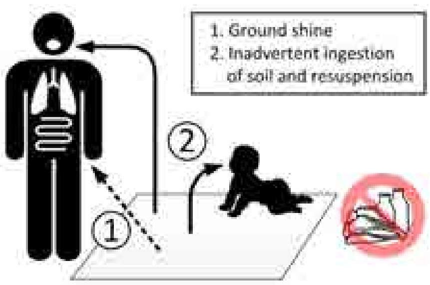
'BEFORE USE' CHECKLIST: If the answer to any of the following is 'No', do not use this chart.

Is the nuclear power plant a LWR or RBMK?	☐ Yes	☐ No
Are you assessing the health hazard from living in the affected area?	☐ Yes	☐ No
Is the dose rate representative of the inhabited area?	☐ Yes	☐ No
Is the dose rate representative of that from deposition at 1m above ground?	☐ Yes	☐ No
Is the dose rate value in µSv/h?	☐ Yes	☐ No
Are you outside the area for which evacuation or relocation was recommended?	☐ Yes	☐ No

PURPOSE: This chart places in perspective the link between the measured dose rate from deposition and the possible health hazard from living normally for the period indicated in the affected area following a release from a reactor or spent fuel pool of a LWR or RBMK.

MEASURED QUANTITY: Dose rate (µSv/h) from deposition measured at 1m above ground level in the inhabited areas.

EXPOSURE SCENARIO: Members of the public are living normally in an area affected by a release without taking any protective actions, except they do not consume contaminated food, milk or water. All the important ways of being exposed to radioactive material on the ground were taken into account, including: external exposure from deposition (ground shine), inadvertent ingestion (e.g. from eating dirt on hands or from children playing on the ground) and inhalation of resuspension of the deposition (dust).



The chart only considers the health hazard resulting from deposited radioactive material. Therefore, those who were in the area during the plume's passage where the dose rate from deposition is greater than 25 µSv/h need to have their dose estimated to determine if a medical examination, counselling or medical follow-up is warranted.

POPULATION CONSIDERED: The possible health hazards shown are for the members of the public most sensitive to radiation (e.g. children and pregnant women (fetus)). For this reason all members of the public have been covered.

HEALTH HAZARD IN PERSPECTIVE:

Possibly dangerous to health (red): There is a possibility of radiation induced health effects that are life threatening or can result in a permanent injury that reduces the quality of life (severe deterministic effects) to include: (a) permanently suppressed ovulation and sperm counts, (b) hypothyroidism (a condition in which the thyroid gland does not produce sufficient thyroid hormones) and (c) severe effects to the fetus. At this level there is also the small possibility of an observable increase in the incidence of cancer due to radiation induced cases, if the number of exposed people is more than a few hundred.

Health concerns (orange): The danger to health is very low. However, there is a possibility of doses exceeding the international criteria [1] that call for taking protective actions and other response actions, to include a medical screening, in order to further assess: (a) the small possible risk to pregnant women (fetus), and (b) the small possible increase in the risk of radiation induced cancers.

Provisionally safe (yellow): It is safe if remaining in the area is limited to the specific time period and the following protective actions are implemented:

- prevent the consumption of food, milk or water with concentrations greater than OIL7, and
- prevent inadvertent ingestion, such as: washing hands before eating and not playing on the ground, or not doing other activities that could result in the creation of dust that could be ingested.

Safe (green): This meets international standards [1] as the doses are less than the generic criteria at which protective actions and other response actions are justified to minimize the health effects from radiation exposure, provided the food, milk or water is safe (i.e. does not have concentrations that exceed OIL7 values). Below this level there will not be any severe deterministic effects or an observable increase in the incidence of cancer, even in a very large exposed group. Furthermore, the risk of cancers and other health effects is too low to justify taking any action, such as a medical screening [1].

Natural background dose rate: The average annual dose rate from natural sources of radiation exposure is shown for perspective. The worldwide average fluctuates around 0.2 µSv/h, but in some locations it can be much higher (up to 15 µSv/h).

PROTECTIVE ACTIONS AND OTHER RESPONSE ACTIONS:

If an individual **has been in an area** where conditions indicate the health hazard level is 'possibly dangerous to health' (red) or 'health concerns' (orange), the individual needs to be registered and have their doses estimated to determine if a medical examination or counselling and medical follow-up are warranted. Health effects from radiation exposure can only be assessed by experts in diagnosing and treating the health effects of radiation exposure. Others, such as local physicians, probably will not have the expertise needed to make such assessments.

If an individual **is in an area** where conditions indicate the health hazard level is 'possibly dangerous to health' (red) or 'health concerns' (orange), take protective actions and other response actions in accordance with OIL1 and OIL2 in Table 7 of the IAEA publication: Actions to Protect the Public in an Emergency due to Severe Conditions at a Light Water Reactor, EPR-NPP PUBLIC PROTECTIVE ACTIONS, 2013.

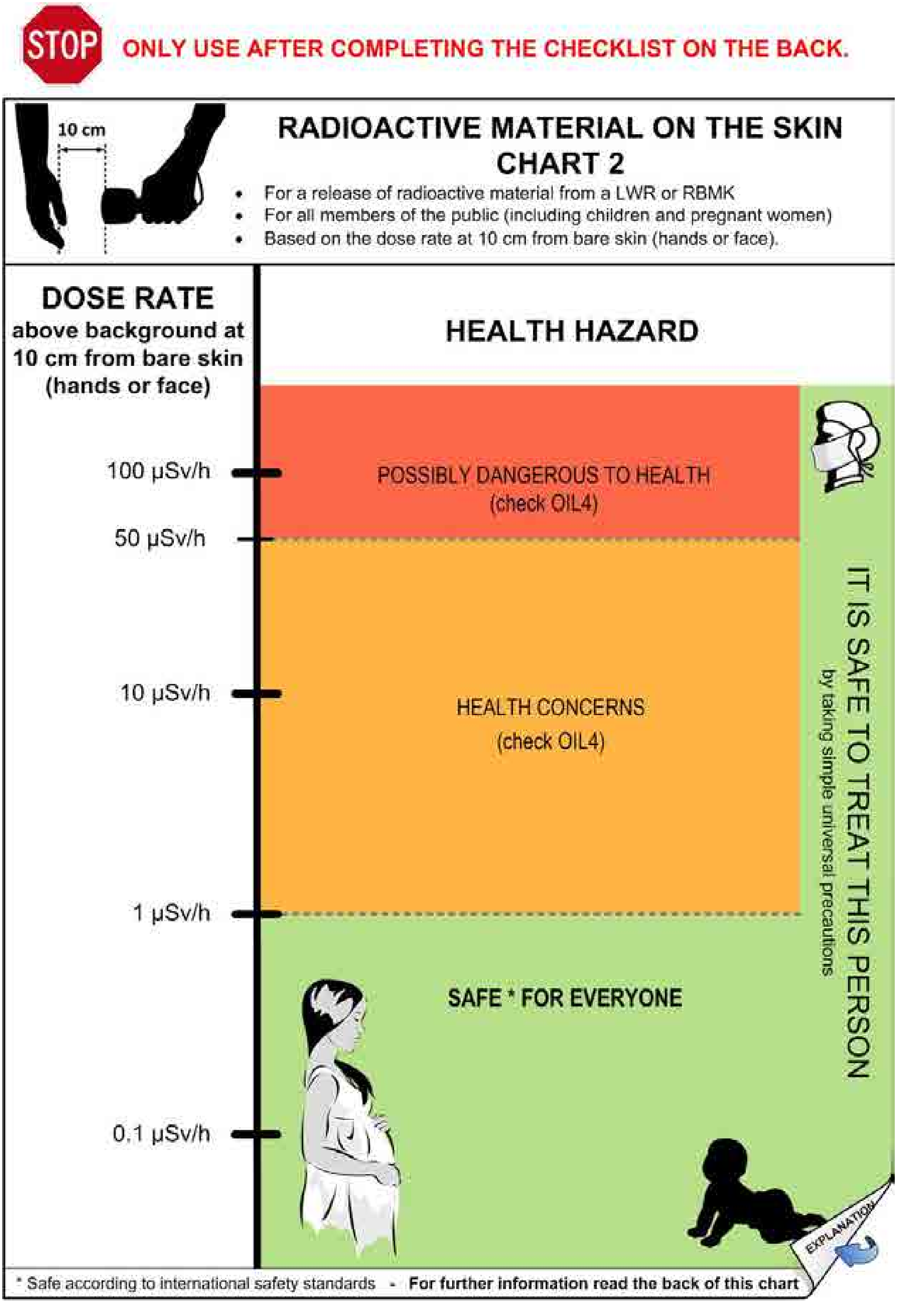


Chart 2. Health hazard from radioactive material on the skin following a release from a reactor or spent fuel pool of a LWR or RBMK based on dose rate.

CHART 2 EXPLANATION

'BEFORE USE' CHECKLIST: If the answer to any of the following is 'No', do not use this chart:

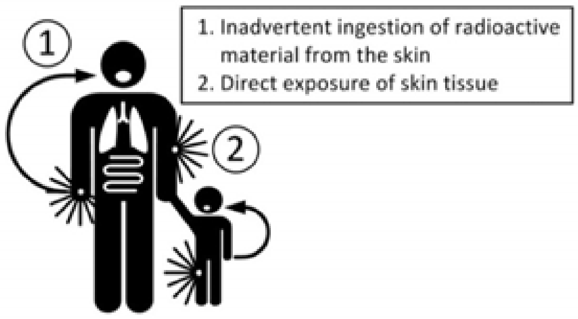
Is the nuclear power plant a LWR or RBMK?	☐ Yes ☐ No
Are you assessing the health hazard from radioactive material on the skin?	☐ Yes ☐ No
Is the dose rate measurement taken at 10 cm from bare skin?	☐ Yes ☐ No
Is the dose rate in µSv/h?	☐ Yes ☐ No
Are you using the above background dose rate?	☐ Yes ☐ No
Are you outside the area for which evacuation or relocation was recommended?	☐ Yes ☐ No

PURPOSE: This chart places in perspective the link between the dose rate of the skin and the possible health hazard from radioactive material on the skin resulting from a reactor or spent fuel pool of a LWR or RBMK.

MEASURED QUANTITY: The dose rate (µSv/h) above background measured by a dose rate instrument at 10 cm from bare skin (hands or face).

EXPOSURE SCENARIO: All the important ways of being exposed to radiation from radioactive material deposited on the skin and from eating contaminated dirt on hands (inadvertent ingestion) were taken into account.

POPULATION CONSIDERED: The possible health hazards shown are for the members of the public most sensitive to radiation (e.g. children and pregnant women (fetus)). For this reason all members of the public have been covered.



HEALTH HAZARD IN PERSPECTIVE:

Always safe to treat a contaminated person: Universal precautions against infection (gloves, mask, etc.) provide sufficient protection for those treating any individual possibly contaminated.

Possibly dangerous to health (red): There is a possibility of radiation induced health effects that are life threatening or can result in a permanent injury that reduces the quality of life (severe deterministic effects) to include hypothyroidism (a condition in which the thyroid gland does not produce sufficient thyroid hormones). At this level there is also the small possibility of an observable increase in the incidence of cancer due to radiation induced cases, if the number of exposed people is more than a few hundred.

Health concerns (orange): The danger to health is very low. However, there is a possibility of doses exceeding the international criteria [1] that call for taking protective actions and other response actions, to include a medical screening, in order to further assess: (a) the small possible risk to pregnant women (fetus) and (b) the small possible increase in the risk of radiation induced cancers. This may also indicate that the person may have inadvertently ingested or inhaled enough contamination to result in doses greater than the generic criteria calling for a medical follow-up.

Safe (green): This meets international standards [1] as the doses are less than the generic criteria at which protective actions and other response actions are justified to minimize the health effects from radiation exposure. Below this level there will not be any severe deterministic effects or an observable increase in the incidence of cancer, even in a very large exposed group. Furthermore, the risk of cancers and other health effects is too low to justify taking any action, such as a medical screening [1].

PROTECTIVE ACTIONS AND OTHER RESPONSE ACTIONS:

If an individual has levels of radioactive material on the skin that indicates the health hazard level is 'possibly dangerous to health' (red) or 'health concerns' (orange), the individual needs to:

- take protective actions and other response actions in accordance with OIL4 of Table 8 of the IAEA publication: Actions to Protect the Public in an Emergency due to Severe Conditions at a Light Water Reactor, EPR-NPP PUBLIC PROTECTIVE ACTIONS, 2013; and
- be registered and have their doses estimated to determine if a medical examination or counselling and medical follow-up are warranted. Health effects from radiation exposure can only be assessed by experts in diagnosing and treating the health effects of radiation exposure. Others, such as local physicians, probably will not have the expertise needed to make such assessments.

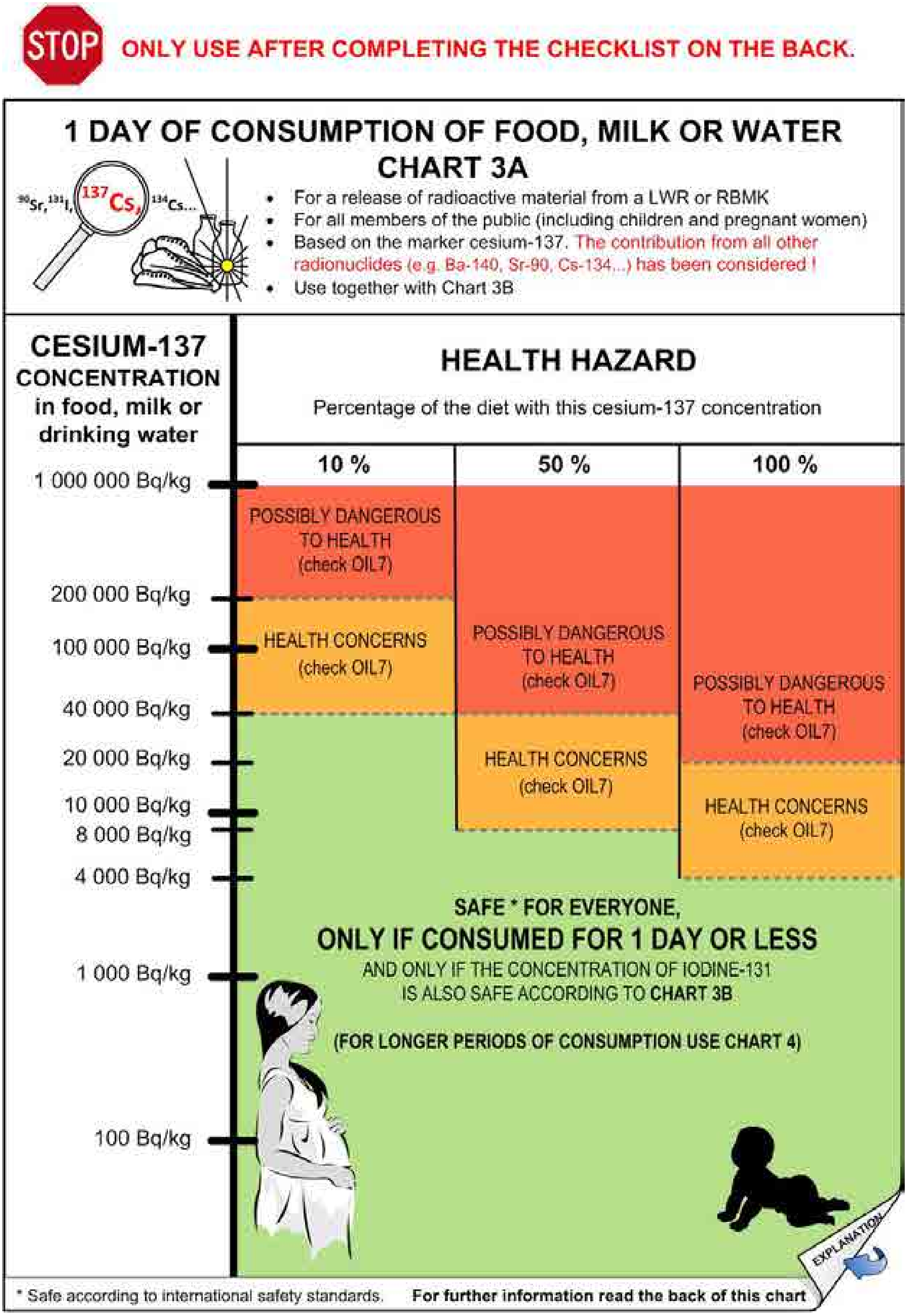


Chart 3A. Health hazard from ***1 day*** *of consumption of affected food, milk or drinking water following a release from a reactor or spent fuel pool of a LWR or RBMK based on marker Cs-137 concentration.*

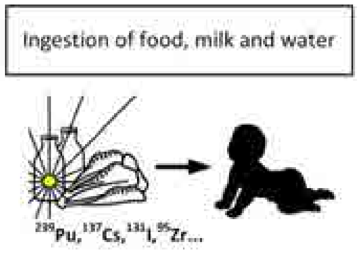
CHART 3A EXPLANATION

'BEFORE USE' CHECKLIST: If the answer to any of the following is 'No', do not use this chart:

Is the nuclear power plant a LWR or RBMK?	☐ Yes	☐ No
Are you assessing the health hazard from consuming food, milk and water for 1 day?	☐ Yes	☐ No
Is the quantity the concentration of Cs-137 in food, milk or water?	☐ Yes	☐ No
Is the concentration in Bq/kg?	☐ Yes	☐ No
Was the I-131 concentration in food, milk or water also assessed using Chart 3B?	☐ Yes	☐ No
Are you outside the area for which evacuation or relocation was recommended?	☐ Yes	☐ No

PURPOSE: This chart places in perspective the link between measured Cs-137 concentrations in food, milk and drinking water and the possible health hazard from consumption of food, milk or water affected by a release from a reactor or spent fuel pool of a LWR or RBMK when also used with Chart 3B.

MEASURED QUANTITY: Concentration of I-131 and Cs-137 marker in food, milk or drinking water (Bq/kg) as determined by laboratory analysis. All the other radioactive material from a release that would be present (e.g. Sr-90, Te-132, I-135, Cs-134...) were considered based on their expected amounts relative to the concentrations of Cs-137 (given in this Chart) and I-131 (given in Chart 3B).



EXPOSURE SCENARIO: This is for a single contaminating event. It is assumed that either 10%, 50% or 100% of the diet has the indicated concentration and it was consumed for a period **of 1 day or less**.

POPULATION CONSIDERED: The possible health hazards shown are for the members of the public most sensitive to radiation (e.g. children and pregnant women (fetus)). For this reason all members of the public have been covered.

HEALTH HAZARD IN PERSPECTIVE:

Possibly dangerous to health (red): There is a possibility of radiation induced health effects that are life threatening or can result in a permanent injury that reduces the quality of life (severe deterministic effects) to include hypothyroidism (a condition in which the thyroid gland does not produce sufficient thyroid hormones). At this level there is also the small possibility of an observable increase in the incidence of cancer due to radiation induced cases, if the number of exposed people is more than a few hundred.

Health concerns (orange): The danger to health is very low. However, there is a possibility of doses exceeding the international criteria [1] that call for taking protective actions and other response actions, to include a medical screening, in order to further assess: (a) the small possible risk to pregnant women (fetus) and (b) the small possible increase in the risk of radiation induced cancers.

Safe (green): ***Is safe only for 1 day of consumption.*** This meets international standards [1] as the doses are less than the generic criteria at which protective actions and other response actions are justified to minimize the health effects from radiation exposure, provided that the concentration of I-131 is also safe according to Chart 3B. Below this level there will not be any severe deterministic effects or observable increase in the incidence of cancer, even in a very large exposed group. Furthermore, the risk of cancers and other health effects is too low to justify taking any action, such as a medical screening [1].

PROTECTIVE ACTIONS AND OTHER RESPONSE ACTIONS:

If an individual has consumed food, milk or water with concentrations that indicate the health hazard level is 'possibly dangerous to health' (red) or 'health concerns' (orange), the individual needs to be registered and have their doses estimated to determine if a medical examination or counselling and medical follow-up are warranted. Health effects from radiation exposure can only be assessed by experts in diagnosing and treating the health effects of radiation exposure. Others, such as local physicians, probably will not have the expertise needed to make such assessments.

If food, milk or water concentrations indicate that the health hazard level is 'possibly dangerous to health' (red) or 'health concerns' (orange), take protective actions and other response actions in accordance with OIL7 of Table 9 of the IAEA publication: Actions to Protect the Public in an Emergency due to Severe Conditions at a Light Water Reactor, EPR-NPP PUBLIC PROTECTIVE ACTIONS, 2013.

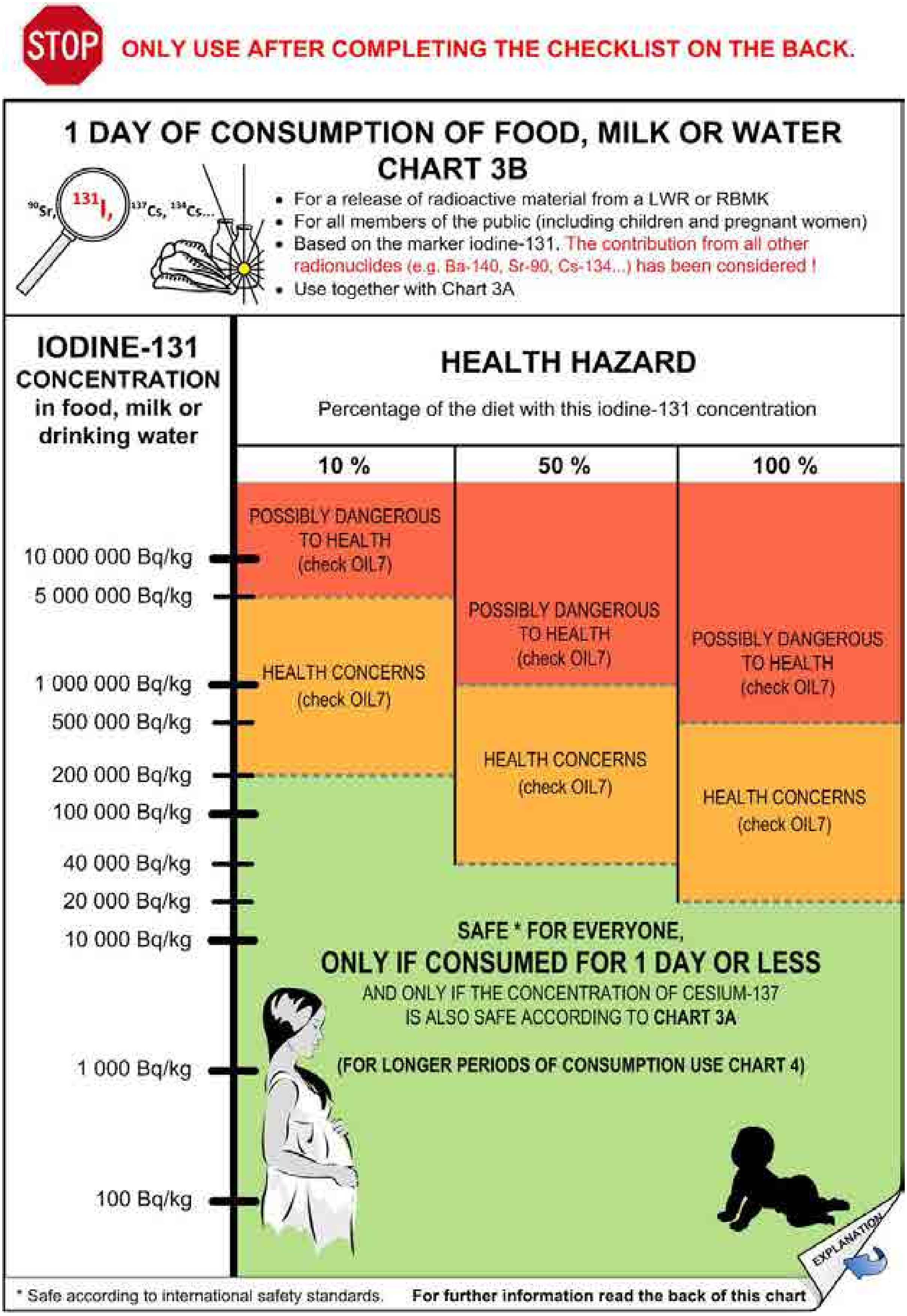


*Chart 3B. Health hazard from **1 day** of consumption of affected food, milk or drinking water following a release from a reactor or spent fuel pool of a LWR or RBMK based on marker I-131 concentration.*

CHART 3B EXPLANATION

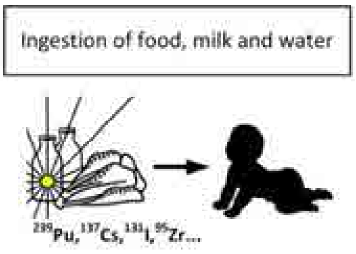
'BEFORE USE' CHECKLIST: If the answer to any of the following is 'No', do not use this chart:

Is the nuclear power plant a LWR or RBMK?	☐ Yes	☐ No
Are you assessing the health hazard from consuming food, milk and water for 1 day?	☐ Yes	☐ No
Is the quantity the concentration of I-131 in food, milk or water?	☐ Yes	☐ No
Is the concentration in Bq/kg?	☐ Yes	☐ No
Was the Cs-137 concentration in food, milk or water also assessed using Chart 3A?	☐ Yes	☐ No
Are you outside the area for which evacuation or relocation was recommended?	☐ Yes	☐ No

PURPOSE: This chart places in perspective the link between measured I-131 concentrations in food, milk and drinking water and the possible health hazard from consumption of food, milk or water affected by a release from a reactor or spent fuel pool of a LWR or RBMK when also used with Chart 3A.

MEASURED QUANTITY: Concentration of I-131 and Cs-137 marker in food, milk or drinking water (Bq/kg) as determined by laboratory analysis. All the other radioactive material from a release that would be present (e.g. Sr-90, Te-132, I-135, Cs-134...) were considered based on their expected amounts relative to the concentrations of I-131 (given in this Chart) and Cs-137 (given in Chart 3A).

EXPOSURE SCENARIO: This is for a single contaminating event**.** It is assumed that either 10%, 50% or 100% of the diet has the indicated concentration and it was consumed for a period of **1 day or less.**



POPULATION CONSIDERED: The possible health hazards shown are for the members of the public most sensitive to radiation (e.g. children and pregnant women (fetus)). For this reason all members of the public have been covered.

HEALTH HAZARD IN PERSPECTIVE:

Possibly dangerous to health (red): There is a possibility of radiation induced health effects that are life threatening or can result in a permanent injury that reduces the quality of life (severe deterministic effects) to include hypothyroidism (a condition in which the thyroid gland does not produce sufficient thyroid hormones). At this level there is also the small possibility of an observable increase in the incidence of cancer due to radiation induced cases, if the number of exposed people is more than a few hundred.

Health concerns (orange): The danger to health is very low. However, there is a possibility of doses exceeding the international criteria [1] that call for taking protective actions and other response actions, to include a medical screening, in order to further assess: (a) the small possible risk to pregnant women (fetus) and (b) the small possible increase in the risk of radiation induced cancers.

Safe (green): ***Is safe only for 1 day of consumption.*** This meets international standards [1] as the doses are less than the generic criteria at which protective actions and other response actions are justified to minimize the health effects from radiation exposure provided that the concentration of Cs-137 is also safe according to Chart 3A. Below this level there will not be any severe deterministic effects or observable increase in the incidence of cancer, even in a very large exposed group. Furthermore, the risk of cancers and other health effects is too low to justify taking any action, such as a medical screening [1].

PROTECTIVE ACTIONS AND OTHER RESPONSE ACTIONS:

If an individual has consumed food, milk or water with concentrations that indicate the health hazard level is 'possibly dangerous to health' (red) or 'health concerns' (orange), the individual needs to be registered and have their doses estimated to determine if a medical examination or counselling and medical follow-up are warranted. Health effects from radiation exposure can only be assessed by experts in diagnosing and treating the health effects of radiation exposure. Others, such as local physicians, probably will not have the expertise needed to make such assessments.

If food, milk or water concentrations indicate that the health hazard level is 'possibly dangerous to health' (red) or 'health concerns' (orange), take protective actions and other response actions in accordance with OIL7 of Table 9 of the IAEA publication: Actions to Protect the Public in an Emergency due to Severe Conditions at a Light Water Reactor, EPR-NPP PUBLIC PROTECTIVE ACTIONS, 2013.

STOP ONLY USE AFTER COMPLETING THE CHECKLIST ON THE BACK.

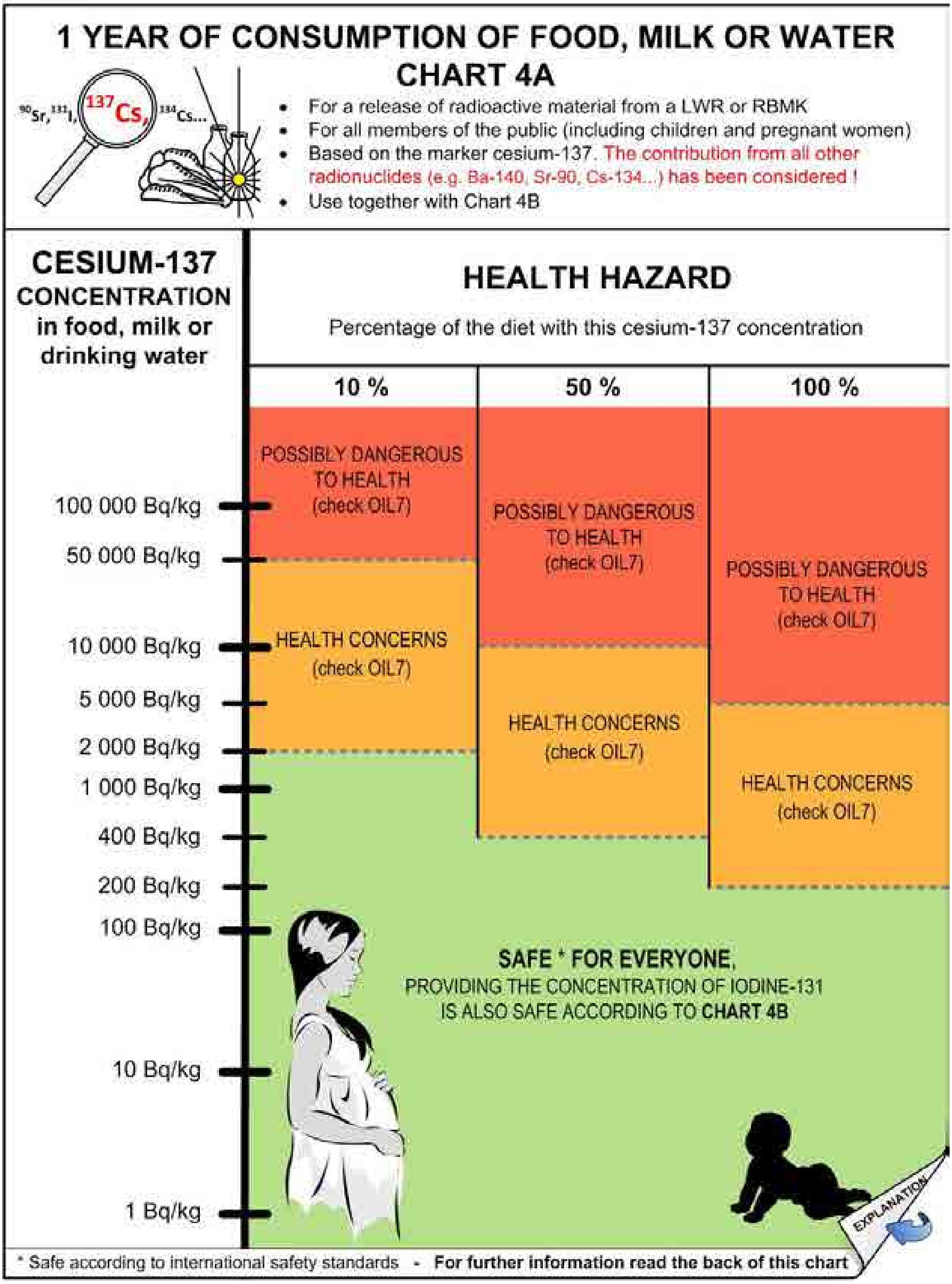


*Chart 4A. Health hazard from **1 year** of consumption of affected food, milk or drinking water following a release from a reactor or spent fuel pool of a LWR or RBMK based on marker Cs-137 concentration.*

CHART 4A EXPLANATION

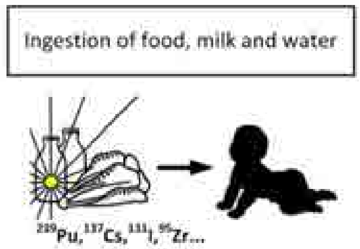
'BEFORE USE' CHECKLIST: If the answer to any of the following is 'No', do not use this chart:

Is the nuclear power plant a LWR or RBMK?	☐ Yes	☐ No
Are you assessing the health hazard from consuming food, milk and water for 1 year?	☐ Yes	☐ No
Is the quantity the concentration of Cs-137 in food, milk or water?	☐ Yes	☐ No
Is the concentration in Bq/kg?	☐ Yes	☐ No
Was the I-131 concentration in food, milk or water also assessed using Chart 4B?	☐ Yes	☐ No
Are you outside the area for which evacuation or relocation was recommended?	☐ Yes	☐ No

PURPOSE: This chart places in perspective the link between measured Cs-137 concentrations in food, milk and drinking water and the possible health hazard from consumption of food, milk or water affected by a release from a reactor or spent fuel pool of a LWR or RBMK when also used with Chart 4B.

MEASURED QUANTITY: Concentration of I-131 and Cs-137 marker in food, milk or drinking water (Bq/kg) as determined by laboratory analysis. All the other radioactive material from a release that would be present (e.g. Sr-90, Te-132, I-135, Cs-134...) were considered based on their expected amounts relative to the concentrations of Cs-137 (given in this Chart) and I-131 (given in Chart 4B).

EXPOSURE SCENARIO: This is for a single contaminating event. It is assumed that 10%, 50% or 100% of the diet for **1 year** initially has the indicated concentration.



POPULATION CONSIDERED: The possible health hazards shown are for the members of the public most sensitive to radiation (e.g. children and pregnant women (fetus)). For this reason all members of the public have been covered.

HEALTH HAZARD IN PERSPECTIVE:

Possibly dangerous to health (red): There is a possibility of radiation induced health effects that are life threatening or can result in a permanent injury that reduces the quality of life (severe deterministic effects) to include hypothyroidism (a condition in which the thyroid gland does not produce sufficient thyroid hormones). At this level there is also the small possibility of an observable increase in the incidence of cancer due to radiation induced cases, if the number of exposed people is more than a few hundred.

Health concerns (orange): The danger to health is very low. However, there is a possibility of doses exceeding the international criteria [1] that call for taking protective actions and other response actions, to include a medical screening, in order to further assess: (a) the small possible risk to pregnant women (fetus), and (b) the small possible increase in the risk of radiation induced cancers.

Safe (green): This meets international standards [1] as the doses are less that the generic criteria at which protective actions and other response actions are justified to minimize the health effects from radiation exposure provided the concentration of I-131 is also safe according to Chart 4B. Below this level there will not be any severe deterministic effects or an observable increase in the incidence of cancer, even in a very large exposed group. Furthermore, the risk of cancers and other health effects is too low to justify taking any action, such as a medical screening [1].

PROTECTIVE ACTIONS AND OTHER RESPONSE ACTIONS:

If an individual has consumed food, milk or water with concentrations that indicate the health hazard level is 'possibly dangerous to health' (red) or 'health concerns' (orange), the individual needs to be registered and have their doses estimated to determine if a medical examination or counselling and medical follow-up are warranted. Health effects from radiation exposure can only be assessed by experts in diagnosing and treating the health effects of radiation exposure. Others, such as local physicians, probably will not have the expertise needed to make such assessments.

If food, milk or water concentrations indicate the health hazard level is 'possibly dangerous to health' (red) or 'health concerns' (orange), take protective actions and other response actions in accordance with OIL7 of Table 9 of the IAEA publication: Actions to Protect the Public in an Emergency due to Severe Conditions at a Light Water Reactor, EPR-NPP PUBLIC PROTECTIVE ACTIONS, 2013. The OILs were established at levels well below those at which any radiation induced health effects would be expected; therefore, if restriction of consumption is likely to result in severe malnutrition or dehydration because replacements are not available, food, milk or water with concentration levels above the OIL7 value may be consumed, as directed by local officials, until replacements are available.

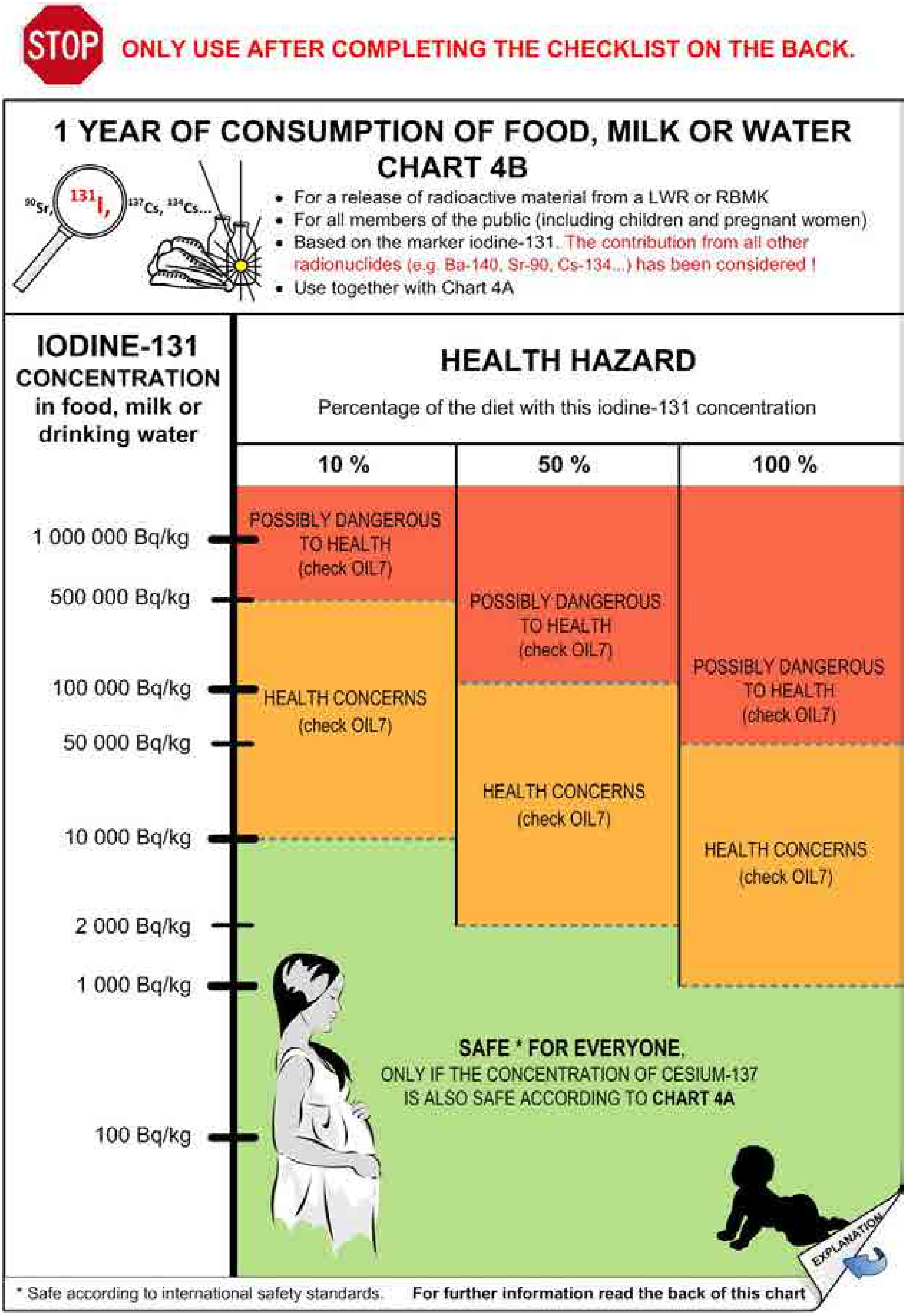


Chart 4B. Health hazard from __1 year__ of consumption of affected food, milk or drinking water following a release from a reactor or spent fuel pool of a LWR or RBMK based on marker I-131 concentration.

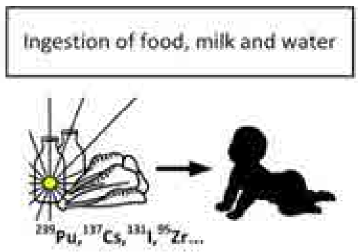
CHART 4B EXPLANATION

'BEFORE USE' CHECKLIST: If the answer to any of the following is 'No', do not use this chart:

Is the nuclear power plant a LWR or RBMK?	☐ Yes	☐ No
Are you assessing the health hazard from consuming food, milk and water for 1 year?	☐ Yes	☐ No
Is the quantity the concentration of I-131 in food, milk or water?	☐ Yes	☐ No
Is the concentration in Bq/kg?	☐ Yes	☐ No
Was the Cs-137 concentration in food, milk or water also assessed using Chart 4A?	☐ Yes	☐ No
Are you outside the area for which evacuation or relocation was recommended?	☐ Yes	☐ No

PURPOSE: This chart places in perspective the link between measured I-131 concentrations in food, milk and drinking water and the possible health hazard from consumption of food, milk or water affected by a release from a reactor or spent fuel pool of a LWR or RBMK when also used with Chart 4A.

MEASURED QUANTITY: Concentration of I-131 and Cs-137 marker in food, milk or drinking water (Bq/kg) as determined by laboratory analysis. All the other radioactive material from a release that would be present (e.g. Sr-90, Te-132, I-135, Cs-134...) were considered based on their expected amounts relative to the concentrations of I-131 (given in this Chart) and Cs-137 (given in Chart 4A).



EXPOSURE SCENARIO: This is for a single contaminating event. It is assumed that 10%, 50% or 100% of the diet for **1 year** initially has the indicated concentration.

POPULATION CONSIDERED: The possible health hazards shown are for the members of the public most sensitive to radiation (e.g. children and pregnant women (fetus)). For this reason all members of the public have been covered

HEALTH HAZARD IN PERSPECTIVE:

Possibly dangerous to health (red): There is a possibility of radiation induced health effects that are life threatening or can result in a permanent injury that reduces the quality of life (severe deterministic effects) to include hypothyroidism (a condition in which the thyroid gland does not produce sufficient thyroid hormones). At this level there is also the small possibility of an observable increase in the incidence of cancer due to radiation induced cases, if the number of exposed people is more than a few hundred.

Health concerns (orange): The danger to health is very low. However, there is a possibility of doses exceeding the international criteria [1] that call for taking protective actions and other response actions, to include a medical screening, in order to further assess: (a) the small possible risk to pregnant women (fetus), and (b) the small possible increase in the risk of radiation induced cancers.

Safe (green): This meets international standards [1] as the doses are less that the generic criteria at which protective actions and other response actions are justified to minimize the health effects from radiation exposure provided the concentration of Cs-137 is also safe according to Chart 4A. Below this level there will not be any severe deterministic effects or an observable increase in the incidence of cancer, even in a very large exposed group. Furthermore, the risk of cancers and other health effects is too low to justify taking any action, such as a medical screening [1].

PROTECTIVE ACTIONS AND OTHER RESPONSE ACTIONS:

If an individual has consumed food, milk or water with concentrations that indicate the health hazard level is 'possibly dangerous to health' (red) or 'health concerns' (orange), the individual needs to be registered and have their doses estimated to determine if a medical examination or counselling and medical follow-up are warranted. Health effects from radiation exposure can only be assessed by experts in diagnosing and treating the health effects of radiation exposure. Others, such as local physicians, probably will not have the expertise needed to make such assessments.

If food, milk or water concentrations indicate the health hazard level is 'possibly dangerous to health' (red) or 'health concerns' (orange), take protective actions and other response actions in accordance with OIL7 of Table 9 of the IAEA publication: Actions to Protect the Public in an Emergency due to Severe Conditions at a Light Water Reactor, EPR-NPP PUBLIC PROTECTIVE ACTIONS, 2013. The OILs were established at levels well below those at which any radiation induced health effects would be expected; therefore, if restriction of consumption is likely to result in severe malnutrition or dehydration because replacements are not available, food, milk or water with concentration levels above the OIL7 value may be consumed, as directed by local officials, until replacements are available.

7.4 COMMON ERRORS MADE USING MEASURED QUANTITIES OR CALCULATED DOSES TO PLACE THE HEALTH HAZARDS IN PERSPECTIVE

In an emergency, various measured quantities, such as dose rate, food concentration, and calculated doses are reported and often used for explaining the possible health hazard from radioactive material released from a reactor core or spent fuel pool. This has often been done incorrectly, which has led to significant confusion between experts, decision makers and the public, resulting in the public taking unjustified actions that do more harm than good in the belief that they are protecting themselves and their families.

As discussed in Section 7.2.1, actions that have been taken that were not warranted based on the radiation risk, include: voluntary abortions, rejecting products from the affected area, endangering lives due to evacuations (e.g. patients in hospitals) [10], unwarranted relocations, taking inappropriate forms of ITB and the demanding of medical examinations when it was not warranted (e.g. the 'worried well') that interfered with the treatment of those who were most at risk.

Table 15 summarizes the common errors that have previously been made when trying to place in perspective the health hazards from radioactive material released from a reactor core or spent fuel pool. Table 15 can be used to identify common errors in assessment and provides an explanation of why such assessment may not be reliable or effective.

If an assessment of the health hazard is provided to the public, decision makers or an individual based on a calculated dose or measured quantity:

- Check if any of the common errors listed in Table 15 have been made, and
- If any errors are identified, provide the associated explanation, also given in Table 15, to the public and decision makers as to why it may not be reliable or useful.

TABLE 15. COMMON ERRORS MADE IN ASSESSMENT OF THE RADIOLOGICAL HEALTH HAZARDS

Common errors	Explanation and possible consequences
Not answering the public's principal question: 'Am I safe?'	Assessments that do not answer the public's principal question 'Am I safe?' may result in unjustified actions being taken by the public and/or decision makers that do more harm than good in the belief that they are making themselves and others safe.
Not clearly stating that all members of the public, to include children and pregnant women (and the fetus), have been considered, as well as all the ways they can be exposed	Assessments that do not consider the members of the public most sensitive to radiation (i.e. children and pregnant women) and/or all the ways they can be exposed (or it is not clearly explained that this was considered), may result in unjustified actions being taken by the public and/or decision makers that do more harm than good in the belief that they are protecting all members of the public to include the most sensitive to radiation.
Not providing a consistent assessment of the health hazard (e.g. having several sources of official information) and/or using undefined and ambiguous terms	Assessments that are inconsistent and/or ambiguous will result in confusion and undermine public confidence in official statements.
Using early, incomplete or uncertain data without clearly indicating the possible health hazard	Assessments that use incomplete and/or uncertain data could result in an over or underestimation of the health hazard and lead to changing assessments as the data improves, which could undermine public confidence. If early data is used it needs to be made clear that these are preliminary assessments expected to change as new and/or improved data becomes available.
Using effective dose	Assessments that are based only on effective dose are unreliable. Effective dose cannot be used to reliably assess the possible radiation induced health effects [24, 36]. The use of effective dose can underestimate the health hazard for a release from a reactor core or spent fuel pool.
Using sievert (Sv) without clearly stating what quantity it represents	Assessments that do not clearly state the type of sievert being used are not useful. Several different dosimetric quantities (e.g. equivalent dose to an organ or tissue, effective dose, ambient dose equivalent or personal dose equivalent) are given in sieverts and although the units are the same, these are different quantities that cannot be compared [24, 36]. Only equivalent dose, which is the dose to a particular person's organ or tissue (e.g. thyroid), can be used to assess the possible health effects, but only if it has been calculated correctly (See section 7.5 for further information).
Projecting excess cancer deaths	Assessments that project excess cancer deaths are unreliable. This is because it is impossible to predict the possible number of cancers resulting from an emergency within the first months to years after the emergency. The only way that excess cancers can be detected with certainty is by studying cancer statistics for the population affected by high doses over a period of many years. At low doses (doses below the international generic criteria calling for protective or other response actions), there will not be an observable increase in the incidence of cancer, even in a very large exposed group. Projections of excess deaths are often based on the inappropriate use of the fatal risk coefficient (as "deaths per sievert of collective effective dose") given by the International Commission on Radiation Protection (ICRP) and others. This coefficient was intended to be used for the purposes of radiological protection only, and its use for projecting health consequences was never intended, as stated by ICRP [36], for the following reasons: o Because of the uncertainty of health effects at low doses, the ICRP judges that it is not appropriate, for the purposes of public health planning, to calculate the hypothetical number of cases of cancer or heritable disease that might be associated with very small radiation doses received by large numbers of people over very long periods of time [36].

	o Effective dose is intended to be used for planning and optimization in radiological protection, and demonstration of compliance with dose limits for regulatory purposes. Effective dose is not recommended for epidemiological evaluations, nor should it be used for detailed specific retrospective investigations of individual exposure and risk [36]. o Collective effective dose is not intended as a tool for epidemiological risk assessment, and it is inappropriate to use it in risk projections. The aggregation of very low individual doses over extended time periods is inappropriate, and in particular, the calculation of the number of cancer deaths based on collective effective doses from trivial individual doses should be avoided [36].
Comparing doses with 'safety' limits and implying health effects are possible if the limits are exceeded	Assessments that compare doses with 'safety' limits are unreliable because these limits are typically established as part of the license requirements for the nuclear power plant and exceeding these limits does not mean that the situation is unsafe. These limits are established to ensure the safe operation of the nuclear power plant by limiting releases to levels well below those at which health effects will occur.
Using terms such as 'high dose rates' or 'highly contaminated', 'Bq/m^2' and '100 times above normal levels' without making it clear how this is related to the possible health hazard	Assessments that use these terms are meaningless and could imply an exaggerated or understated health hazard.
Making irrelevant comparisons with other exposure situations, for example comparing the calculated dose with a dose received from an X ray or an intercontinental flight	Assessments that compare the calculated dose with other exposure situations can lead to underestimations of the health hazard. These doses cannot be compared due to the different types of radiation and the different exposure pathways that are possible in the context of a reactor core or spent fuel release (e.g. the dose from inhalation of radioiodine and the possible health effects to the thyroid gland).
Using only external dose rate (e.g. µSv/h)	Assessments that only use external dose rate are unreliable because this only considers external exposure, which can greatly underrepresent the health hazard. This is because other important exposure pathways such as inhalation from the passing plume or inadvertent ingestion of radioactive material have not been considered.
Not considering the fact that the dose is a calculated quantity that must be calculated in a very specific way in order to correctly place its health hazard into perspective, as described in Section 7.5. Any dose calculation needs to clearly state the steps and assumptions used in the calculations	Assessments that do not explain in detail how the calculations were performed are unreliable. Dose is a calculated quantity that must be determined in a very specific way in order to correctly place its health hazard into perspective.

7.5. DOSE IN PERSPECTIVE

7.5.1. Relating calculated doses to the radiological health hazard

The use of the charts for measured operational quantities (Charts 1–4 in Section 7.3) are preferable over the use of calculated dose for putting the health hazard in perspective because of: (a) the confusion that could arise from the different units and the variety of different doses with the same name (sieverts) and, (b) the complex calculations as shown in FIG. 16 that must be performed in order to place dose into perspective in terms of the health hazards. These calculations have already been performed for the measured operational quantity and the results presented in Charts 1–4 in Section 7.3. Therefore, Charts 1–4 need to be used during an emergency. However, calculated doses are frequently reported during an emergency relating to a reactor core or spent fuel pool. Therefore, the following has been provided in this Section of the publication:

- A tool to determine whether the doses reported have been calculated correctly for the purpose of placing the health hazard in perspective; and
- Charts that can be used for placing the dose in perspective in terms of the health hazard (to be used only if the doses have been calculated correctly).

The dose to the following organs needs to be assessed in order to determine the possible health hazard from radioactive material released from a reactor core or spent fuel pool:

- Equivalent dose to the thyroid ($H_{thyroid,}$ mSv) from inhalation and ingestion;
- Equivalent dose to the fetus ($H_{fetus,}$ mSv) from all exposure pathways; and
- RBE weighted absorbed dose to the red marrow ($AD_{red\ marrow,}$ mGy) from external exposure. The $AD_{red\ marrow}$ (mGy) dose from external exposure can be estimated based on ambient dose rate (mSv/h) for a release from a reactor core or spent fuel pool (mSv/h ≈ mGy/h).

7.5.2. Why effective dose cannot be used to place the radiological health hazard into perspective

Effective dose cannot be used as a basis for estimating the possible health hazard from radiation exposure [36] in an individual because the use of effective dose alone can greatly underestimate the possible risk to an individual.

7.5.3. Charts to place the health hazards in perspective based on calculated dose

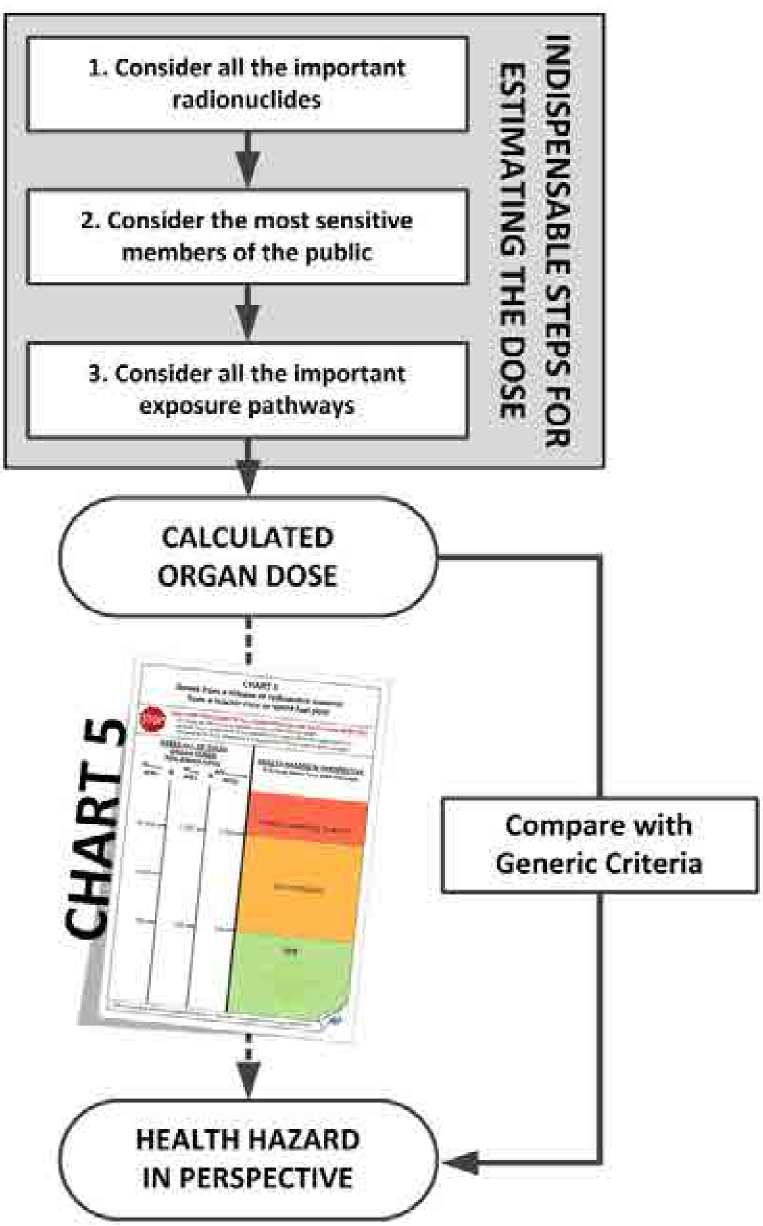


FIG. 16. Steps required for placing the radiological health hazard in perspective based on calculated dose.

Charts 5 and 6 were developed to place in perspective the link between the dose that has been calculated following a release from a reactor core or spent fuel pool and the possible health hazard due to a radiation exposure. Table 16 lists the doses and the exposure pathways that need to be assessed in order to place the health hazard in perspective following a release from a reactor core or spent fuel pool.

TABLE 16. DOSES TO BE CONSIDERED WHEN ASSESSING THE POSSIBLE RADIOLOGICAL HEALTH HAZARD AND PLACING THEM INTO PERSPECTIVE FOLLOWING A RELEASE FROM A REACTOR CORE OR SPENT FUEL POOL

Dose quantity	Exposure pathways[a] to consider	Discussion	Chart No.
$H_{thyroid}$ Equivalent dose to the thyroid (mSv)	• Inhalation of the plume; • Inadvertent ingestion (e.g. soil on hands); and • Ingestion of food, milk or water.	The dose to the thyroid can be the principal concern in an emergency involving a reactor core or spent fuel pool because of large amounts of radioiodine that can be released and that concentrates in the thyroid. The dose to thyroid mainly comes from inhaling radioactive iodine released in the plume or from eating food, milk or water that has been affected by the plume. After the accident at the Chernobyl nuclear power plant, radiation induced cancers developed among children as a result of consuming contaminated milk.	**5**
H_{fetus} Equivalent dose in the fetus (mSv)	• External exposure from the plume; • External exposure from ground deposition during the period of exposure; • Inhalation of the plume; • Inadvertent ingestion (e.g. soil on hands); and • Ingestion of food, milk or water.	For a reactor emergency the dose from inhalation or ingestion of radioactive iodine can be the most important exposure pathway.	
$AD_{red\ marrow}$ RBE weighted absorbed dose to the red marrow (mGy)	• External exposure from the plume; and • External exposure from ground deposition during the period of exposure.	Used to assess the radiation induced health effects that result primarily from external exposure, to include effects to the fetus and reproductive organs. The $AD_{red\ marrow}$ (mGy) dose from external exposure can be estimated based on ambient dose rate (mSv/h) for a release from a reactor core or spent fuel pool (mSv/h ≈ mGy/h).	
E Effective dose (mSv)	• External exposure from the plume; • External exposure from ground deposition during the period of exposure; • Inhalation of the plume; • Inadvertent ingestion (e.g. soil on hands); and • Ingestion of food, milk or water.	Effective dose cannot be used to assess the possible radiation induced health effects to the individual; however it is often reported in an emergency. Effective dose may identify some situations that are not safe (but not all), such as those that result in doses that in accordance with international guidance require protective actions [1]; however, all the organ doses listed above need to be considered in order to assess the health hazard.	**6[b]**

[a] For an explanation of the different exposure pathways important for a release from a reactor core or spent fuel pool, see Appendix II.
[b] The dose to the thyroid, fetus and red marrow needs to be determined and evaluated according to Chart 5 in order to assess the health effects.

7.5.4. Use of charts for dose

Step 1 – Confirm the dose was calculated correctly for the purpose of placing the health hazards in perspective:

Confirm that all of the following doses were calculated:

- Equivalent dose to the thyroid ($H_{thyroid,}$ mSv) from inhalation and ingestion;
- Equivalent dose to the fetus ($H_{fetus,}$ mSv) from all exposure pathways; and
- RBE weighted absorbed dose to the red marrow ($AD_{red\ marrow,}$ mGy) from external exposure.

Confirm that incomplete or uncertain data was not used for the calculations.

Confirm that all the following were considered and are known with certainty when calculating the doses:

- The radionuclide mixture released from the reactor core or spent fuel pool;
- The members of the public most sensitive to radiation (e.g. children and pregnant women (fetus));
- All relevant exposure pathways of the specified dose (see Table 16):
  - external exposure from the plume (cloud shine);
  - external exposure from ground deposition for total period of exposure (ground shine);
  - inhalation of the plume;
  - inadvertent ingestion (e.g. from soil on hands); and
  - ingestion of food, milk or water.

Step 2 – Select the appropriate chart

Select the chart based on which dose was calculated using Table 16.

Step 3 – Explaining the charts

The front of each chart has a 'description' which summarizes what is being addressed by the chart. The back of each chart (the page following the chart) describes the basis, has a checklist of what needs to be considered for the calculation of the specified dose and provides a perspective on the possible health hazard. When discussing the charts with the public the following points need to be stressed:

- The dose is a calculated quantity that must be determined in a very specific way in order to correctly place the associated health hazard into perspective. Not all dose calculations may be useful in assessing possible radiation induced health effects and cannot be used with these charts.
- If a particular radiation induced health effect is indicated it means that there is only a small chance of someone suffering the effect, it does not mean that the health effects will definitely take place.
- The radiation induced health effects would not be expected to occur in anyone at levels below those indicated in the charts.
- More accurate assessments of the possible radiation induced health effects can only be performed after the exposure scenarios are better understood and can only be performed by experts in diagnoses and treatment and management of the radiation induced health effects.
- If the situation is possibly dangerous to health or there are health concerns, the appropriate protective actions and other response actions (e.g. medical follow-up) indicated on the charts need to be taken.
- The quality of the data being used and how representative it is needs to be explained. If future refinements of the data are expected, this needs to be stressed.

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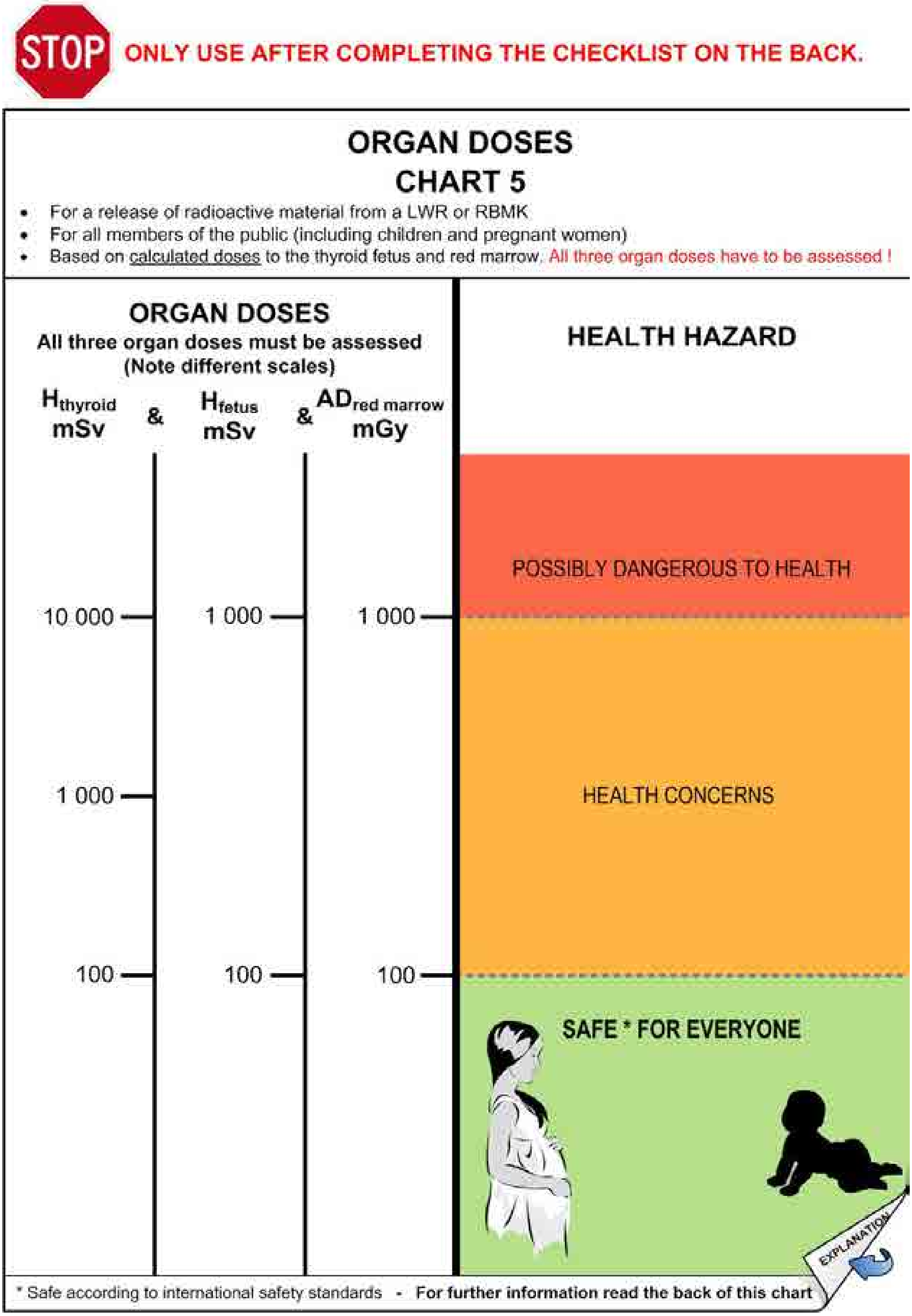


Chart 5. Health hazard in perspective for organ doses calculated after a release from a reactor or spent fuel pool of a LWR or RBMK.

CHART 5 EXPLANATION

PURPOSE: This chart places in perspective the link between the dose that has been calculated following a release from a reactor or spent fuel pool of a LWR or RBMK and the possible health hazard.

CALCULATED DOSE: Organ doses of the thyroid, fetus and red marrow.

CHECKLIST FOR CALCULATION OF THE DOSE:
Do not use incomplete or uncertain data for dose calculations.

Calculation of the dose considers:

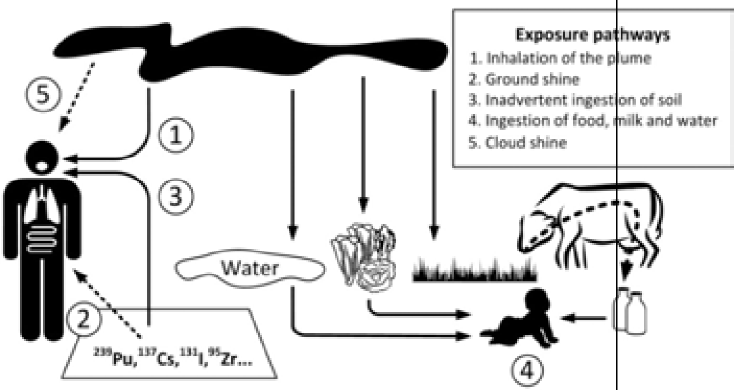
- $H_{thyroid}$, H_{fetus} and $AD_{red\ marrow}$;
- The radionuclide mixture released from the reactor core or spent fuel pool;
- The members of the public most sensitive to radiation (e.g. children and pregnant women (fetus)); and
- All exposure pathways, relevant for a release from a LWR or RBMK, to include:

For the equivalent dose to the thyroid ($H_{thyroid}$):

☐ inhalation of the plume;
☐ inadvertent ingestion (e.g. from soil on hands); and
☐ ingestion of food, milk or water.

For the equivalent dose in the fetus (H_{fetus}):

☐ external exposure from the plume (cloud shine);
☐ external exposure from ground deposition (ground shine)
☐ inhalation from the passing plume;
☐ inadvertent ingestion (e.g. from soil on hands); and
☐ ingestion of food, milk or water.



For the RBE weighted absorbed dose to the red marrow ($AD_{red\ marrow}$):

☐ external exposure from the plume (cloud shine); and
☐ external exposure from ground deposition (ground shine).

HEALTH HAZARD IN PERSPECTIVE:

Possibly dangerous to health (red): There is a possibility of radiation induced health effects that are life threatening or can result in a permanent injury that reduces the quality of life (severe deterministic effects) to include: (a) permanently suppressed ovulation and sperm counts, and (b) hypothyroidism (a condition in which the thyroid gland does not produce sufficient thyroid hormones) and (c) severe effects to the fetus. At this level there is also the small possibility of an observable increase in the incidence of cancer due to radiation induced cases, if the number of exposed people is more than a few hundred.

Health concerns (orange): The danger to health is very low. However, there is a possibility of doses exceeding the international criteria [1] that call for taking protective actions and other response actions to include medical screening in order to further assess: (a) the small possible risk to pregnant women (fetus) and (b) the small possible increase in the risk of radiation induced cancers.

Safe (green): This meets international standards [1] as the doses are less than the generic criteria at which protective actions and other response actions are justified. Below these doses there will not be any severe deterministic effects or an observable increase in the incidence of cancer, even in a very large exposed group. Furthermore, the risk of cancers and other health effects is too low to justify taking any action, such as a medical screening [1].

PROTECTIVE ACTIONS AND OTHER RESPONSE ACTIONS:

If the dose to an individual has been calculated that indicates that the health hazard level is ‘possibly dangerous to health’ (red) or ‘health concerns’ (orange), the individual needs to be registered and have their individual doses estimated to determine if a medical examination or counselling and medical follow-up are warranted. Health effects from radiation exposure can only be assessed by experts in diagnosing and treating the health effects of radiation exposure. Others, such as local physicians, probably will not have the expertise needed to make such assessments.

STOP

THIS CHART MUST NOT BE USED AS A BASIS FOR ASSESSING HEALTH HAZARDS (READ THE BACK).

EFFECTIVE DOSE
CHART 6

- For a release of radioactive material from a LWR or RBMK
- Based on the calculated effective dose.

EFFECTIVE DOSE E	**HEALTH HAZARD**
	NOT SAFE Exceeds international criteria for taking protective actions or other response actions. TAKE PROTECTIVE AND OTHER RESPONSE ACTIONS (SEE BACK OF CHART)
100 mSv	
	MAY NOT BE SAFE ALWAYS ASSESS DOSE TO THE THYROID, FETUS AND RED MARROW, USING CHART 5

EXPLANATION

For further information read the back of this chart

Chart 6. Assessment of effective dose calculated after a release from a reactor or spent fuel pool of a LWR or RBMK.

CHART 6 EXPLANATION

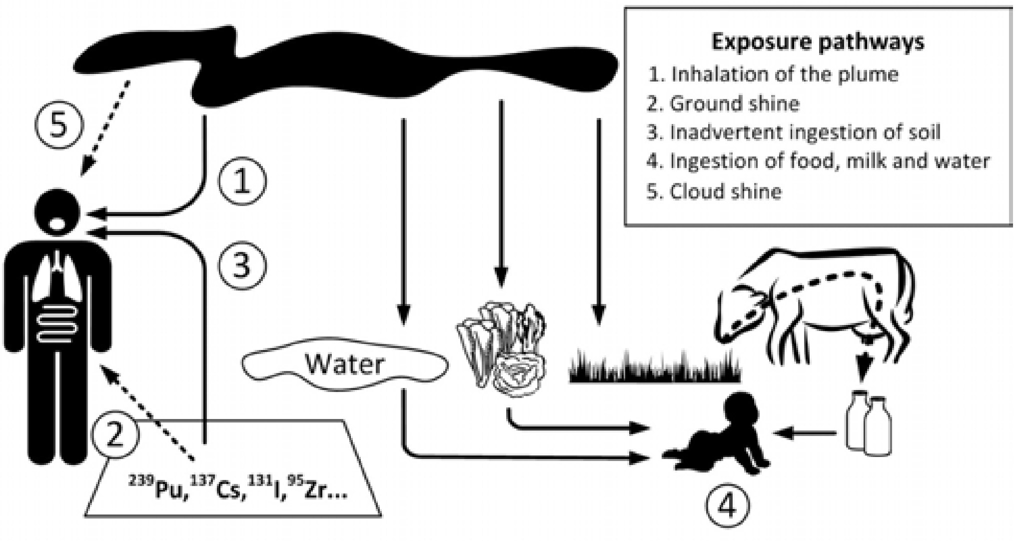
PURPOSE: This chart cannot be used alone to place in perspective the link between the dose that has been calculated following a release from a reactor or spent fuel pool of a LWR or RBMK and the possible health hazard. Chart 5 must also be used to place the calculated dose in perspective.

CALCULATED DOSE: Effective dose.

CHECKLIST FOR THE CALCULATION OF THE DOSE:
Do not use incomplete or uncertain data for dose calculations.

Calculation of the effective dose considers:

- The radionuclide mixture released from the reactor core or spent fuel pool;
- The members of the public most sensitive to radiation (e.g. children and pregnant women (fetus));
- All relevant exposure pathways, to include:
  - ☐ external exposure from the plume (cloud shine);
  - ☐ external exposure from ground deposition (ground shine);
  - ☐ inhalation of the plume;
  - ☐ inadvertent ingestion (e.g. from soil on hands); and
  - ☐ ingestion of food, milk or water.



ASSESSMENT

Not safe: An effective dose above 100 mSv is not safe as it has exceeded the international safety standards that warrant a medical follow-up.

- Take protective actions and other response actions in accordance with the OILs in the IAEA publication: Actions to Protect the Public in an Emergency due to Severe Conditions at a Light Water Reactor, EPR-NPP PUBLIC PROTECTIVE ACTIONS, 2013.

Below 100mSv may not be safe:

- Always assess the dose to the thyroid, fetus and red marrow for a release from a reactor core or spent fuel pool. Chart 5 can be used to place the dose to the thyroid, fetus and red marrow in perspective, provided that the doses have been calculated correctly.

8. IMPLEMENTATION

The criteria and tools explained in this publication need to be integrated into the site specific emergency plans, procedures and other arrangements that would be used in an emergency and need to be adapted for national and local use.

8.1. INTERIM IMPLEMENTATION

The full implementation of emergency preparedness and response arrangements for an emergency relating to a reactor core or spent fuel pool can be a long process, but an emergency warranting protective actions off the site could occur at any time, even before arrangements have been completed. Therefore, an *interim* emergency response capability needs to be put in place [6]. This interim capability will not be optimal. It will probably be necessary to improvise, if an emergency occurs, with whatever means and resources are available.

Initial efforts need to be focused on using existing capabilities effectively and efficiently. The most important factor is to ensure that decisions can be made quickly and that existing capabilities (e.g. communication systems, monitoring personnel and public information offices) are identified and can quickly be brought into the response. The efforts invested in developing an interim organization and capability will provide significant savings during the implementation of the full emergency response plan and provide a capability to respond before all the response arrangements are in place.

The interim arrangements put in place need to be tested in exercises as soon as possible. This is the only way to determine if they are workable under emergency conditions. Evaluations of exercises, as well as responses to actual emergencies, need to be used to revise and improve the response arrangements. The checklist in Table 17 is designed to assess readiness in the event of an emergency relating to a reactor core or spent fuel pool if it occurs tomorrow. The aim is to identify where improvements may be required and assist in the rapid development of the interim capability.

References. [1, 9, 19] as well as the other documents in the IAEA EPR series provide guidance on the full arrangements (e.g. public notification and education systems) needed for an effective emergency response capability; however, care needs to be taken to use the updated guidance of this publication where appropriate.

When developing the capability to respond a severe reactor core or spent fuel emergency the important facts listed in Table 18 need to be recognized.

TABLE 17. MINIMUM RESPONSE CAPABILITIES CHECKLIST

Response capability:
□ Does the off-site decision maker have the authority, training and means to initiate protective actions and other response actions within 45 minutes after being notified of the emergency?
□ Have EALs been determined and incorporated into procedures for each nuclear power plant?
□ Does the shift supervisor of the nuclear power plant have the authority and responsibility to declare an emergency (within 15 minutes) and notify off-site decision makers (within 30 minutes) of detection that an EAL has been exceeded?
□ Has a contact point for notifying the off-site decision maker within 30 minutes been established?
□ Have off-site emergency zones and distances been established?
□ Have the public been informed, in advance, of the action to take in the event of an emergency?
□ Will the public living within the zones and distances be notified to take the urgent protective actions and other response actions within about 1 hour of detection of conditions indicating actual or projected damage to fuel (EAL for declaration of General Emergency exceeded)?
□ Have ITB agents been pre distributed to those living within the PAZ and UPZ?
□ Have arrangements been made for the prompt and prioritized evacuation of the PAZ to beyond the UPZ?
□ Have predetermined arrangements been made for special facilities within the PAZ and UPZ to be safely evacuated (e.g. patients from hospitals and nursing care homes will continue to receive necessary care and medical treatment) to a location outside the EPD (to ensure multiple evacuations are not required)?
□ Have provisions been made for dose rate monitoring and for the protection of personnel staffing special facilities (e.g. hospitals and prisons) that may not be immediately evacuated?
□ Have arrangements been made to provide a means of evacuation to beyond the UPZ for those within the PAZ and UPZ?
□ Have arrangements been made for instructing those within the PAZ, UPZ and EPD to reduce inadvertent ingestion?
□ Have arrangements been made for the designation and briefing of any individual as an emergency worker who may: a) assist with the onsite response, b) manage the medical treatment of possibly contaminated people, or c) return to within the emergency zones or distances (PAZ, UPZ or EPD) after the declaration of a General Emergency?
□ Have arrangements to provide (within hours) the public and media with clear and consistent information, placing the possible health hazard into perspective, addressing concerns and correcting misinformation (e.g. rumours) been established?
□ Have predetermined criteria for identifying who needs to be decontaminated or given an immediate medical examination been established?
□ Have arrangements been made for establishing centres outside the UPZ, to register, monitor, decontaminate and medically screen evacuees from the PAZ and UPZ?
□ Have predetermined hospitals located outside the EPD been notified to make arrangements and preparation for the medical management of: (a) those injured or showing symptoms of radiation exposure; (b) those with skin or thyroid contamination; (c) those who have possibly consumed contaminated food; (d) concerned pregnant women; and (e) other individuals who may need medical treatment or a medical follow-up.
□ Have hospitals been instructed on how to treat possibly contaminated patients (i.e. taking universal precautions against infection will provide sufficient protection)?

- □ Have default OILs been established?
- □ Have arrangements been made for monitoring, sampling and analysis to determine if OILs are exceeded and for taking protective actions and other response actions if they are?

TABLE 18. REALITIES OF A RESPONSE

- The decision to act needs to be made promptly. There is no time for meetings to determine what to do, and off-site decision makers cannot wait to see if a release actually occurs.
- The response needs to be based on predetermined generic and operational criteria that were agreed upon in advance at the preparedness stage.
- Use the IAEA generic and operational criteria for protective actions and other response actions. The IAEA considered all the potential emergencies relating to potential releases due to fuel damage in developing the criteria. The criteria provide a defendable basis for actions early in the emergency.
- In a worst emergency postulated, failure to act before a release (upon detection of conditions in the nuclear power plant leading to damage to fuel, a General Emergency), would result in deaths and severe deterministic effects among those off the site that could have been prevented.
- The control room operators monitor the systems needed to protect the fuel in the core and spent fuel pool. Based on these observations, they can identify a potential problem, and the shift supervisor can initiate a response. In the majority of cases, the General Emergency may be declared hours before a release takes place and thus allowing time to initiate protective actions and other response actions before the release.
- The timing, size and duration of a release are unpredictable, therefore: (a) protective actions and other response actions need to be taken in all directions that can be affected, as long as there is a possibility for a severe release, and (b) dose projection models cannot be used as a basis for taking urgent protective actions and other response actions effectively in most circumstances.
- A release is most likely to occur over many days and result in complex deposition patterns, with hotspots found in all directions around the nuclear power plant.
- Hotspots requiring relocation of the public can occur at distances of more than 50 km from the nuclear power plant (within the EPD).
- Hotspots requiring restriction on consumption and distribution of local produce, wild-grown products (e.g. mushrooms and game) milk, rainwater, animal feed and commodities can occur at distances of more than 300 km from the nuclear power plant.
- Early monitoring results will probably be inconsistent and limited. A plan for dealing with the inconsistencies and limited data needs to be developed.
- Operational criteria need to be developed in advance in order to trigger response actions based on environmental measurements and samples. Procedures to revise default OILs needs to be developed according to the prevailing circumstances. When criteria are developed during an emergency they are not trusted by the public.
- Local physicians and most general medical professionals usually do not have specific knowledge of radiation induced health effects and cannot provide adequate medical examinations of radiation injuries or recommend appropriate treatment.
- To reduce detrimental social, psychological and economic impacts, questions from the public and off-site decision makers need to be answered in a simple, consistent and understandable way that explains health hazards.
- In several past emergencies medical staff have refused to treat potentially contaminated patients (e.g. those evacuated from the affected area) because they did not understand how to protect themselves from contamination. Therefore, provisions need to be in place to provide advice to medical facilities in the vicinity that might treat potentially contaminated patients that universal precautions against infection (gloves, mask, etc.) will provide sufficient protection when treating potentially contaminated patients.
- In past emergencies it has been necessary to use personnel that were not trained as emergency workers. Therefore, provisions should be in place to register these individuals and provide ‘just in time’ training for safely working under the emergency conditions.
- The news media and social media will learn of the emergency immediately. They are a primary means of communicating with the public after the start of the emergency.
- Assessments performed by various experts will be provided through the media; their content may conflict with the official assessments or simply be wrong.

- A large number of technical quantities and units will be used by experts to describe the health hazard to the public. Many of these terms will be used inconsistently and incorrectly. In several past emergencies it lead to confusion and resulted in the public and off-site officials taking inappropriate actions.
- The public and officials in many cases have taken inappropriate actions (e.g. voluntary abortions, evacuation of patients under dangerous conditions, stigmatizing and shunning of local population, restrictions on goods even though they are not contaminated) because of their exaggerated fear of the radiation and because they were not provided with clear and concise information concerning the health hazard and the actions they need to take.
- It is important to provide a single source of official information for the public and media. In past emergencies, having several different sources of official information resulted in impression being given that the assessments are not consistent. The official source needs to address the public's concerns and explain the risks to the public.

8.2. CHANGES IN GUIDANCE COMPARED TO EARLIER PUBLICATIONS

This publication is based on: (a) the latest IAEA guidance [1], which was developed in consideration of the latest ICRP guidance [36], taking into account the findings of UNSCEAR [27], and was co-sponsored by the Food and Agriculture Organization of the United Nations (FAO), the International Labour Office (ILO), the Pan American Health Organization (PAHO) and the World Health Organization (WHO), and (b) the lessons learned from the accident at the Fukushima Daiichi nuclear power plant in Japan [3, 4, 7, 10].

The established emergency response arrangements made consistent with previous IAEA guidance [1, 6, 9, 11] are considered adequate, in most cases. However, it is important that a review of emergency response arrangements is conducted against the guidance provided in this publication. The most important revisions compared with the previous IAEA guidance are:

- The protective actions and other response actions that are to be taken within the UPZ have been revised to reflect analysis that indicates they need to be taken before monitoring can be performed, and the fact that experience indicates that monitoring within the UPZ could take considerably longer than previously expected.
- Revisions have been made to the protective actions and other response actions to be taken within the PAZ and UPZ.
- The minimum distances to be established for the PAZ and UPZ have been specified based on further analysis of emergencies relating to a reactor core or spent fuel pool (see Appendix I).
- Planning distances (EPD and ICPD) have been introduced to stress the need to be prepared to take protective and other response actions and conduct monitoring at these distances. Under the previous guidance, the actions to be taken at these distances were indicated, but the specific extended planning distance and ingestion and commodities planning distance have been added to make this clearer.
- The system of OILs has been updated. Care needs to be taken to note the new numbering of the OILs. The OILs values (e.g. dose rate from ground deposition) at which various protective actions and other response actions need to be taken are consistent with the previous guidance [11, 37].
- Additional response actions have been introduced when the OILs are exceeded that primarily deal with the need for a medical follow-up.
- Additional OILs have been introduced for monitoring of the thyroid and skin.
- Tools are provided to place the health hazards to the public in perspective.

APPENDIX I
BASIS FOR THE SUGGESTED SIZE AND PROTECTIVE ACTIONS WITHIN THE EMERGENCY ZONES AND DISTANCES

This Appendix provides a basis for: (a) the size of the emergency zones and distances given in Table 3 and (b) the urgent protective actions and other response actions that are to be taken within the zones and distances upon declaration of a General Emergency, as listed in Table 4.

The goals of the protective actions and other response actions are to:

- Prevent the occurrence of severe deterministic effects; and
- Keep the doses below the generic criteria at which protective actions and other response actions are justified to reduce the risk of stochastic effects.

To meet these goals, zones and distances need to be identified in advance where arrangements are made for the effective implementation of protective actions and other response actions. These zones and distance need to be established such that they provide the most effective response considering local conditions.

Due to the large variety of site specific characteristics of the existing power plants it is impossible to provide a single set of specific distances that would be most effective for all nuclear power plants. Therefore the sizes of the zones and distances given in Table 3 are to be considered as a first approximation that needs to be adjusted to specific plant designs, emergency scenarios and local conditions.

In establishing the sizes given in Table 3 consideration was given to: (a) the spectrum of reasonable releases of radioactive material, (b) the effectiveness of various protective action strategies and (c) the behaviour of radioactive material released to the atmosphere.

I.1. PRECAUTIONARY ACTION ZONE (PAZ) AND URGENT PROTECTIVE ACTION PLANNING ZONE (UPZ)

This section of the appendix provides the dosimetric basis and considerations for determining the size of the emergency zones – the PAZ and UPZ.

Table 19 lists the dosimetric criteria used in the calculations that form part of the basis for the first approximation of the sizes of the PAZ and UPZ in Table 3. These criteria are for the most sensitive members of the public. The calculations assume the exposure pathways that are the primary sources of exposure before monitoring can be used as an effective basis for taking protective actions. This was assumed in order to identify those actions that need to be taken to protect all members of the public and initiated based on plant conditions.

TABLE 19 DOSIMETRIC CRITERIA USED FOR DETERMINING THE SIZE OF THE EMERGENCY ZONES

Zone	**Actions taken based on plant conditions to prevent**	**Dosimetric quantity**	**Dose criterion**	**Most important exposure pathway and considered in the calculations**[g]		
				Inhalation	Cloud shine	Ground shine
PAZ	Severe deterministic effects	$AD_{red\ marrow}$[a]	1Gy[e]	X	X	1 day
		$AD_{fetus,inh}$[b]	1 Gy[e]	X		
UPZ	Stochastic effects	E_{inh}[c]	100 mSv[f]	X		
		$H_{fetus,inh}$[d]	100 mSv[f]	X		

a. $AD_{Red\ marrow}$ 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 [24].

b. AD_{fetus} is the RBE weighted absorbed dose to the fetus from inhalation, which is dominated by the dose to the fetal thyroid.

c. Committed effective dose from inhalation.

d. Equivalent dose to the fetus following inhalation by the pregnant woman. This dose is dominated by the dose to the fetal thyroid. The equivalent dose to an adult from inhalation is approximately equal to the equivalent dose to the fetal thyroid [38].

e. Assumed threshold for severe deterministic effects, see Table 25 for the basis.

f. Generic criteria [1] at which, if projected, protective actions and other response actions are to be taken to reduce the risk of stochastic effects.

g. Primary sources of exposure that can result in severe deterministic effects and stochastic effects (exceed GC in Ref. [1]) in the most sensitive members of the public before off-site monitoring could be used as an effective basis for protective actions.

I.1.1. Dosimetric basis for the size of the PAZ

The PAZ is defined by the international requirements [9] as the area within which arrangements are required to be made with the goal of taking urgent protective actions, before a severe release of radioactive material occurs or shortly after a release of radioactive material begins, on the basis of conditions at the nuclear power plant (using the emergency classification system discussed in Section 3) in order to substantially reduce the risk of severe deterministic effects.

I.1.2. Dosimetric basis for the size of the UPZ

The urgent protective action planning zone (UPZ) is defined by the international requirements [9] as the area within which arrangements are required to be made for urgent protective actions to be taken promptly in order to substantially reduce the risk of stochastic effects off the site in accordance with international criteria [1] (reproduced in Table 19).

I.1.3. Zone size calculations

The calculations were performed considering (a) the release characteristics, (b) the meteorological conditions, and (c) public behaviour (protective action strategies for the doses and exposure pathways as described below). These calculations are very uncertain and based on very simple assumptions. These calculations are intended to be a first approximation and may be modified to be compatible with specific power plant analysis and local conditions.

I.1.3.1. Release characteristics

The assumptions made for the release characteristics are summarized in Table 20. Only severe damage to the fuel in the reactor core or spent fuel pool can result in doses off-site that could exceed the criteria given in Table 19. Studies [39, 40] indicate that the majority of the releases to the atmosphere following severe fuel damage are projected to contain about 0.5–2% of the volatile fission products (e.g. I and Cs) in the fuel and the maximum expected to be released is about 10%. Therefore, a release of about 10% of the volatile fission products into the atmosphere was assumed in the calculations. These studies also indicated that a severe release would probably occur over many hours, for this reason a 10 hour release was assumed. It is considered very unlikely that nuclear power plants with power levels below about 100 MW(th) could give rise to a release of fission products causing exposures off the site with doses leading to severe deterministic effects. Therefore, emergency zones recommended for nuclear power plants with a power level of less than 100 MW(th) are not suggested in this publication.

TABLE 20. RELEASE CHARACTERISTICS

Characteristic	Assumption/comment
Plant power level	3000 MW(th)
Release amount	10% of the volatile fission products in the core of a reactor
Release height	Ground level
Release rate and duration	10 hours as illustrated in FIG. 17

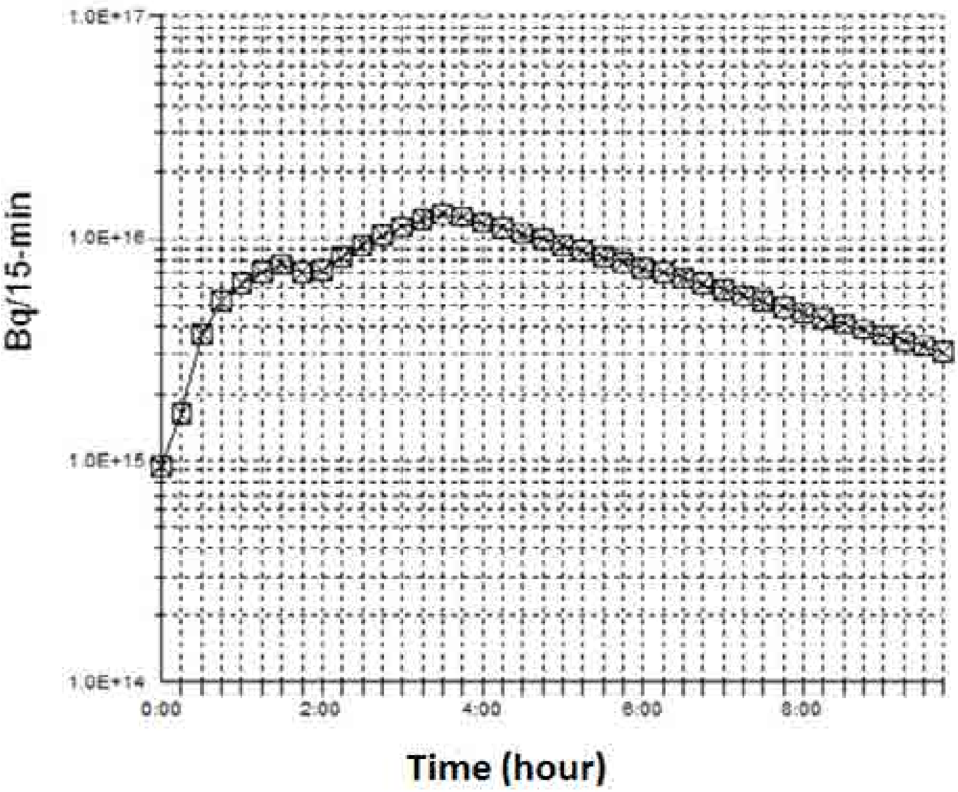


FIG. 17. Assumed time-dependent release rate for I-131.

I.1.3.2. Meteorological conditions

The meteorological conditions assumed during the release are summarized in Table 21.

TABLE 21. METEOROLOGICAL CONDITIONS

Conditions	Assumed	Comment
Stability class	D	Most common meteorological stability class [41]. Other stability classes could result in doses 2 or 3 times higher or lower.
Wind direction	90° change in direction over the 10 hour period of release	This is consistent with average meteorological data from the USA.

I.1.3.3. Public behaviour

The calculations used the dose reduction factors given in Table 22 to examine the impact of public behaviour (i.e. protective actions) on the distance to which the criteria in Table 19 may be exceeded. The dose reduction factors in Table 22 are intended to be representative for:

- House sheltering: this case assumes the public is sheltered in a wooden house during and after the release;
- Large building sheltering: this case assumes the public is sheltered inside a large multi-storey building during and after the release; and,
- Taking an iodine thyroid blocking (ITB) agent before or within one to two hours after inhalation of the radioiodine from a release.

TABLE 22. DOSE REDUCTION FACTORS FOR PUBLIC BEHAVIOUR

Public behaviour	Reduction factor	Applies to:
House sheltering	0.4 [42]	Ground shine
	0.6 [16]	Cloud shine
	0.5 [16]	Inhalation[a]
Large building sheltering	0.02 [16]	Ground shine
	0.3 [16]	Cloud shine
	0.2 [16]	Inhalation[a]
Taking ITB agent	0.1 [16]	Thyroid and fetal[52] dose from inhalation of radioiodine

[a.] Assumes an air exchange for 2 hours in the plume.

I.2. RESULTS OF THE CALCULATIONS

The calculations described in this section are for the release characteristics listed in Table 20, the meteorological conditions listed in Table 21 and the public behaviour listed in Table 22. The insights drawn from an examination of these calculations and the results of previous studies are discussed below.

I.2.1. PAZ

The suggested starting point for determining the boundaries of PAZ given in Table 3 is approximately 3 to 5 km which is supported by the first approximation calculations described below.

The calculations presented below in FIGs.18–21 show that the risk of severe deterministic effects is dominated by the dose to those within about 3 to 5 km. The impact of the plant size on the size of the PAZ is not significant as will be discussed in Section I.2.3.

FIG. *18* FIG. *19* show that the criterion of 1 Gy to the red marrow ($AD_{red\ marrow}$, Table 19) is projected to be exceeded out to about a distance of:

- 1 km for an individual sheltering in a house when it is not raining during the release. However it is not exceeded beyond the site boundary for an individual sheltering in a large building for a day; and
- 3 km for an individual sheltering in a house when it is raining during the release and may be exceeded at the site boundary for an individual sheltering in a large building for a day.

1 Gy to the red marrow ($AD_{red\ marrow}$, Table 19) may be exceeded beyond 5 km from the site if sheltering is implemented for a longer period since ground shine is a significant source of dose to the red marrow particularly if it was raining during the release.

FIG. *20* shows that if an ITB agent is taken before inhalation, the criterion of 1 Gy (AD_{fetus}) to the fetus (Table 19) is projected to be exceeded out to about a distance of 2 km for a pregnant woman sheltering in a large building and out to about a distance of 3 km if sheltering in a house.

FIG. *21* shows that if an ITB agent *is not taken* before or shortly after inhalation then 1 Gy (AD_{fetus}) to the fetus (Table 19) is projected to be exceeded out to about a distance of 30 km for a pregnant woman sheltering in a house.

[52] The equivalent dose to the fetus ($H_{fetus,inh}$) from inhalation originates predominantly from radioiodine intake by the pregnant woman.

This shows that in order to prevent severe deterministic effects for a severe release (about 10% release of volatiles): (a) the area within about 3 to 5 km of the nuclear power plant should be evacuated before the release and (b) an iodine thyroid blocking agent taken before a release out to about a distance of 15–30 km. Evacuation at speeds greater than about 5 km/h (walking speed) even in the plume (i.e. during a release), is more effective than sheltering within a radius of about 3 to 5 km from the nuclear power plant [15, 16, 39]. Since a release can occur over a number of days, providing that the evacuation can be conducted safely, evacuation need not be delayed because a release has already started.

Taking an ITB agent combined with sheltering, especially in a large building, significantly reduces the dose to the red marrow and to the fetus. Therefore, if safe evacuation is not possible, those located close to the plant need to take an ITB agent and shelter until safe evacuation is possible.

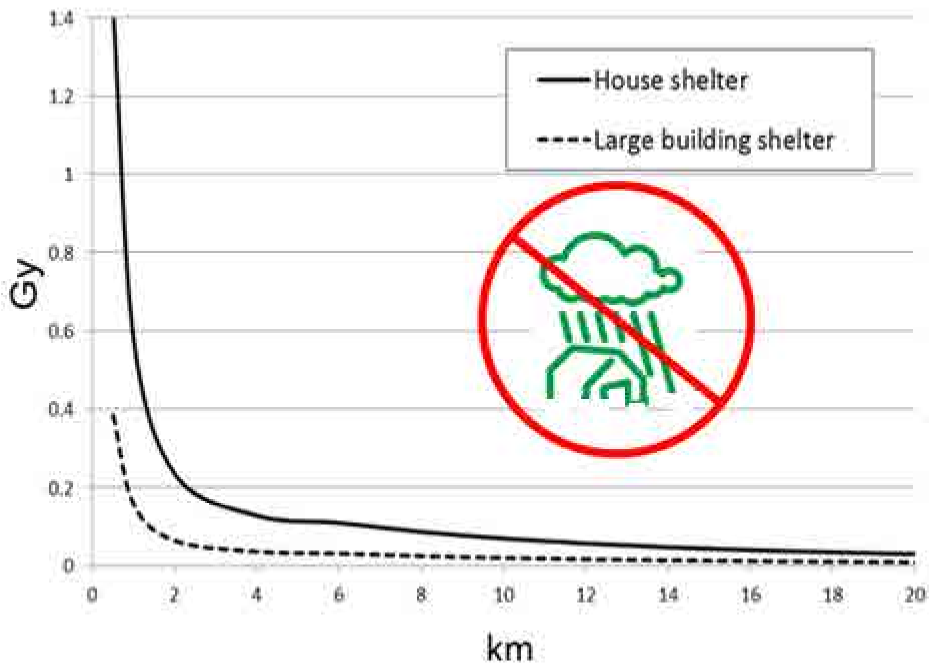


FIG. 18. RBE weighted absorbed dose to the red marrow ($AD_{red\ marrow}$) from cloud shine, inhalation and one day of ground shine without rain.

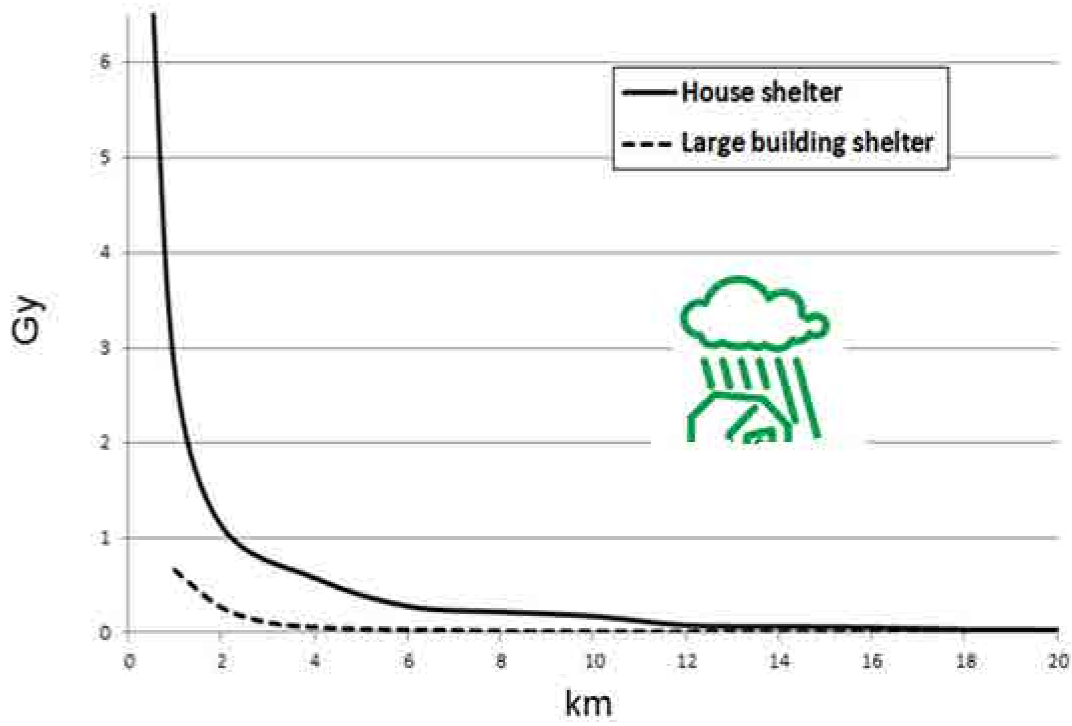


FIG. 19. RBE weighted absorbed dose to the red marrow ($AD_{red\ marrow}$) from cloud shine, inhalation and one day of ground shine with rain.

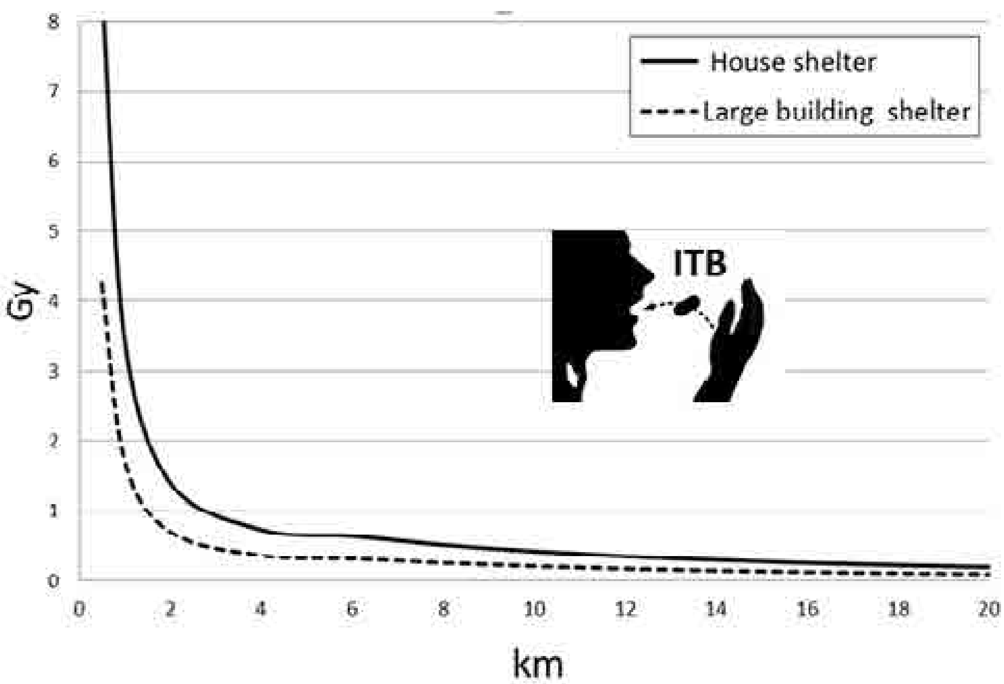


FIG. 20. RBE weighted absorbed dose to the fetus from inhalation ($AD_{fetus,inh}$) after taking ITB agent.

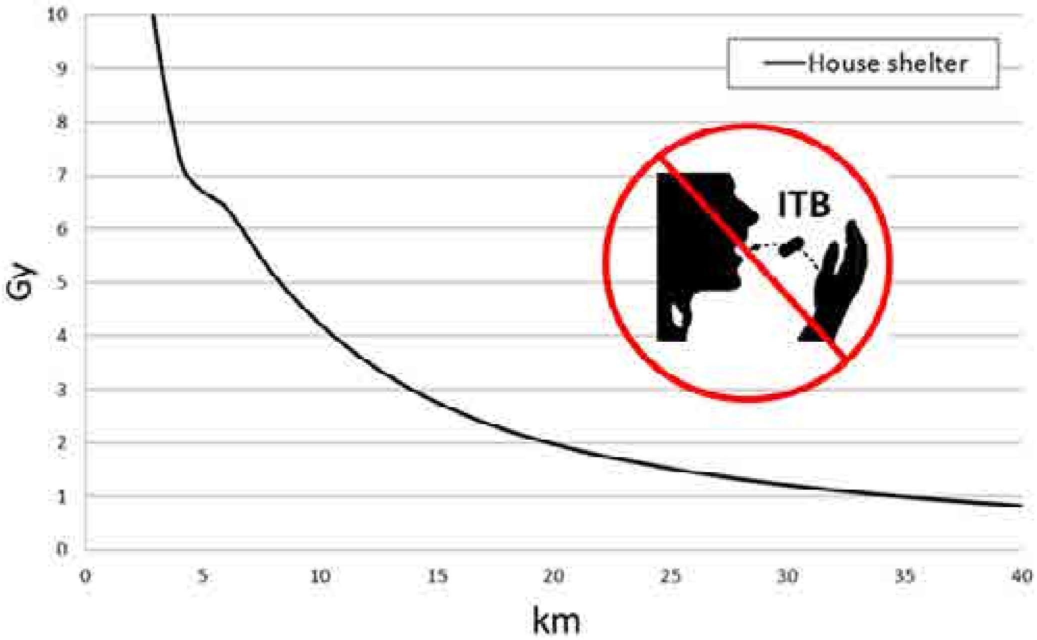


FIG. 21. RBE weighted absorbed dose to the fetus from inhalation ($AD_{fetus,inh}$) without taking ITB agent when sheltering in a house.

I.2.2. UPZ

The suggested size of the UPZ given in Table 3 is approximately 15–30 km which is supported by the first approximation calculations describe below.

FIG. *22* shows that the criterion 100mSv of effective dose (E_{inh}) (Table 19), that if projected, should trigger urgent protective actions to avoid or minimize stochastic effects [1], are projected to be exceeded from inhalation out to about a distance of 30 km for an individual sheltering in a house and out to about a distance of 15 km if sheltering in a large building.

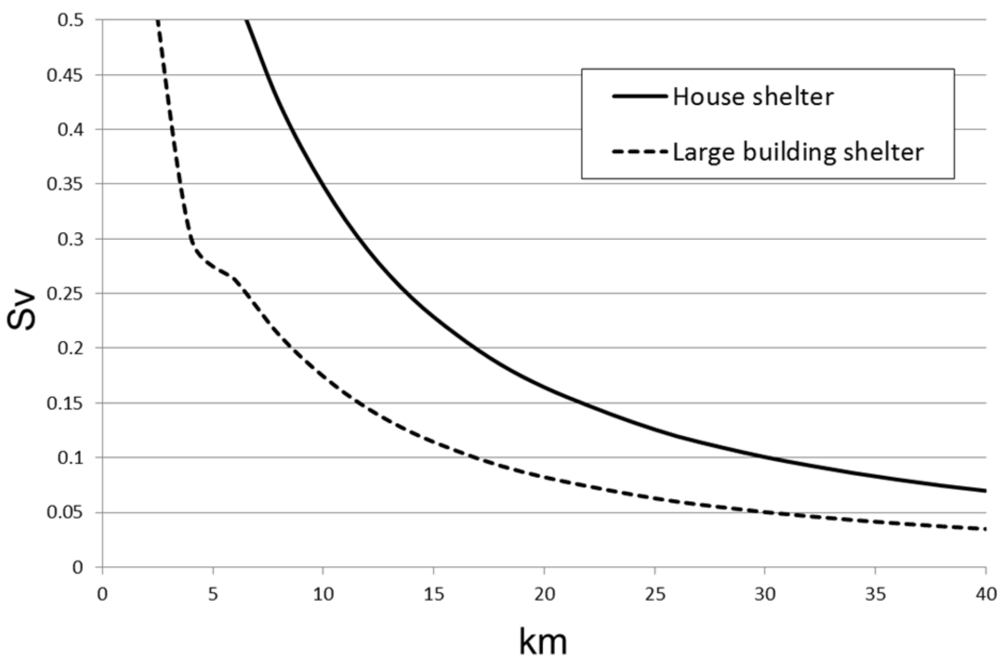


FIG. 22. Effective dose from inhalation (E_{inh}).

FIG. *23* shows that if an ITB agent is taken before or shortly after the inhalation the criterion of 100 mSv to the fetus ($H_{fetus,inh}$) (Table 19) is projected to be exceeded out to about a distance of 20 km for a pregnant woman sheltering in a large building and at about a distance of 30 km if sheltering in a house.

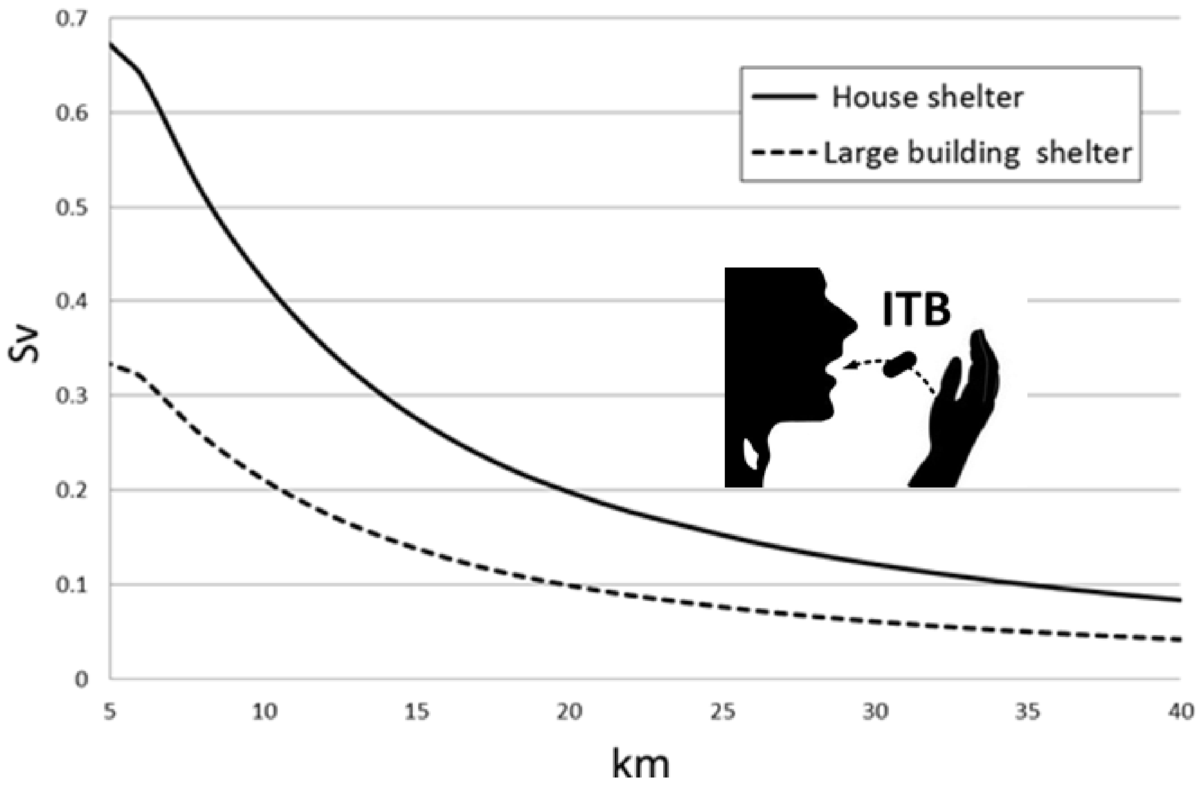


FIG. 23. Equivalent dose to the fetus from inhalation ($H_{fetus,inh}$) after taking an ITB agent.

I.2.3. Determining sizes of emergency zones by taking into account site-specific local conditions

FIG. *24* shows the decrease in the concentration with plume travel distance and thus the dose with distance from the release point for typical meteorological conditions[53] and the distances encompassed by the sizes for the zones suggested in Table 3. The figure shows that within about 3 to 5 km there is a reduction by a factor of 10 and another reduction of a factor 3 after the plume has travelled about another 10 km, however, there is not another reduction by a factor of 3 until the plume has travelled an additional 25 km (out to about a distance of 40 km).

FIG. *24* shows the importance of concentring on taking prompt protective actions within the first few kilometres of the nuclear power plant in order to substantially reduce the exposure of the population and the associated health hazard. Establishing a PAZ with a boundary less than about 3 km should be avoided because it could greatly increase the risk to the public and establishing the boundary at significantly more than 5 km should be carefully considered to ensure it will not reduce the effectiveness of the protective actions for those close to the plant who are at greatest risk.

[53] Typical for D stability, ground level release and no rain.

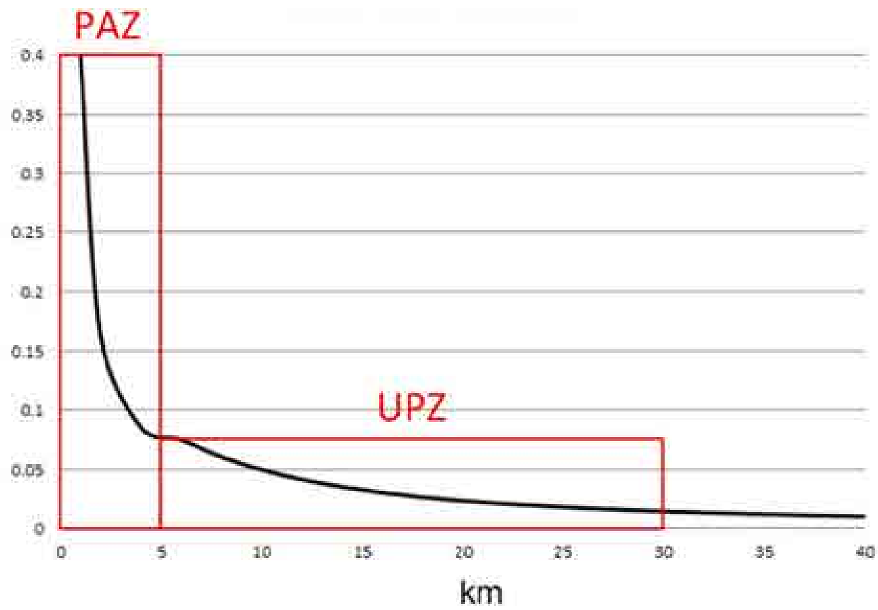


FIG. 24. Concentration in the plume relative to that at 0.5 km for typical meteorological conditions (D stability), as a function of plume travel distance from the release point.

FIG. *24* also shows that beyond about 3 to 5 km it would be most efficient to concentrate on taking protective actions within approximately 15 to 30 km, which is the suggested starting point for establishing the boundary of the UPZ. Establishing the boundary of the UPZ at substantially less than 15 km should be avoided because of the increased risk to the public. However, establishing the boundary of the UPZ at significantly more than 30 km should also be carefully considered since: (a) it provides very little additional benefit because of the very gradual decrease in dose with distance and (b) may delay implementation of protective actions for those at greatest risk close to the plant. The impact of the distance at which the boundary of a zone is established is illustrated in FIG. 25. This figure shows the approximate area for which protective actions would need to be implemented within a zone as a function of distance of the zone boundary from the nuclear power plant. For example, a UPZ with a boundary out to about 30 km would be comprised of an area about four times the area of a UPZ with a boundary established at about 15 km and would include an additional 2000 km^2.

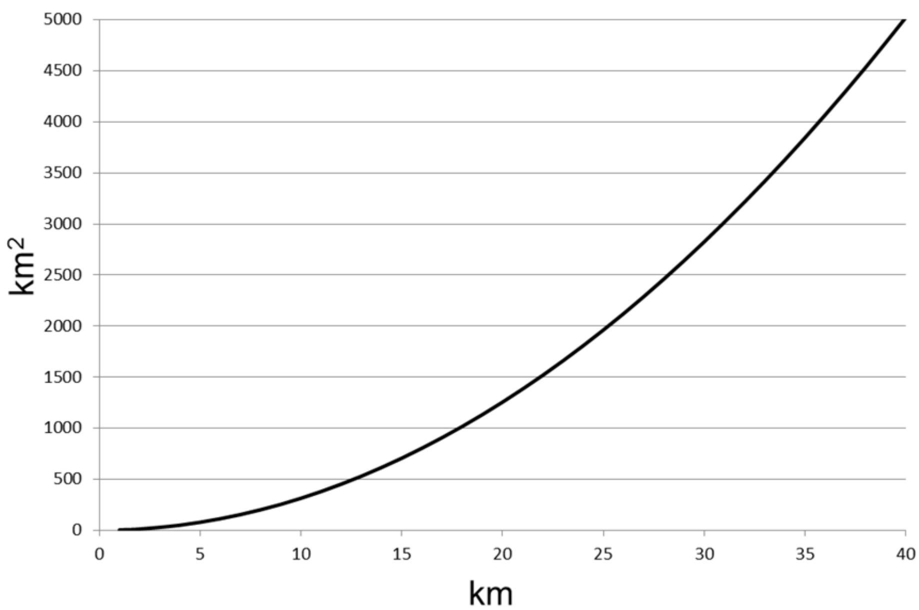


FIG. 25. Approximate area size for which protective actions would need to be implemented and its relationship to the distance of the zone boundary from the plant.

The sizes of the zones and distances can be established based on specific analysis of the nuclear power plant, as long as releases from emergencies involving severe damage to reactor fuel and containment failure or by-pass are considered as appropriate. However, boundaries that are more than a factor of two less than or greater than the recommended ranges given in Table 3 need to be avoided, unless supported by specific analysis of the nuclear power plant, because it could reduce the effectiveness of the associated protective actions and other response actions as demonstrated in this appendix.

The impact of power rating of the nuclear power plant on the zone sizes is linear and secondary when considering the uncertainties associated with the release size, composition, effective release height, duration and meteorological conditions, as illustrated in FIG. 26.

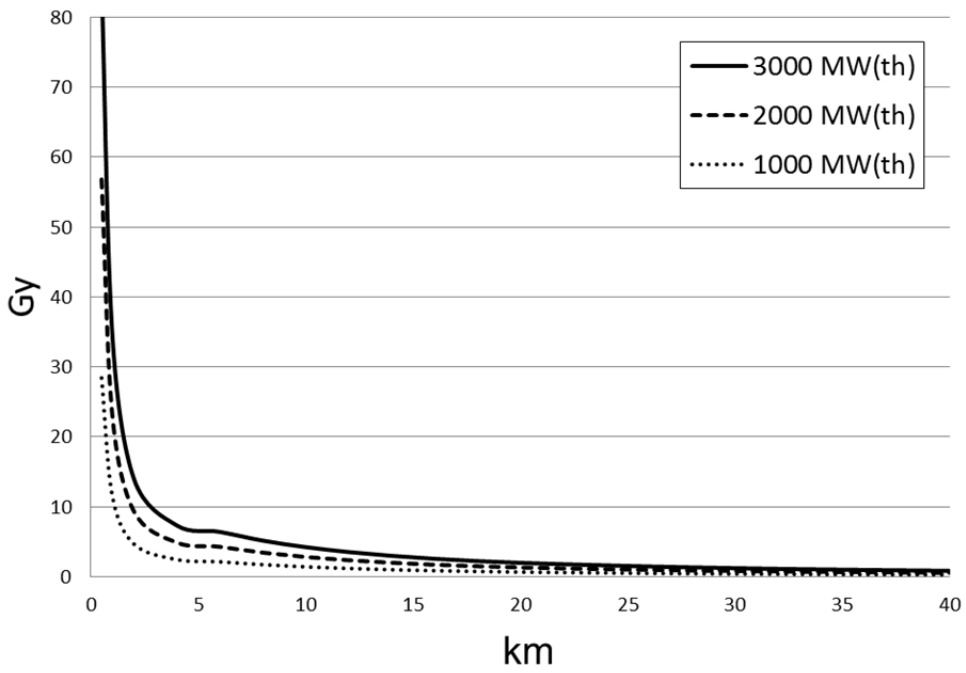


FIG. 26. The projected RBE weighted absorbed dose to the fetus from inhalation ($AD_{fetus,inh}$) without taking an ITB agent when sheltering in a house for releases from plants with different power levels.

I.3. FURTHER ANALYSES SUPPORTING THE ZONE SIZES

The results discussed in Section 1.2 are consistent with other studies [e.g. see Refs. 14, 16, 39, 43] and the Chernobyl experience[54, 55] [27] which demonstrated that for an emergency relating to a release from the most severe reactor core or spent fuel pool [44] emergencies, the area located within about 3 to 5 km may need to be evacuated. Phased evacuation [16] (i.e. evacuating the area within a radius of 3 to 5 km first, followed by evacuation of the area beyond) is likely to be more effective than evacuating the entire area recommended for the UPZ, because it allows the people within the first 3 to 5 km to be evacuated faster.

[54] The release from the accident at the Chernobyl nuclear power plant (30–50% of the volatile fission products).
[55] The initial release from the accident at the Chernobyl nuclear power plant resulted in doses that would have been lethal to anyone outdoors within the first few kilometres of the plant (in the area where trees were killed by radiation creating the so-called ‘Red Forest’). Fatalities did not occur because this initial release was not over a populated area.

The effectiveness of various protective actions for very severe emergencies at a large reactor (≈3000 MW(th)) have also been evaluated in Ref. [39] and the results are illustrated in FIG. 27 and FIG. 28. This analysis was for very severe emergencies involving melting of the fuel in the core and a large early release from the containment. This includes a spectrum of releases, some of which are more severe than that described in Table 20 and are no longer considered credible for many reactor designs. However the analysis provided valuable insights into the effectiveness of various protective actions.

The bars in FIG. 27 and FIG. 28 represent a range which accounts for the uncertainties of the size of the release and the weather conditions. These figures show the probability of a member of the public receiving an RBE weighted absorbed dose to the red marrow exceeding 2 Gy (FIG. 27) and 0.5 Gy (FIG. 28) depending on the various protective actions taken by the public. The analysis considers a range of meteorological conditions and releases involving core melt and early containment failure (early release). An early containment failure is one that occurs within a few hours of core damage; however, for the majority of early releases it is expected that they would occur no sooner than 2 hours [40] after the loss of a safety function (causing the declaration of a General Emergency). Therefore, there is likely to be a warning time of two or more hours in which to initiate urgent protective actions before the release, even for these worst cases in postulated emergencies. FIG. 27 shows the probability of exceeding 2 Gy, which is an indication of the probability of early fatalities due to radiation exposure among the public. FIG. 28 shows the probability of exceeding 0.5 Gy, which can be used to provide insights on the probability of severe deterministic effects in the fetus, if it is assumed that ITB agent has also been taken to protect the fetal thyroid. It needs to be noted that these projections are very uncertain and can only be used in comparing the efficacy of different protective actions. The protective actions that were evaluated are:

- Normal activity: no protective actions were taken during the release, but it was assumed that people were evacuated within 6 hours after the plume's arrival.
- Home basement sheltering: Protection from ground shine, cloud shine and inhalation that are representative of what would be provided by masonry houses without basements, as well as wood frame houses with basements was assumed. People were evacuated from the shelter within 6 hours after the plume's arrival.
- Large building shelter: protection was provided by a large building, for example, an office building, hospital, apartment building, or school. People were evacuated from the shelter within 6 hours after the plume's arrival.
- Evacuation: starting at the time of the release, 1 hour before the start of the release, and 1 hour after the start of the release. A slow evacuation speed of 5 km per hour (walking speed) was assumed.

Examination of FIG. 27 and FIG. 28 shows that prompt evacuation, implemented before a release when conditions at the nuclear power plant (EALs exceeded) indicate severe damage to the fuel, is the most effective protective action within the PAZ and UPZ. This is true for the vast majority of emergencies postulated that could warrant protective actions off the site, if the evacuation can be carried out safely[56]. It is preferred over large building sheltering because:

- Evacuation before a release is the only urgent protective action that greatly reduces the probability of severe deterministic effects;
- A conservative evacuation speed of 5 km/h (walking speed) was assumed in the calculations. Increasing this evacuation speed greatly increases the effectiveness of evacuation; and
- In most emergencies, the timing and duration of a release will be unknown and thus the most effective way of evacuating the public from the areas close to the nuclear power plant before a release is to act when conditions leading to severe fuel damage are detected (EAL for a General Emergency is exceeded).

[56] If evacuation is not possible (e.g. owing to floods, storms or snow) large building sheltering combined with ITB needs to be undertaken until it can.

FIG. 27 shows that people within 5 km (maximum suggested PAZ size) of the nuclear power plant that start to evacuate 1 hour before the start of the release, even if they travel at a slow speed (5 km per hour), essentially have no probability of receiving 2 Gy. However, both home basement and large building sheltering within 5 km or evacuation at the start of the release may not prevent a dose above 2 Gy. People located within 5 km of the nuclear power plant who waited until one hour after the start of a release to begin the evacuation (i.e. evacuation in the plume) also have a significant chance of receiving 2 Gy but their risk is still lower than for those who are sheltered in a home basement. However, this probability would, in most cases, be reduced for higher evacuation speeds. Therefore, for those within 5 km (which is the PAZ) of the nuclear power plant the only response that greatly reduces their chance of receiving 2 Gy is to start to evacuate before the release. At 8 km people can greatly reduce their probability of receiving a dose exceeding 2 Gy either by starting to evacuate at, or before the start of the release, or by sheltering in large buildings. For those starting from 5 km at one hour after a release the effectiveness of evacuation is reduced[57]. Beyond 16 km, in most cases, no protective actions except the evacuation/relocation from hotspots would be necessary in order to avoid a dose of 2 Gy.

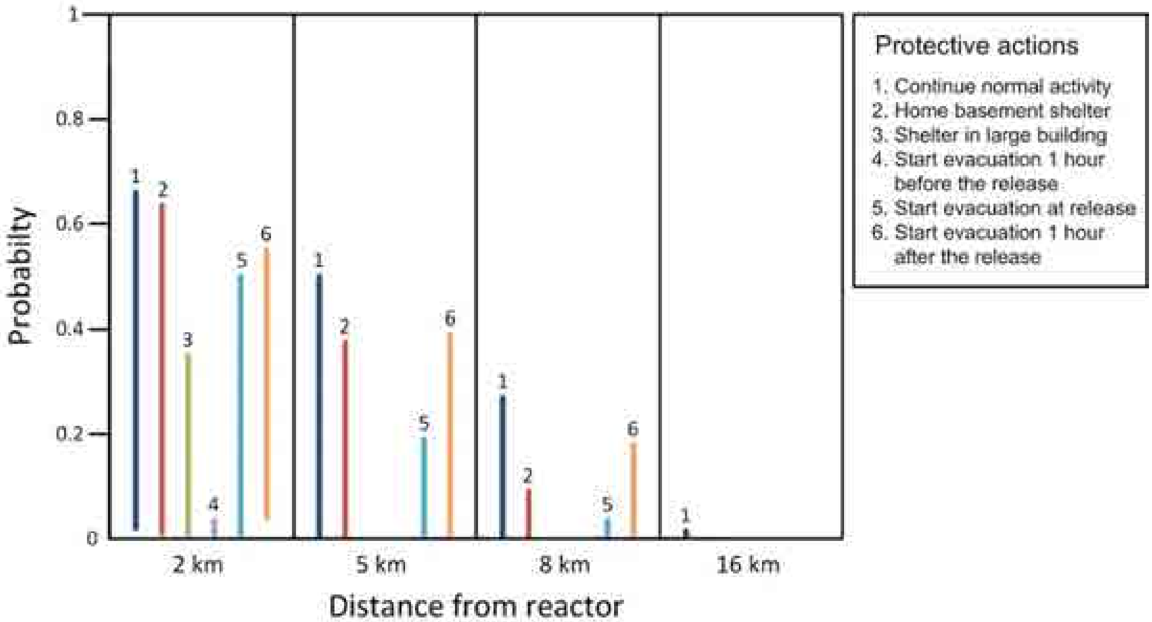


FIG. 27. Probability of exceeding 2.0 Gy RBE weighted absorbed dose to the red marrow for various protective actions assuming core melt and an early containment failure for a nuclear power plant of about 3000 MW(th).

FIG. 28 shows the effectiveness of the various protective actions in keeping the dose below 0.5 Gy. This figure provides insights on the effectiveness of the various protective actions in preventing severe deterministic effects in the fetus provide ITB was give before plume arrival. It shows that within 5 km even slow evacuation, at a speed of 5 km per hour that begins one hour before or at the time of the release is more effective than sheltering in preventing doses greater than 0.5 Gy. However, to avoid 0.5 Gy in all cases would require evacuation starting more than 1 hour before the release. This also shows that at 8 km large building shelter and evacuation before a release are most effective in preventing doses greater than 0.5 Gy but would not be effective in all cases.

[57] The dose from a release reduces more gradually with distance the further the evacuation starting point is from the plant (see for example FIG. 19), thus evacuations in a plume that begin close to a plant are more effective than those that begin further away.

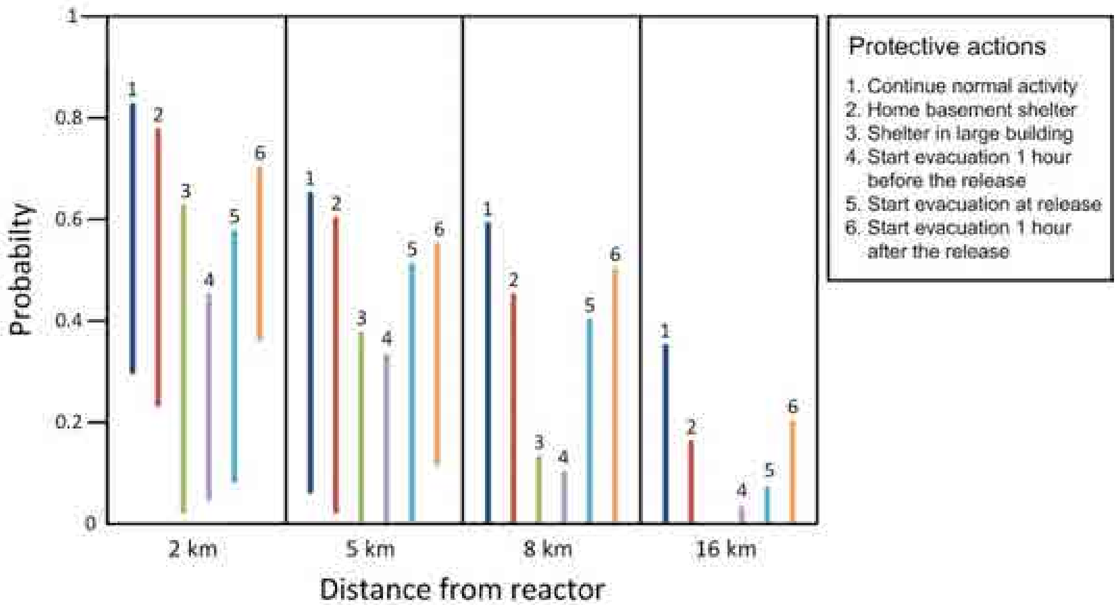


FIG. 28. Probability of exceeding 0.5 Gy RBE weighted absorbed dose to the red marrow for various protective actions assuming core melt and an early containment failure for a nuclear power plant of about 3000 MW(th).

For some emergencies that progress very rapidly with a very short warning time (for a release that starts 0.5 hour after an initiating event), studies [16, 39] show that home basement sheltering followed by prompt evacuation after the plume's passage may be more effective in preventing early fatalities[58], than a slow (e.g. < 5 km per hour) evacuation starting at or after the release within 5–10 km. This is the result of an unlikely combination of conditions that include a very short warning time before the start of the release (e.g. less than 0.5 hour), short release duration, slow effective evacuation speed (< 5 km/h) and starting the evacuation during a specific time window of about 1.5 hours. However, these studies [16, 39] also show that evacuations at speeds of greater than about 5 km per hour are as effective as sheltering in preventing early fatalities, even for this unlikely type of release.

The recommended protective action is always an evacuation of the PAZ and if there is a potential for a severe airborne release, of the UPZ[59] if it can be carried out safely because: (a) prompt evacuation is the most effective protective action within the PAZ and UPZ for the vast majority of emergencies postulated that could warrant protective actions off the site; and, (b) in most cases the timing and duration of a release will be unknown. Sheltering combined with ITB needs to be undertaken until evacuation can be conducted safely.

I.4. EXTENDED PLANNING DISTANCE (EPD)

The extended planning distance is the distance within which arrangements at the preparedness stage (before an emergency) need to be made to monitor the dose rates from deposition. This is done in order to locate hotspots that require evacuation or relocation within a week to a month following a release. Doing so would meet international criteria at which implementation of protective actions and other response actions is required. Table 23 [1] lists the international criteria at which relocation is warranted.

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[58] Effectiveness in preventing severe deterministic effects in the fetus or thyroid was not assessed.

[59] Evacuation of the UPZ may be phased in such a way that those areas at immediate risk are evacuated first (e.g. considering the projected wind direction), or in such a way to be implemented most effectively (e.g. optimization of the existing road network). However, ultimately the UPZ may need to be evacuated in all directions due to the wind shifts that could take place during a release or throughout the time period of a potential severe release.

TABLE 23. GENERIC CRITERIA FOR EARLY PROTECTIVE ACTIONS TO REDUCE THE RISK OF STOCHASTIC EFFECTS

<table>
<tr><th>Dosimetric quantity</th><th>Take early protective actions if the projected dose is greater than the following generic criteria:</th><th>Examples of early protective actions and other response actions</th></tr>
<tr><td>Total effective dose (E)</td><td>100 mSv per annum</td><td rowspan="2">Relocation, decontamination, replacement of food, milk and water and public reassurance

If the generic criteria value is reached (dose is received) provide medical screening</td></tr>
<tr><td>Total equivalent dose in the fetus (H_{fetus})</td><td>100 mSv for the full period of in utero development</td></tr>
</table>

The suggested sizes of the extended planning distance given in Table 3 are:

- 50 km for reactors with power levels less than 1000 MW(th) and greater than 100 MW(th); and
- 100 km for reactors with power levels greater than 1000 MW(th).

These suggested distances consider that:

- Following the release during the accident at the Chernobyl nuclear power plant [27], hotspots occurred beyond 200 km causing the need for relocation in accordance with the generic criteria given in Table 23. Assuming that the distance to which a specific ground concentration is exceeded (distance to which a generic criteria is exceeded) is directly proportional to the size of the release [41]. This demonstrates that contamination due to rain warranting relocation can occur beyond the suggested size of the extended planning distance (i.e. 100 km) for all reactors with power levels of 1000 MW(th) and larger. For reactors with power levels of less than 1000 MW(th) the suggested extended planning distance size was scaled down proportionally; and

- Planning within this distance provides a substantial basis for the expansion of monitoring, if found to be necessary.

I.5. INGESTION AND COMMODITIES PLANNING DISTANCE (ICPD)

The ingestion and commodities planning distance is the distance at which urgent restrictions are placed on the consumption and distribution of local produce, wild-grown products (e.g. mushrooms and game), milk from grazing animals or rainwater that need to be implemented before or shortly after a release in order to: (a) significantly reduce the risk of an increase in the thyroid cancer incidence due to radiation induced cases, and (b) to reduce doses in excess of the generic criteria given in Table 23.

The suggested sizes of the ingestion and commodities planning distance given in Table 3 are:

- 100 km for nuclear power plants with power levels less than 1000 MW(th); and
- 300 km for nuclear power plants with power levels greater than or equal to 1000 MW(th).

These suggested distances are based on consideration of the following:

(a) Due to the accident at the Chernobyl nuclear power plant about 30–50 % of the iodine in the core was released (a release that was three times the amount that was assumed here for the typical case). This resulted in: (i) detectable increases in the thyroid cancer rate due to radiation induced cases [25] that developed because of thyroid doses recieved from ingestion of contaminated milk at distances greater than 300 km away from the nuclear power plant, and (ii) contamination warranting restrictions in accordance with the generic criteria given in Table 23 at distances of more than 2000 km (ingestion restrictions were warranted in parts of the UK due to deposition of radioactive material after the plume had travelled 4000 km). In addition, the accident at the Fukushima Daiichi nuclear power plant resulted in a release of about 3% of the iodine in a core [7] and resulted in food restrictions at distances of more than 200 km away. Assuming that the distance to which a specific ground concentration is exceeded (distance to which a generic criteria is exceeded) is directly proportional to the size of the release [41], this demonstrates that, even for an elevated release, such as the one that occurred at the Chernobyl nuclear power plant, in order to prevent a dose exceeding the generic criteria given in Table 23, the replacement of food, milk or rainwater may be required at distances well beyond 300 km. This is for a release of 10% of the iodine (typical case) from even from a nuclear power plant with power levels less than 1000 MW(th).

(b) Model projections assuming the release characteristics and meteorological conditions described in Section I.1 of this Appendix for a reactor with power levels greater than or equal to 1000 MW(th). The generic criteria in Table 23 [1] requiring restrictions on consumption and medical screenings are projected to be exceeded beyond 300 km as a result of consumption of leafy vegetables and milk from grazing cows, if 10% of the diet is assumed to be contaminated.

(c) The patterns of the deposition resulting from a release are very complex and will be changing. Even the relatively small ongoing releases expected to occur for days or weeks after the emergency can result in hotspots that could result in the contamination of food, milk or rainwater exceeding international criteria requiring implementation of protective actions and other response actions. These complex and changing deposition patterns make it impossible to identify, within days to weeks, where ingestion is a concern, the areas warranting restriction of consumption based on monitoring and sampling alone. During the accident at the Chernobyl nuclear power plant, the main source of dose resulting in radiation induced thyroid cancers was ingestion of milk from cows grazing on contaminated grass. Within two days following the release the milk being consumed by people was contaminated. Therefore, restrictions need to be implemented before monitoring and sampling can be performed.

In summary, the distance of 300 km for the ingestion and commodities planning distance is suggested for reactors with power levels greater than or equal to 1000 MW(th) because: (a) this could be the distance at which food, milk or rainwater contamination could result in a detectable increase in thyroid cancers due to radiation induced cases for the worst possible releases, as demonstrated by the Chernobyl accident, (b) the generic criteria in Table 23 [1] requiring restrictions on consumption and medical screenings are projected to be exceeded beyond 300 km and (c) planning within this distance provides a substantial basis for expansion of the restrictions if found to be necessary.

For reactors with power levels of less than 1000 MW(th), the suggested ingestion and commodities planning distance size was scaled down proportionally.

APPENDIX II
DESCRIPTION OF DEFAULT OPERATIONAL INTERVENTION LEVELS

II.1. OVERVIEW

This Appendix provides an overview of the basis for the default operational intervention levels (OILs) in Section 6. The default OILs were developed using reasonably conservative assumptions. Conservative means that the generic criteria are expected to be exceeded in the representative individual at a measured value higher than the default OIL values.

In the case of a release from a reactor core or spent fuel pool, OILs expressed in terms of dose rate can be used to make decisions concerning most urgent and early protective and other response actions. Dose rate is the preferred quantity for the OIL because it can be quickly and easily measured using commonly available instruments. Table 24 provides a summary description of the basis for the OILs and the sections of this appendix provide more details. The goal of taking protective actions based on OILs is that: (a) all members of the public are protected in accordance with the international safety standards and guidance [1]; (b) that there will be no severe deterministic effects in even the members of the public most sensitive to radiation (e.g. children or pregnant women (fetus)), and (c) that there will be no detectable increase in the cancer rate due to radiation induced cases.

The OILs are established for a 'representative person'. The representative person is defined so that this person would receive the highest doses reasonably expected to be received by any member of the public in an emergency. In most cases, due to the conservative nature of the assumptions made, no one would be expected to receive a dose approaching that calculated for the representative person. Basing the response action on the dose to the representative person will protect every member of the public. These default OILs were established for releases into the environment from the fuel in a light water reactor or a graphite moderated (RBMK) or the fuel in their spent fuel pools. It is assumed that the fuel was uncovered (lack of coolant) and heated up until it was damaged, resulting in the release. The full spectrum of the possible types of fuel damage and releases were considered, ranging from failure of the fuel cladding to full melting of all of the fuel.

Reasonably conservative assumptions are made in calculating the default OIL values, as listed below:

- Representative person: the exposure of the representative person reflects the exposure of the member of the public most sensitive to radiation (e.g. children or the pregnant women (fetus)), or their individual organs or tissues.
- Exposure conditions:
  - The population lives normally; and
  - Maximum dose factors are used from among those provided for different chemical and physical forms for ingestion and inhalation.
- Mixture of radionuclides: the mixture of radionuclides released from the reactor core or spent fuel pool that gave the most conservative OIL values was assumed.

The generic criteria used for protecting the public from radioactive material deposited on the ground or skin or that contaminates local produce, milk or water during an emergency are summarized in Table 24. These generic criteria are from Ref. [1 and 2], which was developed in consideration of the latest ICRP guidance [36], taking into account the findings of UNSCEAR [27], and was co-sponsored by the Food and Agriculture Organization of the United Nations (FAO), the International Labour Office (ILO), the Pan American Health Organization (PAHO) and the World Health Organization (WHO). The OILs in this publication were developed based on the generic criteria established by international standards that warrants protective actions and other response actions as outlined in Ref. [1] except where noted in Table 24. Not all of the international generic criteria in Ref. [1] are considered for a fission product release because meeting a subset of these generic criteria ensures that the others are also met.

TABLE 24. SUMMARY DESCRIPTION OF THE DEFAULT OILS

<table>
<tr><th>OIL</th><th>Purpose</th><th>Generic dose criteria/
exposure period</th><th colspan="2">Exposure pathway/
scenario considered[a]</th></tr>
<tr><td colspan="5">Ground Deposition</td></tr>
<tr><td rowspan="4">OIL1</td><td rowspan="4">Assessing ground deposition monitoring results for taking urgent actions.</td><td rowspan="2">100 mSv of effective dose to the representative person over an exposure period of 7 days[b]</td><td rowspan="4">Living normally in the affected area (assumed to be inside 60% of the time)</td><td>External exposure from deposited radioactive material (ground shine)</td></tr>
<tr><td>Inhalation of resuspended radioactive material[c]</td></tr>
<tr><td rowspan="2">100 mSv of equivalent dose to the fetus of the representative person over an exposure period of 7 days[b]</td><td>External exposure from resuspended radioactive material[c]</td></tr>
<tr><td>Inadvertent ingestion of soil</td></tr>
<tr><td rowspan="4">OIL2</td><td rowspan="4">Assessing ground deposition monitoring results for taking early actions.</td><td rowspan="2">100 mSv of effective dose to the representative person over an exposure period of 1 year[d]</td><td rowspan="4">Living normally in the affected area (assumed to be inside 60% of the time)</td><td>External exposure from deposited radioactive material (ground shine)</td></tr>
<tr><td>Inhalation of resuspended radioactive material[c]</td></tr>
<tr><td rowspan="2">100 mSv of equivalent dose to the fetus of the representative person over an exposure period of 1 year[d]</td><td>External exposure from resuspended radioactive material[c]</td></tr>
<tr><td>Inadvertent ingestion of soil</td></tr>
<tr><td>OIL3</td><td>Assessing monitoring of ground deposition to identify where consumption of possibly contaminated local produce, milk and rainwater[g] needs to be restricted because it can result in contamination levels that exceed the international criteria warranting restriction.</td><td>10 mSv[f] total effective dose to the representative person from 1 year of consumption.</td><td colspan="2">Single contaminating event followed by ingestion of local produce (such as locally grown vegetables) and milk from animals grazing in the area contaminated by the release. It is assumed: (a) that: 50% of the food, milk and water consumed is affected, (b) realistic consumption rates, (c) reduction due to decay, and (d) removal of contamination (where appropriate) due to weathering.</td></tr>
<tr><td colspan="5">Skin contamination</td></tr>
<tr><td rowspan="3">OIL4</td><td rowspan="3">Assessing monitoring of the skin to identify those who warrant registration for later medical follow-up.</td><td>1 Gy RBE weighted absorbed dose to the skin to the representative person over an exposure period of 4 days[e];</td><td colspan="2" rowspan="3">Skin dose and inadvertent ingestion of radioactive material on the skin.</td></tr>
<tr><td>100 mSv of effective dose to the representative person over an exposure period of 4 days[e];</td></tr>
<tr><td>100 mSv of equivalent dose to the fetus of the representative person over an exposure period of 4 days[e]</td></tr>
</table>

OIL	Purpose	Generic dose criteria/ exposure period	Exposure pathway/ scenario considered[a]
Food, milk and water radionuclide concentrations			
OIL7	Assessing analysis of the radionuclide concentrations to determine if consumption of food, milk or water needs to be restricted.	10 mSv[f] committed effective dose to the representative person from 1 year of consumption.	Single contaminating event followed by ingestion of affected food, milk, or water. It is based on very conservative assumptions, including assuming all of the food and water consumed are affected. Reduce due to decay is considered.
Thyroid from radioactive iodine intake			
OIL8	Assessing monitoring of the thyroid to identify those who warrant registration for later medical follow-up.	100–200 mSv of committed equivalent dose in thyroid of the representative person.[h]	Inhalation and ingestion of thyroid seeking fission products.

[a] The scenarios and pathways are described in Section II.2.
[b] 7 day exposure period is used to establish where urgent actions need to be taken within a day to be most effective.
[c] Considered but not a significant source of dose for this scenario.
[d] 1 year exposure period is used to establish where early actions need to be taken within days to a month to be most effective.
[e] This is the conservative time period assumed for radioactive material to remain on the skin if no decontamination measures are taken (such as washing the skin). It is assumed that the skin will no longer show relevant concentrations of radioactive material after 4 days due to natural processes.
[f] A lower criterion than that given in Ref. [1] is used to ensure that those people in areas not evacuated or relocated will not receive a total dose (including the dose from ingestion) greater than the generic criteria of 100 mSv per year [1] and to ensure that the equivalent dose to the fetus (H_{fetus}) is less than the generic criteria given in Ref. [1] and that the equivalent dose to the thyroid is less than about 100 mSv.
[g] Only consumption of non-essential drinking water that comes undiluted directly from the collection of rainwater is to be restricted where OIL3 is exceeded. Other sources of drinking water (e.g. wells, reservoirs or rivers) will have much lower concentration levels due to dilution and will only need to be restricted if analysis of samples exceed the OIL7 values.
[h] See explanation in Section II.2.5

II. 2. DESCRIPTION OF OILS

II.2.1. Description of OIL1 and OIL2

The default OIL1 and OIL2 values in Table 7 are for the ambient dose rate at 1m above ground level and were developed for the protection of someone living in an affected area. When developing the OILs, all the important exposure pathways were assumed as shown in FIG. 29. It is assumed that everybody (including pregnant women) are living normally in an area affected by a release and are being exposed to ground shine (external exposure from deposition) and inadvertent ingestion, for example, from dirt on hands. Inhalation of resuspended radioactive material and external exposure from resuspended radioactive material were also considered but these are not important sources of exposure. However, it is assumed that the person is not eating or drinking food, milk or water from the affected area because protective actions have been implemented to restrict consumption.

OIL1 is based on the generic criteria for taking urgent protective actions and other response actions when the effective dose of 100 mSv or equivalent dose of 100 mSv to the fetus is projected to be exceeded in seven days. OIL2 is based on generic criteria for taking early protective actions and other response actions when the effective dose of 100 mSv or equivalent dose of 100 mSv to the fetus is projected to be exceeded in one year. Two values are given for OIL2: 100 µSv/h for measurements that are taken less than 10 days after the shutdown of a reactor and 25 µSv/h for measurements that are taken more than 10 days after shutdown of a reactor. This is in order to account for the short-lived radionuclides that cause a high dose rate measurement over the first 10 days after shutdown of the reactor, but do not contribute significantly to the dose.

The calculations made for OIL1 and OIL2 considered decay and in-growth, reductions due to weathering and reductions due to people continuing to live normally (carrying out normal activities, and being inside about 60% of the time).

The OIL values were selected to ensure that they would be reasonably conservative for the possible mixtures of radionuclides released from a reactor core or spent fuel pool. This is illustrated by FIG. 30 and FIG. 31 with the shaded area showing the range of OIL1 and OIL2 values calculated for the different mixtures of radionuclides that can be released at different times after shutdown. The dashed line shows the OIL1 and OIL2 selected as the default values given in FIG. 30.

1000 μSv/h was chosen as the default OIL1 value, as shown in FIG. 30, despite the fact that it is greater than the range of dose rates calculated (grey area in FIG. 30) starting from about 1 day after shutdown. This is considered acceptable because this OIL will trigger the implementation of urgent protective actions in the first few hours after the start of an emergency. Therefore, the exposure period is expected to be a fraction of the 7 days assumed in the calculations and if protective actions are taken in accordance with the OIL, the resulting dose will be well below the generic criteria of 100 mSv in all cases.

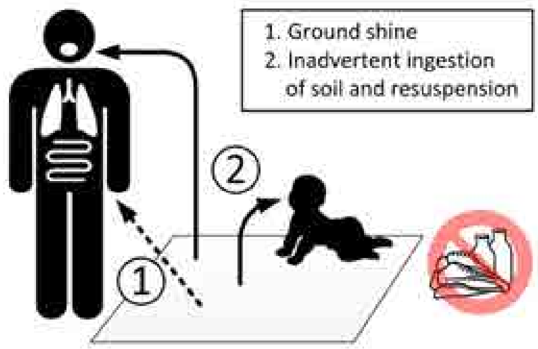

FIG. 29. Important exposure pathways for living in an affected area taken into account in developing OIL1 and OIL2.

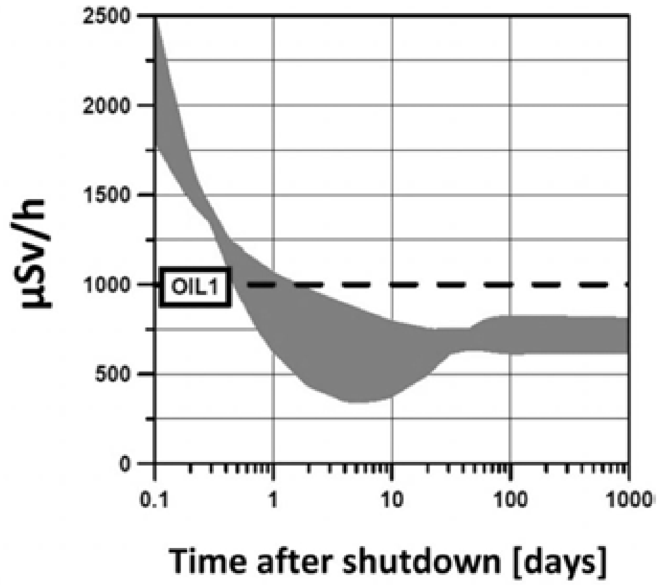

FIG. 30. Basis for selection of default OIL1. The area in grey shows the dose rates that are calculated for the different release mixtures as a function of time after shutdown that meet the generic criteria for establishing OIL1. The dash line shows the selected default OIL1.

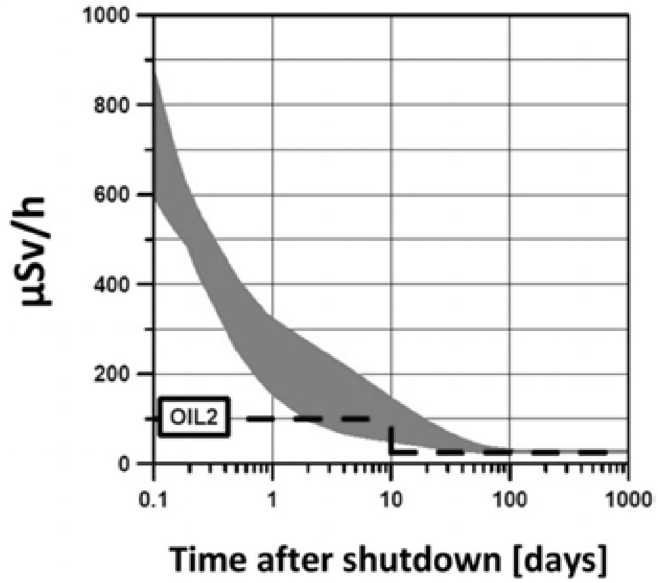

FIG. 31. Basis for selection of default OIL2. The area in grey shows the dose rates that are calculated for the different release mixtures as a function of time after shutdown that meet the generic criteria for establishing OIL2. The dash line shows the selected default OIL2.

II.2.2. Description of OIL3

The default OIL3 value in Table 7 is for the assessment of local produce (such as locally grown vegetables) and milk from animals grazing in the area contaminated by the release based on field measurements (FIG. 32). It was assumed that people:

- eat food produced in the affected area;
- drink milk from animals grazing in the affected area; and
- drink rainwater from the affected area.

In addition, it was assumed that:

- the member of the public most sensitive to radiation (e.g. children or pregnant women) is consuming the items for an entire year;
- there will be no reduction in the concentration of radioactive materials due to preparations of the food (e.g. peeling, washing) before consumption;
- the contamination on plant surfaces (e.g. before harvest or consumption by cows) is reduced due to decay and natural process;
- consumption rates are consistent with the realistic rate for child consumption of vegetables and milk; and
- 50% of the diet is contaminated.

These more realistic assumptions (as compared with the more conservative assumptions used for calculation of the OIL7 values) are used to identify where local produce, milk from grazing animals, rainwater need to be immediately restricted because it can result in concentrations that exceed the international criteria warranting restrictions if it was directly contaminated by a release.

Since in the calculations for OIL3 decay, in-growth and reductions due to weathering were considered, most of the dose may be received during the first weeks due the contribution of I-131.

The default OIL3 values are for the dose rate from deposition that can be quickly measured by ground or aerial survey. This allows areas to be identified where restrictions are justified before the time consuming sampling and laboratory analysis process can be completed. OIL3 is established for 10 mSv/a, which is 1/10 of the generic criteria given in Ref. [1]. This is used to ensure that those people in areas not evacuated or relocated will not receive a total dose (including the dose from ingestion) greater than the generic criteria of 100 mSv per year [1] and to ensure that the equivalent dose to the fetus (H_{fetus})[60] is less than the generic criteria given in Ref. [1] and that the equivalent dose to the thyroid ($H_{thyroid}$) is less than about 100 mSv.

The OIL value was selected to ensure that it would be reasonably conservative for the possible mixtures of radionuclides released from a reactor core or spent fuel pool. This is illustrated by FIG. 33 with the shaded area showing the range of OIL3 values calculated for different mixtures of radionuclides that can be released at different times after shutdown. The dashed line shows the default OIL3 values in Table 7. 1µSv/h was chosen as the default OIL3 value, despite the fact that it is greater than the range of the dose rates calculated (grey area in FIG. 33) by as much as a factor of 2 between 1 and 10 days after shutdown. This is considered acceptable because: (a) 1µSv/h is considered the lowest dose rate that can be used under emergency conditions and (b) the calculated OIL values are very conservative due to: (i) the assumption that 50% of all the food, milk and water ingested is contaminated, and (ii) due to the use of 10 mSv as the generic criteria for the effective dose from ingestion instead of the generic criteria of 100 mSv given in Ref. [1].

[60] For the range of radionuclides present following a release from a reactor core or spent fuel pool, the equivalent dose to the thyroid ($H_{thyroid}$) and to the fetus (H_{fetus} in sieverts (Sv) could be more than ten times higher than the effective dose in sieverts (Sv).

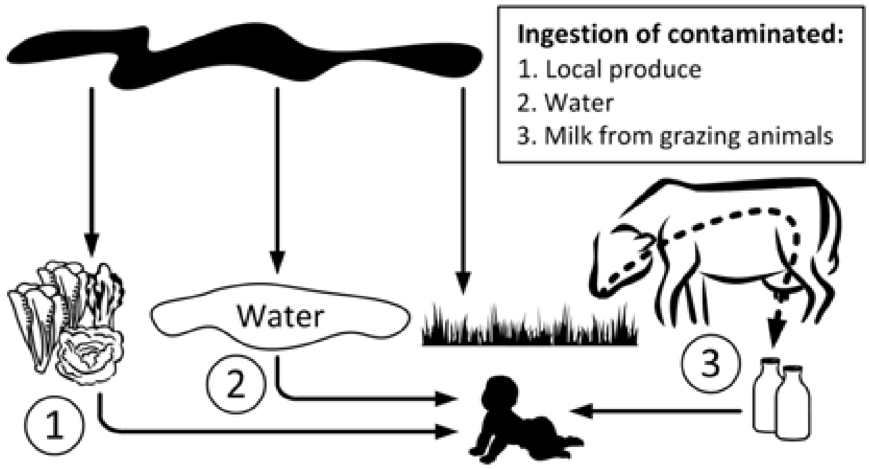

FIG. 32. Important exposure pathways for ingestion taken into account in developing OIL3.

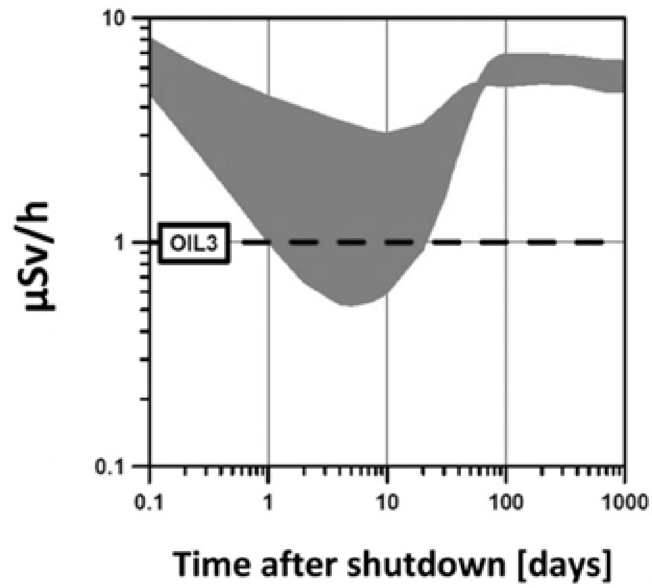

FIG. 33. Basis for selection of default OIL3. The area in grey shows the dose rates that are calculated for the different release mixtures as a function of time after shutdown that meet the generic criteria for establishing OIL3. The dashed line shows the selected default OIL3.

II.2.3. Description of OIL4

The default OIL4 value in Table 8 is for the ambient dose rate (µSv/h) from radioactive material on the skin. For this scenario the most important exposure pathways (FIG. 34) are inadvertent ingestion and dose to the skin derma from the contamination on the skin. These pathways were considered in the development of OIL4. If the OIL4 level is exceeded, this may indicate that the person being monitored may have inadvertently ingested or inhaled enough contamination to result in doses greater than the generic criteria calling for a medical follow-up.

The default OIL value was selected to ensure that it would be reasonably conservative for the possible mixtures of radionuclides released from a reactor core or spent fuel pool. This is illustrated by FIG. 35 with the shaded area showing the range of OIL4 values calculated for different mixtures of radionuclides that can be released at different times after shutdown. The dashed line shows the default OIL4 values Table 8.

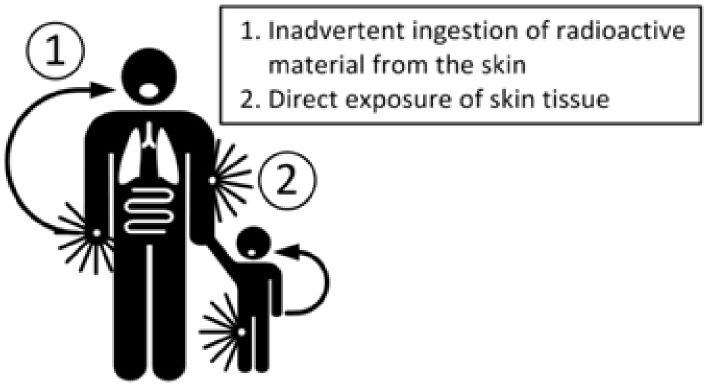

FIG. 34. Important exposure pathways for radioactive material on the skin taken into account in developing OIL4.

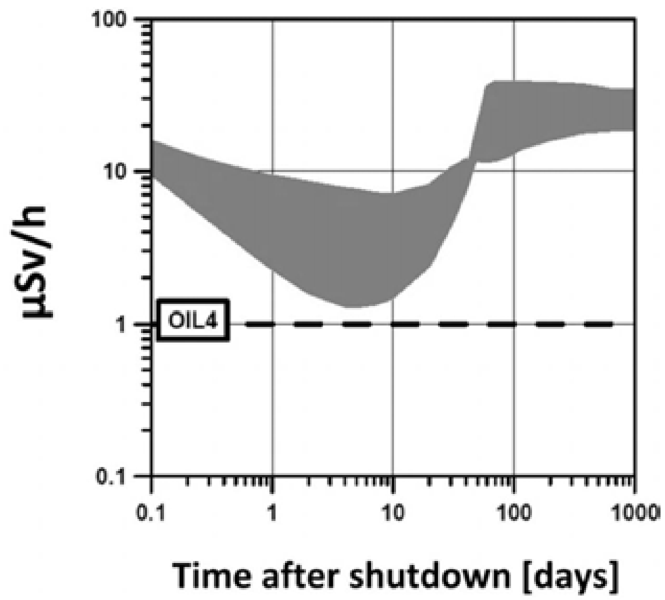

FIG. 35. Basis for selection of default OIL4. The area in grey shows the dose rates that are calculated for the different release mixtures as a function of time after shutdown that meet the generic criteria for establishing OIL4. The dash line shows the selected default OIL4.

II.2.4. Description of OIL7

The default OIL7 values in Table 9 are for the two marker radionuclides ^{131}I and ^{137}Cs. The OIL is exceeded if either of these values is exceeded.

The default OIL7 values were established to include the contribution of all the other radionuclides that would be present in a fission product release. Only the concentration of the marker radionuclides (isotopes) ^{131}I and ^{137}Cs needs to be measured when deciding if food needs to be restricted. For example, when a concentration of ^{137}Cs in food, water or milk is shown on the chart, not only are the doses from ^{137}Cs considered, but also the doses from other radionuclides expected to be present (e.g. ^{131}I, ^{134}Cs, ^{140}Ba, ^{90}Sr, ^{106}Ru). These marker radionuclides (^{131}I and ^{137}Cs) are assumed to have a concentration proportional to those of other released radionuclides which are considered important contributors to the dose.

The default OIL7 values are established for the generic criteria of 10 mSv/a effective dose which is 1/10 of the generic criteria given in Ref. [1]. This is used to ensure that those people not relocated will not receive a total dose (including the dose from ingestion) greater than the generic criteria of 100 mSv per year [1] and to ensure that the equivalent dose to the thyroid ($H_{thyroid}$) and fetus (H_{fetus})[61] are less than the generic criteria given in Ref. [1].

The OIL7 values were calculated using very conservative assumptions and for the members of the public most sensitive to radiation (e.g. children and pregnant women). It was assumed that: (a) all the food, milk and water consumed is contaminated, (b) that the food, milk and water were consumed over a period of 1 year, and (c) there is no reduction due to processing or preparation. However, reduction due to decay is considered; therefore, for radionuclides with a short half-life (e.g. I-131), most of the dose from ingestion after a release from a reactor core is received in the first months.

The OIL values were selected to ensure that they would be conservative for the possible mixtures of radionuclides released from a reactor core or spent fuel pool. This is illustrated by FIG. 36 and FIG. *37* with the shaded area showing the range of OIL7 values calculated for different mixtures of radionuclides that can be released at different times after shutdown. The dashed line shows the default OIL7 values for the marker radionuclides ^{131}I and ^{137}Cs given in Table 9. The default OIL7 value for ^{131}I is slightly less than the calculated values for the first 10 days after which the calculated values for ^{131}I fall dramatically and the default OIL7 value for ^{137}Cs becomes conservative. The dramatic variations on the OIL7 values for the ^{131}I and ^{137}Cs show the need to assess both of these OILs.

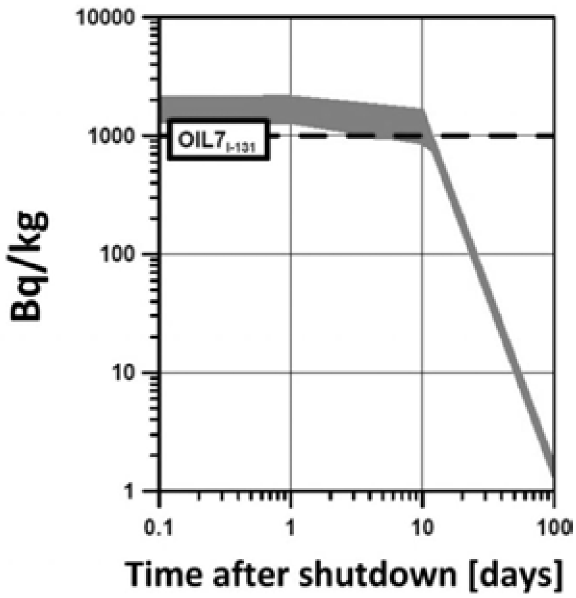

FIG. 36. Basis for selection of default OIL7 value for ^{131}I. The area in grey shows the concentration of the marker radionuclide ^{131}I that meet the generic criteria for establishing OIL7. The dash line shows the selected default OIL7 for the concentration of the marker radionuclide ^{131}I.

[61] For the range of radionuclides present following a release from a reactor core or spent fuel pool, the equivalent dose calculated in sieverts (Sv) to the thyroid ($H_{thyroid}$) and to the fetus could be more than ten times higher than the effective dose calculated in sieverts (Sv).

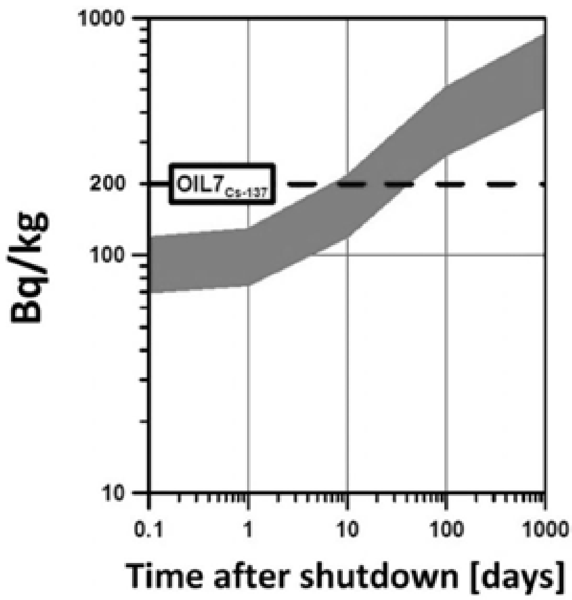

FIG. 37. Basis for selection of default OIL7 value for ^{137}Cs. The area in grey shows the concentration of the marker radionuclide ^{137}Cs that meet the generic criteria for establishing OIL7. The dash line shows the selected default OIL7 for the concentration of the marker radionuclide ^{137}Cs.

II.2.5. Description of OIL8

The minimum OIL8 value was established at 0.5 µSv/h because this is considered the minimum dose rate that could be measurable from the thyroid under emergency conditions. This dose rate is indicative of an equivalent dose to the thyroid ($H_{thyroid}$) of between 100 and 200 mSv for all age groups to include children and the fetus, since the equivalent dose to the pregnant woman's thyroid is approximately equal to the equivalent dose to the fetal thyroid [45]. These screening criteria can be used to identify those who warrant further medical assessments. Below these OIL values no further medical assessment is warranted in accordance with the generic criteria [1].

These values were established after considering the response of the range of instruments that would be expected to be used during an emergency. The actual relationship of the dose to the thyroid and monitor response will depend on many factors such as the size and position of the probe, background dose rates and when the monitoring was conducted. Therefore, the registration form (see Appendix IV) requires the recording of the monitor used, when the monitoring was conducted, the position of the probe (geometry of measurement) and the background dose rate.

APPENDIX III
THE SYSTEM FOR PLACING THE RADIOLOGICAL HEALTH HAZARD IN PERSPECTIVE

This Appendix provides the basis for the system for placing the health hazard in perspective (see charts in Section 7).

III.1. LEVELS

The possible health hazards for a particular exposure situation are placed in perspective using a system of four colour coded levels (see FIG. 14 and Table 11):

- **Possibly dangerous to health (red)**: There is a possibility of radiation induced health effects that are life threatening or can result in a permanent injury that reduces the quality of life (severe deterministic effects). At this level there is also the small possibility of an observable increase in the incidence of cancer due to radiation induced cases, if the number of exposed people is more than a few hundred.
- **Health concerns (orange)**: The danger to health is very low. However, there is a possibility of doses exceeding the international criteria [1, 2] that call for taking protective actions and other response actions to include medical screening in order to further assess: (a) the small possible risk to pregnant women (fetus), and (b) the small possible increase in the risk of radiation induced cancers.
- **Provisionally safe (yellow)**: It is safe for all members of the public – including the most sensitive (e.g. children and pregnant women) and there are no hazards to health due to radiation exposure if the specified limitations are followed, such as remaining in the area is limited to a specific amount of time and/or specified protective actions are taken (e.g. reduce ingestion of radioactive material).
- **Safe (green)**: This meets international standards [1, 2] and is therefore safe for all members of the public – including the most sensitive (e.g. children and pregnant women), as the doses for the specified conditions and public behaviour are less than the generic criteria [1, 2] at which protective actions and other response actions are justified to minimize severe deterministic effects or reduce the risk of stochastic effects. Below this level there will not be any severe deterministic effects or an observable increase in the incidence of cancer, even in a very large exposed group. Furthermore, the risk of radiation induced cancers is too low to justify taking any action, such as a medical screening [1, 2].

It is important to note that when possible radiation induced health effects to the fetus are indicated on the charts, there is only a very low probability of any such adverse effects. The radiation induced health effects to the fetus depend on many factors, such as the stage of development and can only be assessed fully by experts in diagnoses and treatment and management of the effects of radiation exposure. The termination of a pregnancy is not justified, even if the chart indicates radiation induced health effects to the fetus may be possible, without the proper medical examination and counselling from an expert with experience in dealing with overexposures [46]. Others, such as local physicians, usually do not have the expertise needed to make such assessments.

III.2. DOSIMETRIC BASIS

Table 25 provides the dosimetric basis for the health hazard levels discussed in section III.1.

TABLE 25. DOSIMETRIC CRITERIA USED TO DEFINE THE HEALTH HAZARD LEVELS FOR A RELEASE FROM A REACTOR CORE OR SPENT FUEL POOL

Health hazard level	Criterion	Source	Comments
Possibly dangerous to health (red) Severe deterministic effects are possible	**External exposure**		
	$AD_{red\ marrow}$ 1 Gy	Ref. [1] Table 2	Keeping the dose below this criterion will ensure that external exposure to the whole body will not result in any severe deterministic effects (e.g. permanently suppressed ovulation or permanently suppressed sperm counts), except for the fetus which is considered separately [24].
	AD_{fetus} 1 Gy	Ref. [46]	For the 'possibly dangerous to health' level the criterion of 1 Gy was used because it implies a high probability of severe mental retardation in the fetus [46]. A dose value higher than the generic criteria given in Table 2 of Ref. [1] for the fetus was used because: (a) at the generic criteria in Table 2 of Ref. [1] there would only be a very small probability of severe deterministic effects to the fetus and only during certain phases of fetal development (between 8 and 15 weeks of gestation age), and, (b) severe deterministic effects have only been observed at the generic criteria given in Table 2 of Ref. [1] at high dose rates and therefore the thresholds are probably higher due to the lower dose rates that will occur off the site following a release [46].
	Internal exposure		
	$AD_{thyroid}$ 2 Gy	Ref. [1] Table 2	–
	AD_{fetus} 1 Gy	Ref. [46]	For the 'possibly dangerous to health' level the criterion of 1 Gy was used because it implies a high probability of severe mental retardation [46]. A dose value higher than the generic criteria given in Table 2 of Ref. [1] for the fetus was used because: (a) at the generic criteria in Table 2 of Ref. [1] there would only be a very small probability of severe deterministic effects to the fetus and only during certain phases of fetal development (between 8 and 15 weeks of gestation age), and, (b) severe deterministic effects have only been observed at the generic criteria given in Table 2 of Ref. [1] at high dose rates and therefore the thresholds are probably higher due to the lower dose rates that will occur off the site following a release [46].
Health concerns (orange) Low probability of health effects	**Total dose from all possible exposure pathways**		
	$AD_{red\ marrow}$ 100 mGy	Ref. [1] Table 3	For external exposure, this $AD_{red\ marrow}$ dose is numerically equal to the effective dose (E) given in Table 3 of Ref. [1].
	H_{fetus} 100 mSv	Ref. [1] Table 3	–
	$H_{thyroid}$ 100 mSv		The generic criteria given in Table 3 of Ref. [1] was not used because it refers to the need of ITB implementation and not to the dose warranting a medical follow-up. Instead 100 mSv is used because it is assumed that the equivalent dose to the fetus (H_{fetus}) is within a factor of two of the equivalent dose to the pregnant woman's thyroid ($H_{thyroid}$) [45].
	Ingestion only		
	E_{ing} 10 mSv	Ref. [1] para II.22	10 mSv/a effective dose which is 1/10 of the generic criteria given in Ref. [1]. This is used to ensure that those people not relocated will not receive a total dose (including the dose from ingestion) greater than the generic criteria of 100 mSv per year [1] and to ensure that the equivalent dose to the thyroid ($H_{thyroid}$) and fetus (H_{fetus})[62] are less than the generic criteria given in Ref. [1].

[62] For the range of radionuclides present following a release from a reactor core or spent fuel pool, the equivalent dose calculated in sieverts (Sv) to the thyroid ($H_{thyroid}$) and to the fetus could be more than ten times higher than the effective dose calculated in sieverts (Sv).

III.2.1 Possibly dangerous to health (red)

The RBE weighted absorbed dose in an organ or tissue (AD_T) is used to specify the thresholds for severe deterministic effects [24]. The RBE weighted dose in an organ or tissue is defined as the product of the average absorbed dose of radiation (R) in organ or tissue (T) and the relative biological effectiveness ($RBE_{R,T}$). The dose values assigned for 'possibly dangerous to health' are based on the generic criteria given in Ref. [1, 2] except where noted and are at levels at which severe deterministic effects are expected in 5% of those exposed (AD_{05}) [24].

Table 25 lists the dose values indicating 'possibly dangerous to health', in RBE weighted absorbed dose to the organs or tissues that are critical for a release from a reactor core or spent fuel pool. Keeping the doses below the criteria listed will ensure that there will not be any severe deterministic effects, except for the fetus (depending on the stage of development) for which there is a small probability, as already discussed in Table 25. If the criteria for 'possibly dangerous to health' are exceeded an immediate medical examination, consultation and indicated medical treatment for the management of severe deterministic effects is warranted.

It should be noted that the thresholds for severe deterministic effects in Table 25 were based on thresholds for brief exposures at high dose rates. The thresholds are probably higher for an emergency relating to a reactor core or spent fuel pool owing to the lower dose rates that will occur off the site following a release, as illustrated in FIG. 38 [47].

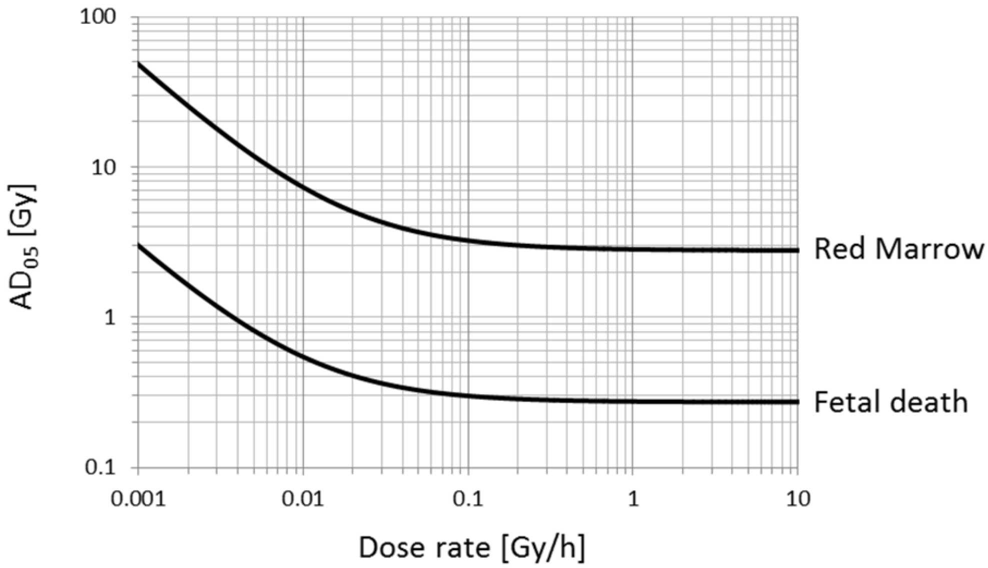

FIG. 38. Threshold doses (AD_{05}) for fatal external exposure to the red marrow and fatal external exposure to the fetus as a function of dose rate.

III.2.2 Health concerns (orange)

The dose values indicating 'health concerns' in Table 25 are equal to or above the international standards (generic criteria) in Table 3 of Ref. [1], except where noted, at which protective actions or other response actions are warranted.

Below these doses an increase in the cancer incidence rate due to radiation induced cases is uncertain and will not be detectable [22, 23, 24, 48]. Furthermore, the risk of radiation induced cancers for doses below the criteria is too low to justify taking any actions, such as a medical screening [1, 2].

The criteria were established for exposures at high dose rates. For the lower dose rates that will occur off the site following a reactor core or spent fuel pool release, a comparable level of radiation induced cancer risk would probably occur at a dose two or more times higher [36].

Table 25 provides one criterion for effective dose (E). However, effective dose does not consider specific organs and cannot be used as a basis for estimating the possible health effects from radiation exposure [36] in an individual. Use of effective dose alone to assess the risk of radiation induced health effects can greatly underestimate the possible risk to an individual's thyroid or to the fetus. Therefore, if the effective dose criterion given in Table 25 is not exceeded it does not mean it is safe. It can only be considered safe if the RBE weighted absorbed dose to the red marrow ($AD_{red\ marrow}$), equivalent dose to the thyroid ($H_{thyroid}$) and equivalent dose to the fetus (H_{fetus}) are also below the criteria.

III.2.3 Provisionally safe (yellow) and safe (green)

'Safe' means that none of the international criteria given in Ref. [1, 2] requiring any protective actions or other response actions to minimize severe deterministic effects or reduce the risk of stochastic effects. This means that none of the dosimetric criteria for the 'health concerns' and 'possibly dangerous to health' levels can be exceeded for the specified conditions and public behaviour.

'Safe' also means, as described in Ref. [1], that all members of the public, including those who are more sensitive to radiation exposure such as children and pregnant women (fetus): (a) do not receive a dose to any organ approaching that resulting in severe deterministic effects, and (b) do not receive a dose above which the risk of stochastic health effects (e.g. radiation induced cancers) is sufficiently high to justify taking protective actions or other response actions such as a medical screening [1].
At this level there will not be any severe deterministic effects or an observable increase in the incidence of cancer, even in a very large exposed group [22, 23, 24]. Furthermore, the risk of radiation induced cancers is too low to justify taking any action, such as a medical screening [1]. The basis for these conclusions are detailed in Ref. [24] and are consistent with the findings of the UNSCEAR report in Ref. [48], which states that observations are frequently unable to reveal clear evidence of an increased incident of radiation induced health effects at low doses (less than 200 mGy) or low dose rates (less than 0.1 mGy/h).

'Provisionally safe' means it is safe if the specified limitations are followed, such as remaining in the area is limited to a specific amount of time and/or specified protective actions are taken (e.g. with the purpose to reduce ingestion of radioactive material).

III.3. SYSTEM FOR PLACING MEASURED OPERATIONAL QUANTITIES IN PERSPECTIVE

Charts 1–4 for placing measured operational quantities in perspective in terms of the health hazards given in Section 7 (and describe above) are based on doses calculated using the same methods and assumptions that are used for the calculation of the OILs for the relevant exposure scenario, as described in Appendix II. This includes the use of reasonably conservative assumptions such as the use of the 'representative person'. The representative person is a theoretical construct defined to represent the highest doses reasonably expected to be received by any member of the public during an emergency. In most cases, no one would be expected to receive a dose approaching that calculated for the representative person for the relevant exposure scenario. All the radiation induced health effects expected following a fission product release from a light water reactor or RBMK or its spent fuel pool are considered. The radiation induced health effects shown on the charts are intended to represent the risk to the member of the public most sensitive to radiation, such as children or pregnant women (fetus), for this reason all members of the public are considered to be covered.

III.4. SYSTEM FOR PLACING CALCULATED DOSES IN PERSPECTIVE

Chart 5 in Section 7 can be used to place calculated doses in perspective, providing that they have been calculated correctly. Chart 5 is based on the doses given in Table 25, however, only the three doses given in Table 26 need to be calculated because the RBE weighted dose for the thyroid ($AD_{thyroid}$) and fetus (AD_{fetus}) given in Table 25 can be related to the corresponding equivalent doses as discussed in Table 27.

TABLE 26. DOSES INDICATING DIFFERENT LEVELS OF HEALTH HAZARDS GIVEN IN CHART 5

Health hazard level	$\mathbf{H_{thyroid}}$	$\mathbf{H_{fetus}}$	$\mathbf{AD_{red\ marrow}}$
Possibly dangerous to health	≥ 10 000 mSv	≥ 1 000 mSv	≥ 1 000 mGy
Health concerns	≥ 100 mSv	≥ 100 mSv	≥100 mGy[a]

[a] For external exposure this is considered to be numerically equal to the100 mSv equivalent dose to the fetus (H_{fetus})

TABLE 27. HOW RBE WEIGHTED ABSORBED DOSE IS RELATED TO THE THYROID AND FETUS EQUIVALENT DOSE FOR A RELEASE FROM A REACTOR CORE OR SPENT FUEL POOL, FOR INDICATING DOSES THAT ARE 'POSSIBLY DANGEROUS TO HEALTH'

RBE weighted absorbed dose given in Table 25	**Used in Chart 5 to represent RBE weighted dose**	**Explanation**
$AD_{thyroid}$ 2 Gy	$H_{thyroid}$ 10 Sv (10 000 mSv)	Only intake of radioiodine is considered because this radionuclide is the source of dose to the thyroid that is the highest of any organ from inhalation or ingestion after a release from a reactor core or spent fuel pool. This assumes: $H_{thyroid}$ (Sv) = $AD_{thyroid}$ (Gy) / $RBE_{thyroid}$ where $RBE_{thyroid}$ is 0.2 [24].
AD_{fetus} 1 Gy	H_{fetus} 1 Sv (1000 mSv)	It is assumed for a release from a reactor core or spent fuel pool that the equivalent dose in the fetus (Sv) is numerically equal to the RBE weighted absorbed dose to the fetus (Gy). AD_{fetus} from intake for a release from a reactor core or spent fuel pool is dominated by the dose to the fetal thyroid from intake of radioiodine. An RBE_{fetus} = 1 was assumed when calculating the AD_{fetus} for internal exposure to the fetal thyroid (and not an RBE = 0.2 as specified in Ref. [24] for calculating the $AD_{thyroid}$ for the representative person's thyroid). This conservative approach is used because there is no data for the threshold for severe deterministic effects to the fetus following intake of radioiodine.

Effective dose cannot be used as a basis for estimating the possible health hazard from radiation exposure and consequently Chart 6 refers to Chart 5 in order to place the calculated doses in perspective in terms of the health hazard [36]. An effective dose below 100 mSv may not be safe. Always assess the equivalent dose to the thyroid, equivalent dose in the fetus and RBE weighted absorbed dose to the red marrow in order to determine the health hazard following a release from a reactor core or spent fuel pool.

APPENDIX IV
REGISTRATION FORM

Keep this form with you until it is requested. An official will collect it before you leave.

CONTACT INFORMATION

Respondent: ☐ Self ☐ Proxy (state relationship) ______________________________

Name: ______________________________ Date:__________ Time:__________

Date of birth: ______(day)/______(month)/______(year) Sex: ☐ Male ☐ Female

If child, list names of parents/guardian:____________________/____________________

Nationality:________________ Place of birth:______________________________

Current address:____

Address of place of employment/ education:______________________________

Home telephone: __________ Mobile phone number: __________ E-mail: ______________

Name and telephone number/e-mail of a friend or relative who will know how to reach you:

____

Intended new address (if applicable):______________________________

Intended date for moving: ______(day)/______(month)/_______(year)

DETAILS FOR DOSE ASSESMENT

Member of: ☐ Public ☐ Emergency worker ☐ Other (specify)______________

Possibly pregnant? ☐ Yes ☐ No Iodine thyroid blocking agent taken? ☐ Yes ☐ No

Injuries or other medical concerns: ______________________________

____

Consumption of local produce? ☐ Yes ☐ No ☐ Field ☐ Greenhouse ☐ Unknown

Type:____

Consumption of milk from animals grazing in the area? ☐ Yes ☐ No

Amount consumed: ________________ Specify animal: ______________________

Drinking water source: ☐ Tap water (private waterworks) ☐ Collected rainwater ☐ Wells

Building type of place of residence: ☐ House ☐ Large building

Construction type: ☐ Concrete ☐ Wood/steel ☐ Other (specify)__________

Place of employment/education: ☐ House ☐ Large building

Construction type: ☐ Concrete ☐ Wood/steel ☐ Other (specify)__________

Location(s)/activities during emergency:______________________________

Remarks**:**____

TO BE COMPLETED BY RESPONSE PERSONNEL

Hands and face monitored? ☐Yes ☐No OIL4 exceeded? ☐ Yes ☐ No

Face/hands dose rate __________ µS/h Time and date of measurement:______________

Background dose rate __________ µS/h

Thyroid monitored? ☐Yes ☐No OIL8 exceeded? ☐ Yes ☐ No

Thyroid dose rate in contact with skin________ µS/h Time and date of measurement:______________

Background dose rate __________ µS/h Type of monitor used: ______________

Decontaminated? ☐ Yes ☐ No Medical examination needed? ☐ Yes ☐ No

Medical follow-up needed? ☐ Yes ☐ No

Remarks:________________________ Signature:________________________

APPENDIX V
TYPICAL QUESTIONS AND CONCERNS OF THE PUBLIC IN A NUCLEAR OR RADIOLOGICAL EMERGENCY

Typical questions and concerns of the public were collected from published news articles and are listed below. The questions and concerns may not be scientifically accurate or well informed.

Issue:	Question / Concern:
Safety	• Is my family safe now? • What can I do to ensure my family is safe now? • What is contamination and is it dangerous? • Should I buy and wear a dosimeter? • What quantity of radiation exposure is safe? When will I get sick from radiation? • Why has the annual safety limit been changed from 1mSv/year to 100mSv/year? • Can children play outside? • Should I take measures to decontaminate my home (such as remove all topsoil from my garden)? • What does radiation levels 20 times above normal mean?
Health effects	• What could be the consequences for my health? • What dose I may have received and what it means to my health? • Do my internal radiation levels need to be checked? What do the measurements and test results mean? • I was monitored and contamination was found. Am I OK? • What happens when I am exposed to radiation? What are the possible health effects? • I am pregnant. What are the dangers for my baby? Will my baby have birth defects? Should I have an abortion? • Can I breast feed my baby? • Can ________ protect against radiation exposure? • Should I take potassium iodide (KI) pills? • Should I use other forms of iodine to protect against radiation exposure?
Contamination of local produce, milk and water	• Can I drink the milk or tap water? Should I use bottled water? • Can I eat the food? Where was the food I am buying grown? • Should I use a Geiger counter to test radiation levels of the local produce I buy? • Why are some supermarkets restricting acceptable contamination levels of local produce further than the government set limit?

Evacuation	• How long will evacuation be in place and when will I be allowed to return home? • There is conflicting advice for the evacuation area. Which advice should I follow? • Why is it safe to be outside the evacuation areas in an emergency? • What are hotspots? • I am old and have lived here all of my life. Being exposed or contaminated does not concern me, I do not want to evacuate. • I do not want to be on unemployment benefits if evacuated. Where can I find a job? • I need to evacuate but the removal company is refusing to enter the affected area. How should I transport my belongings? • What should I do about my animals (farm animals, pets)?
Stigmatization	• My child is being bullied at school because we are from the affected area. What should I do? • My car is not allowed into the gas station because the number plate is from the affected area. What should I do? • Supermarkets will not sell and consumers will not buy my produce because it is from the affected area. What should I do?

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DEFINITIONS

*Those terms not in the Safety Glossary [33] have been indicated with a *.*
New definitions apply for the purposes of the present publication only.

arrangements (for emergency response). The integrated set of infrastructure elements necessary to provide the capability for performing a specified function or task required in response to a nuclear or radiological emergency. These elements may include authorities and responsibilities, organization, coordination, personnel, plans, procedures, facilities, equipment or training.

contaminated*. Having an amount of radioactive material on or in an object or person that is greater than a predefined criterion, such as an OIL, which requires an action such as relocation, decontamination or restrictions on exports.

dangerous to health*. A possibility of an exposure to ionizing radiation that can result in: (1) severe deterministic effects or (2) an eventual increase in the cancer incidence due to radiation induced cancer cases.

deterministic effect. A health effect of radiation for which generally a threshold level of dose exists above which the severity of the effect is greater for a higher dose. Such an effect is described as a severe deterministic effect if it is fatal or life threatening or results in a permanent injury that reduces quality of life.

extended planning distance (EPD) *. Distance around a nuclear power plant where arrangements are made to conduct early monitoring of deposition to locate hotspots with dose rates warranting (1) evacuation within a day following a release or (2) relocation within a week to a month following a release.

early actions*. A protective action or other response action that can be implemented within days to a month and still be effective. The most commonly considered early protective actions and other response actions in a nuclear or radiological emergency are relocation, restriction of consumption and distribution of potentially contaminated local produce, wild-grown products (e.g. mushrooms and game), milk, animal feed or commodities, and registration for a medical screening.

emergency. A non-routine situation or event that necessitates prompt action, primarily to mitigate a hazard or adverse consequences for human health and safety, quality of life, property or the environment. This includes nuclear and radiological emergencies and conventional emergencies such as fires, release of hazardous chemicals, storms, or earthquakes. It includes situations for which prompt action is warranted to mitigate the effects of a perceived hazard.

emergency action level (EAL). A specific, predetermined, observable criterion used to detect, recognize and determine the emergency class.

emergency class. A set of conditions that warrant a similar immediate emergency response. This is the term used for communicating to the response organizations and the public the level of response needed. The events that belong to a given emergency class are defined by criteria specific to the installation, source or practice, which if exceeded indicate classification at the prescribed level. For each emergency class, the initial actions of the response organizations are predefined.

emergency classification. The process whereby an authorized official classifies an emergency in order to declare the applicable emergency class. Upon declaration of the emergency class, the response organizations initiate the predefined response actions for that emergency class.

emergency phase. The period of time from the detection of conditions warranting an emergency response until the completion of all the actions taken in anticipation of or in response to the radiological conditions expected in the first few months of the emergency. This phase typically ends when the situation is under control, the off-site radiological conditions have been characterized sufficiently well to identify where food restrictions and temporary relocation are required, and all required food restrictions and temporary relocations have been implemented.

emergency plan. A description of the objectives, policy and concept of operations for the response to an emergency and of the structure, authorities and responsibilities for a systematic, coordinated and effective response. The emergency plan serves as the basis for the development of other plans, procedures and checklists.

emergency preparedness. The capability to take actions that will effectively mitigate the consequences of an emergency for human health and safety, quality of life, property and the environment.

emergency procedures. A set of instructions describing in detail the actions to be taken by response personnel in an emergency.

emergency response. The performance of actions to mitigate the consequences of an emergency for human health and safety, quality of life, property and the environment. It may also provide a basis for the resumption of normal social and economic activity.

emergency services. The local off-site response organizations that are generally available and that perform emergency response functions. These may include police, fire fighters and rescue brigades, ambulance services and control teams for hazardous materials.

emergency worker. A person having specified duties as a worker in response to an *emergency*.

emergency zones. The precautionary action zone and/or the urgent protective action planning zone.

exposure. The act or condition of being subject to irradiation. Exposure can be either external exposure (due to a source outside the body) or internal exposure (due to a source within the body).

exposure pathway. A route by which *radiation* or radionuclides can reach humans and cause *exposure*.

ground shine. Gamma *radiation* from radionuclides deposited on the ground.

hotspot*. An area with ground deposition of radioactive material resulting in an OIL or other predetermined criteria being exceeded.

inadvertent ingestion*. Unintentional ingestion of radioactive material, most commonly by transfer from the hands to the mouth.

ingestion and commodities planning distance (ICPD)*. The distance around a nuclear power plant for the area within which arrangements are made, within hours of being notified by the nuclear power plant of the declaration of a General Emergency, to: (a) place grazing animals on covered feed, (b) protect drinking water supplies that directly use rainwater (e.g. to disconnect rainwater collection pipes), (c) restrict consumption and distribution of non-essential local produce, wild-grown products (e.g. mushrooms and game), milk from grazing animals, rainwater, animal feed and (d) restrict distribution of commodities until further assessments are performed.

local produce*. Food that is grown in open spaces that may be directly contaminated by the release and that is consumed within weeks (e.g. leafy vegetables).

marker* see marker radionuclide (isotope).

marker radionuclide (isotope)*. A marker radionuclide is easily identified in the field or laboratory and is representative of all the other radionuclides present and is used to determine if protective actions and other response actions are needed without performing a comprehensive isotopic analysis.

media*. Means of public communication, including radio, television, internet web sites, newspapers and magazines, and social media.

medical follow-up*. Long term health monitoring undertaken following potential radiation exposure, intended to detect and effectively treat radiation induced health effects such as thyroid cancers.

medical screening*. Consideration of symptoms and information to determine if an immediate medical examination or registration for a medical follow-up.

off-site. Outside the site area. Beyond the area controlled by the operator of the nuclear power plant.

off-site decision maker*. The off-site person with the authority and responsibility to immediately, without further consultation, to implement actions to protect the public within the PAZ, UPZ, EPD, and ICPD.

on site. On the site area.

operational intervention level (OIL). A calculated level, measured by instruments or determined by laboratory analysis, that corresponds to an intervention level or action level. OILs are typically expressed in terms of dose rates or of activity of radioactive material released, time integrated air concentrations, ground or surface concentrations, or activity concentrations of radionuclides in environmental, food or water samples. An OIL is a type of action level that can be used immediately and directly (without further assessment) to determine the appropriate protective actions and other response actions on the basis of an environmental measurement.

precautionary action zone (PAZ). An area around a *facility* for which *arrangements* have been made to take *urgent protective actions* in the *event* of a *nuclear or radiological emergency* to reduce the *risk* of *severe deterministic effects off the site*. *Protective actions* within this area are to be taken before or shortly after a release of *radioactive material* or an *exposure* on the basis of the prevailing conditions at the *facility*.

protective action. An *intervention* intended to avoid or reduce *doses* to *members of the public* in *emergencies* or situations of *chronic exposure*.

release*. The radioactive materials that are released from the damaged fuel in a reactor core or spent fuel pool that will form a plume off-site.

response organization. An organization designated or otherwise recognized by a State as being responsible for managing or implementing any aspect of an emergency response.

severe fuel damage*. Damage to nuclear fuel in the reactor core or spent fuel pool involving failure of more than 20% of the fuel pins containing the nuclear fuel.

severe deterministic effect. A *deterministic effect* that is fatal or life threatening or results in a permanent injury that reduces quality of life.

shift supervisor*. A shift supervisor is the person who is in charge of and responsible for actions of the control staff during their work shift. The shift supervisor is responsible for making emergency classifications and off-site notification.

sievert (Sv)*. The SI unit of *equivalent dose* and *effective dose*, equal to 1 J/kg. The several different dosimetric quantities (e.g. equivalent dose to an organ or tissue, effective dose, ambient dose equivalent, personal dose equivalent) are given in sieverts and although the unit is the same, these are different quantities that cannot be compared.

site area. A geographical area that contains an authorized facility, activity or source, and within which the management of the authorized facility or activity may directly initiate emergency actions. This is typically the area within the security perimeter fence or other designated property marker.

special facility. A facility for which predetermined facility specific actions need to be taken if *urgent protective actions* are ordered in its locality in the event of a *nuclear or radiological emergency*. Examples include chemical plants that cannot be evacuated until certain actions have been taken to prevent fire or explosions, and telecommunications centres that must be staffed in order to maintain telephone services.

special population groups. *Members* of *the public* for whom *special arrangements* are necessary in order for effective *protective actions* to be taken in the event of a *nuclear or radiological emergency*. Examples include disabled persons, hospital patients and prisoners.

stochastic effect. A *radiation* induced *health effect*, the probability of occurrence of which is greater for a higher *radiation dose* and the severity of which (if it occurs) is independent of *dose*.

urgent protective action. A *protective action* in the event of an *emergency* which must be taken promptly (normally within hours) in order to be effective, and the effectiveness of which will be markedly reduced if it is delayed.

urgent protective action planning zone (UPZ). An area around a *facility* for which *arrangements* have been made to take *urgent protective actions* in the *event* of a *nuclear or radiological emergency* to avert *doses off the site* in accordance with international *safety standards*. *Protective actions* within this area are to be taken on the basis of *environmental monitoring*— or, as appropriate, the prevailing conditions at the *facility*.

ABBREVIATIONS AND SYMBOLS

AD_T	RBE weighted absorbed dose to organ or tissue T
CANDU	Canada deuterium uranium reactor
E	effective dose
EAL	emergency action level
ECS	emergency command system
ECCS	emergency core cooling system
EPD	extended planning distance
EPR	emergency preparedness and response
GC	generic criteria
FAO	Food and Agricultural Organization
ICPD	ingestion and commodities planning distance
ICRP	International Commission on Radiological Protection
IAEA	International Atomic Energy Agency
ILO	International Labour Organization
ITB	iodine thyroid blocking
H_T	equivalent dose to organ or tissue T
LOCA	loss of coolant accident
LWR	light water reactor
MW(e)	megawatt electric
MW(th)	megawatt thermal
OIL	operational intervention level
PAHO	Pan American Health Organization
PAZ	precautionary action zone
RBE	relative biological effectiveness
RBMK	type of graphite moderated reactor
UPZ	urgent protective action planning zone
UNSCEAR	United Nations Scientific Committee on the Effects of Atomic Radiation
WHO	World Health Organization

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