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EPR-NPP PUBLIC PROTECTIVE ACTIONS
2013

EMERGENCY PREPAREDNESS AND RESPONSE

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

DATE EFFECTIVE: MAY 2013

IAEA
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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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EPR-NPP PUBLIC PROTECTIVE ACTIONS [2013]

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

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.

EDITORIAL NOTE

This publication (including the figures, tables and references) has undergone only the minimum copy editing considered necessary for the reader's assistance.

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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.

[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.

[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.

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[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.

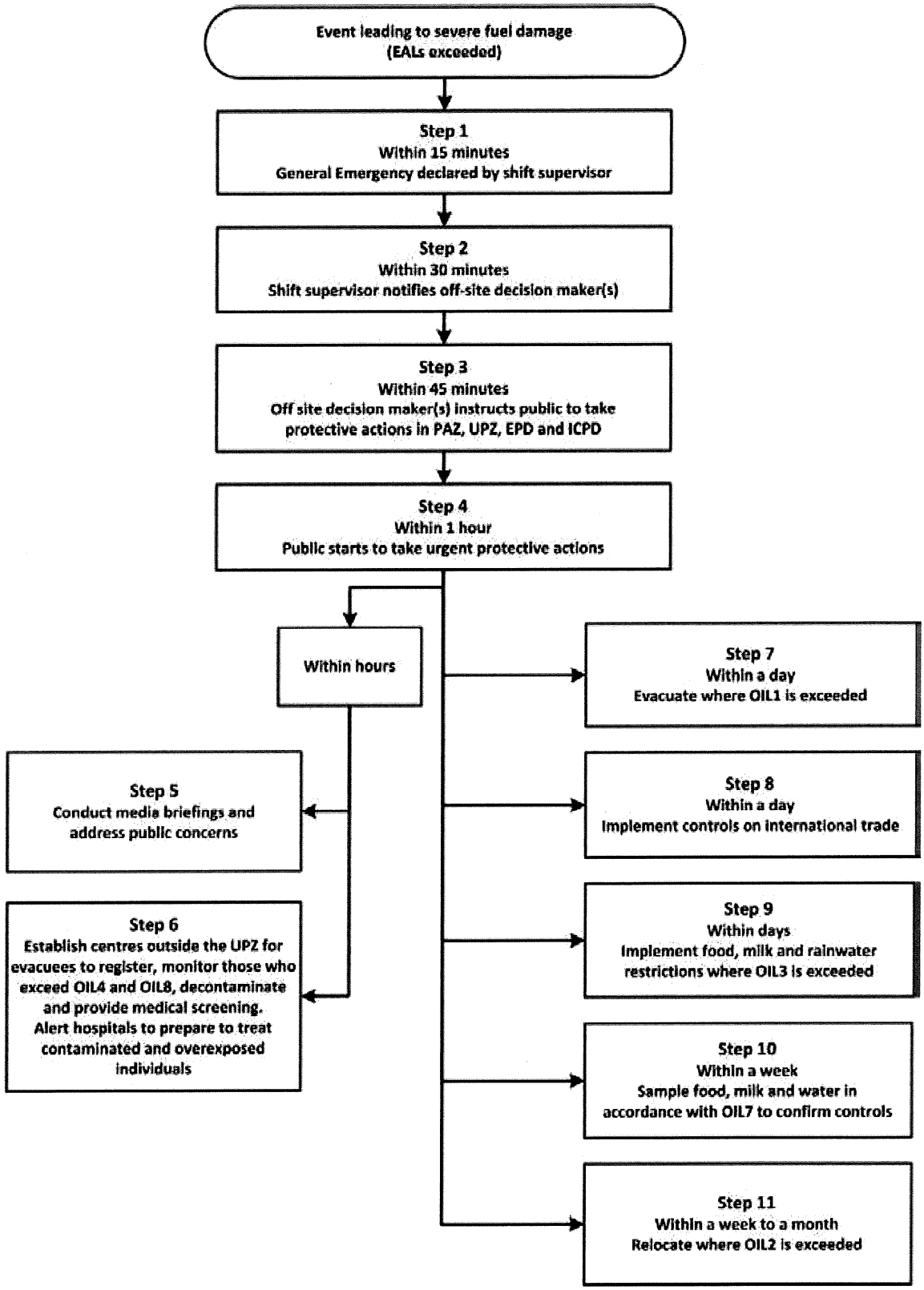

FIG. 1. Steps to take for an event that is projected to result in severe damage to the fuel in a reactor core or a spent fuel pool (General Emergency).

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.

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[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