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**PROTECTION STRATEGY**

**FOR A NUCLEAR AND RADIOLOGICAL ACCIDENT**

**2021**

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# INTRODUCTION

The Protection Strategy for a Nuclear and Radiological Accident[[1]](#footnote-1) (hereinafter: Protection strategy) provides guidelines for taking protective actions[[2]](#footnote-2) in the event of a nuclear and radiological accident. The Protection strategy is adopted by the Government of the Republic of Slovenia on the proposal of the minister responsible for nuclear safety. It is published on the website of the ministry responsible for nuclear safety. Emergency response plans for a nuclear and radiological accident and other documents define in detail the taking of protective actions and other response measures which, on the basis of the results of a hazard assessment, are justified and optimised at the preparedness stage. The Protection strategy is carried out during and after an accident by the operational implementation of respective protective actions and other response measures which must be carefully examined by experts and adjusted on the basis of prevailing conditions.

An emergency is a situation or an event that is not routine and in which radiation or nuclear safety or the level of radiation protection are reduced. The conditions resulting from an emergency require immediate preparations or the implementation of actions to prevent or remedy the consequences for the health and safety of people and their quality of life, to prevent an impact on property and on the environment and to prevent risks leading to such serious consequences [1]. As nuclear and radiological emergencies pose a direct threat to the public and the environment, protective actions must be taken. In general, not every emergency situation entails the occurrence of an accident. It might only entail a decrease in nuclear or radiation safety, which also requires an adequate response from the competent authorities.

An emergency is a deviation from normal operation, which is less frequent and has more severe consequences than abnormal operation. An emergency may cause serious damage to the nuclear facility or irradiation installation, or it may reduce the effectiveness of safety barriers [1]. Nuclear emergencies warrant protective actions due to a dangerous release of energy following a nuclear chain reaction or the decay of the products of a chain reaction. A nuclear emergency can also involve a radiological emergency. This primarily applies to emergencies at category I[[3]](#footnote-3) nuclear facilities, as they contain large quantities of nuclear and radioactive materials which, in the event of major deviations from normal operation, can be released to the environment and potentially irradiate people. A nuclear emergency can occur anyplace where nuclear material is present in sufficient quantities to trigger a chain reaction (i.e. critical mass), for example at category I nuclear facilities, in research reactors, on-board reactors, during the transport of nuclear material, at spent fuel storage and disposal facilities, and in the production of nuclear fuel.

Radiological emergencies warrant protective actions or other response measures due to an uncontrolled exposure to ionising radiation. This can be caused by radioactive sources, including contamination with radioactive material or contamination, and by devices such as X-ray tubes or particle accelerators (usually electrons or other charged particles). They can occur in irradiation or minor irradiation installations (at industrial, research and healthcare facilities with irradiation devices or radioactive material and at operating repositories with mining or hydrometallurgical tailings). A radiological emergency can also occur anyplace where uncontrolled dangerous sources of ionising radiation are present [3] (discarded, lost, found or stolen). The irradiation and contamination of the public can occur during the transport of radioactive material, from a fallen satellite with radioactive material, a dirty bomb[[4]](#footnote-4) or due to a natural disaster in an area of closed facilities where large quantities of radioactive material are still present.

The Protection strategy is based on predefined operational and other levels, such as: dose limits[[5]](#footnote-5), reference levels, operational intervention levels (OILs), absorbed doses, projected doses and received doses.

In the event of a nuclear or radiological emergency, it is necessary to foresee measures to mitigate its consequences.

Depending on its course, an emergency can be divided into three phases: urgent, early and transition.

At the beginning of the urgent response phase, estimates of the probability, timing and quantity of possible releases are highly uncertain. In addition, the course of action is influenced by weather conditions, but despite the lack of accurate information, it is essential to quickly assess and take preventive and urgent protective actions.

The early response phase ends when the level of radiation in the environment is no longer increasing, there is no longer a risk of further releases and early protective actions are no longer needed.

The early response phase is followed by a transition phase during which procedures are implemented that can be used to declare an end to the emergency (Section 2.1 and Figure 1).

After the end of an emergency, the transition can be either to a planned exposure situation or to an existing exposure situation. In the latter case, the emphasis is on recovery and restoration to the original situation, if the current situation permits. The transition between phases is gradual, and certain organisations carry out their tasks during all phases of an emergency.

In the event of a nuclear or radiological emergency, it is not easy to define the end of the hazard in terms of time, because the hazard is long-lasting. As stated by the IAEA (International Atomic Energy Agency) in GSR Part 7 [4, paragraph 5.97], a formal decision on the termination of an emergency is required for the period after the emergency to start.

The Protection strategy describes reference exposure values and operational intervention levels, factors influencing the choice of protective actions, protective actions in the event of a nuclear and radiological emergency, and during and after the emergency. Protective actions for the public and emergency workers, the environment, food (locally produced food, drinking water, milk), feed, commodities and waste are also described.

## 1.1 Requirement and basic documents

The Protection strategy refers to taking protective actions for the public and emergency workers in the event of a nuclear or radiological emergency. The basis of the Protection strategy is described in detail in ICRP Publication 109: Application of the Commission's Recommendations for the Protection of People in Emergency Situations [5]. In accordance with this publication and the requirements of the national legislation [6], which is in this respect harmonised with the EU BSS [7] and IAEA GSR Part 7 [4], a comprehensive Protection strategy was developed at the national level.

In the present Protection strategy, possible emergencies refer to a hazard assessment which includes their estimated probability and consequences. The probability and consequences of an emergency are the main determinants of the priority actions and degree (of precision) in planning protection and response.

## 1.2 Purpose and objectives of the Protection strategy

The Protection strategy sets a general framework for ordering protective actions. It includes instructions on how to order actions referring to the criteria of importance in decision-making. It also includes instructions on which protective actions to take, together with an on-going evaluation of their effectiveness and adjustment based on the prevailing conditions andavailable information, in order to receive the lowest possible dose (i.e. the residual dose), but not at any cost and only up to the level where adaptation is still considered reasonable in terms of the complexity and feasibility of actions.

In all three phases of an emergency, the Protection strategy follows three main objectives of emergency response, namely to save lives, prevent deterministic effects and reduce stochastic effects. The aim of the termination of an emergency is to restore social and economic activity.

## Scope of the Protection strategy

The Protection strategy was prepared at the national level and applies to all stakeholders in Slovenia. It applies to the general public and emergency workers. In accordance with the requirement 4.24 of GSG-11 [8], it also includes the transition phase and prerequisites for the termination of an emergency.

## General information about the methodology

The main principles of the Protection strategy are to simultaneously consider exposure via all exposure pathways and to consider combinations of protective actions in respective phases.

The development of a Protection strategy is a process that is carried out during the preparedness stage and starts with an analysis of all protective actions identified as justified (a measure is justified if it does more good than harm). For each protective action, its effectiveness in reducing the received dose is analysed. Combinations of protective actions are also analysed, which may prove to be more or less justified depending on other conditions and circumstances of an emergency. Based on the overall analysis, a more detailed Protection strategy is drawn up.

Once the combinations of protective actions to be included in the Protection strategy are identified, the doses received as a result of the implementation of the strategy must be assessed. These doses are compared to the appropriate reference level to be used as a measure of the strategy’s adequacy. If the dose is below the reference level, then the optimisation of protective actions follows as far as still reasonable. Otherwise, when the dose is above the reference level, protective actions or the taking of protective actions must be modified and the process repeated by comparing the reference level to the received dose. Some combinations of protective actions may be considered largely independently of each other, such as a restriction on the consumption of contaminated food and evacuation. Other factors such as anxiety, stress, various disruptions in the life of a person or community, economic effects, etc., may also have an impact on the protection strategy. Optimisation should also address these factors, as well as the dose and resources needed to take protective actions. Once the Protection strategy is optimised, the “triggers” initiating protective actions in accordance with the emergency response plan must be defined. These triggers (emergency action levels – EALs) are parameter values that can be obtained from instrument readings (e.g. at a nuclear facility) or from observable on-site conditions (e.g. fire, flood, terrorist attack). Triggers are "entry points" for the emergecy classification system and respective emergency levels (e.g. unusual event, alert, site emergency, general emergency). Based on the emergency level, a set of initial actions, including protective actions, is determined. Once the environmental radiation measurements are available, the decision on protective actions is based on the operational intervention levels (OILs) currently defined in Slovenia in the Decree on dose limits, reference levels and radioactive contamination [9], and on international guidelines and technical documents, such as GSG-2 [10], EPR-NPP 2013 [11] and EPR-NPP-OIL [12].

The unpredictable nature of an emergency, its potential rapid development and a number of factors (e.g. weather conditions, geographical location, population distribution, transport infrastructure) may lead to situations that do not match the assumptions used at the time of the preparation of an optimised Protection strategy. This can result in a person receiving a projected dose (a dose calculated for a specific period without protective actions) exceeding the reference level. In such case, all protective actions or a combination of protective actions that reduce the dose below the reference level are justified. Although the strategy was already optimised at the time of planning, it is considered that, whenever possible, the protective actions must be optimised also during implementation to reduce the dose below the reference level. Optimisation must be carried out in accordance with the strategy, which means that factors such as the size of an area, duration, dietary habits, economic loss, public concern, social impact, etc., must be taken into consideration. However, it must also be taken into account that optimisation may be influenced by the prevailing exposure pathways, the time span of an emergency, various factors affecting the effectiveness of individual protective actions, and the social and economic impact.

The strategy also covers the starting points for urgent action, as there is no time for optimisation in the urgent phase of an emergency. In such case, the time frame for taking protective actions is a few hours (or a maximum of a few days). When the situation is stable, the time frame in which to decide to take protective actions is a week or even several months, which allows for meaningful implementation of the optimisation described above. In the event of an emergency, and if the situation requires urgent protective actions, the application of pre-planned protection strategies, implemented on the basis of predefined triggers, will be carried out without a complex decision-making process, engaging only those authorities responsible for a nuclear and radiological emergency response. The inadequate involvement of too many stakeholders in the decision-making process or overly detailed dose assessments without taking uncertainties into account may result in delays in taking urgent protective actions, which may in turn reduce their effectiveness.

The strategy [4] must include actions to avoid or reduce serious deterministic effects: skin flushing (erythema), radiation-induced organ failure (bone marrow damage), acute radiation sickness, or to reduce the risk of stochastic effects (cancer). When planning the strategy, generic criteria[[6]](#footnote-6) (Appendix 3) are defined as a result of the process of the justification and optimisation of the Protection strategy. If the projected or received dose exceeds any of the generic criteria, then protective actions and other response measures must be taken either individually or in combination. The received dose here refers to the dose that would normally warrant actions to protect human health or long-term medical follow-up.. The generic criteria are not expressed in quantifiable quantities, so it is useful to define initial operational intervention levels, which are discussed in Section 3.3. These initial operational intervention levels were defined on the basis of certain assumptions and hence must be revised as soon as sufficiently accurate measurements are available, i.e. they are converted to the actual situation and conditions during an emergency.

The main implementing steps of the strategy are [4]:

a) Promptly taking urgent protective actions. The time frame is only a few hours, maybe part of a day (a maximum of a few days).

b) Taking early protective actions. In such case, actions must start within a week or a few months following the occurrence of the emergency.

c) Notifying of protective actions, notifying the general public and notification during the transition phase.

d) Registration of inhabitants, health screening and longer term medical follow-up of persons exposed to radiation or potentially exposed to radiation.

e) Protecting emergency workers, including radiation protection and appropriate protective equipment.

f) Mitigating non-radiological consequences: protective actions must be optimised also for non-radiological consequences.

g) Assessing the effectiveness of the adopted protective actions: i.e. their continuous adjustment on the basis of prevailing on-site conditions and available information. This applies in particular to the early protective actions.

h) Revising the Protection strategy in the event of a nuclear and radiological emergency and its further implementation, if appropriate.

i) Discontinuing protective actions (and other response measures) when they are no longer justified.

The effective implementation of the Protection strategy warrants the maintenance of emergency preparedness, which in turn requires adequate organisation, including the provision of the necessary material, human and other resources, their maintenance, regular inspections and continuous improvement (training and exercises, the maintenance and updating of equipment and procedures).

# PROTECTION STRATEGY – GUIDANCE FOR IMPLEMENTATION

## Phases of an emergency to which the Protection strategy applies

The Protection strategy is focused primarily on the period between the declaration of an emergency and the termination of an emergency, which is divided into two phases (Figure 1):

* the emergency response phase, which comprises the urgent response phase (the period of taking preventive and urgent protective actions) and the early response phase (during which the early protective actions are taken);
* the transition phase, i.e. a period of transition to an existing or planned exposure situation (the transition phase): a period during which the urgent and early protective actions are completed and there is a progression to the final objective, i.e. the termination of the emergency.



**Figure 1:** The phases of an emergency (source: Fig. 1 and Fig. 2, GSG-11 [8])

The division into periods or phases was made primarily for the purpose of planning. In practice, it is very difficult to distinguish between the emergency response phase and the transition phase, as certain protective actions may be taken during the transition phase. In general, the emergency response phase is a period during which the situation, in particular the radiological situation, is not very well known and may change, so we have a broad set of protective actions. The end of the early response phase and hence the end of the emergency response phase (the intervention phase, the red line in Fig. 1 above) means that the basic living conditions have been restored. The emergency response phase is terminated when the protective actions are lifted and the end of the hazard has been declared, which should not be equated with the termination of the emergency, as the elimination of the consequences (remediation) of a complex nuclear emergency can take several decades (i.e. the transition phase). The transition phase is a period during which the situation is fairly stable, new protective actions are not expected, the majority (or probably all) of the early protective actions have been discontinued and only respective protective actions are taken. When protective actions are planned well in advance, the future situation is less precisely known. Therefore, it is considerably more difficult to plan detailed actions, and their duration and geographical area. At the same time, the uncertainties or errors in measurements of radiaoctivity in the environment over a large area can be considerable, as it is difficult to cover large areas and to harmonise the results of sometimes different measurement methods. However, in the event of small-scale emergencies, for example in the transport of radioactive material or the discovery of a lost source, it is not even necessary to divide an emergency into phases. If phases are defined, these are much shorter than, for example, in the event of a nuclear emergency, as such an emergency can last several years. In the event of an emergency during transport, this may be only a few hours or a few days.

## Optimisation and justification of protective actions

The planning and implementation of all protective actions must take into account the principle of optimisation, which in such case means that the effectiveness of protective actions is evaluated at regular intervals. The frequency of the intervals must be such that they can be described as continuous. Effectiveness means that the received or residual[[7]](#footnote-7) doses below the reference or operational intervention levels are reduced as far as is still reasonable in relation to the potential harm. Efforts are made to increase the effect of protective actions so that they are minimally disruptive while increasing (not to the greatest extent possible) dose reductions.

Optimisation is not limited to reducing doses (radiological consequences), but also takes into consideration the non-radiological consequences which may have significant adverse effects outweighing taking protective actions or severely restricting their scope and duration.

The right selection of protective actions enables the achievement of the reference level or even values below the reference level, while optimisation seeks to reduce it even further. Excessive dose reductions are not justified as factors other than the projected dose need to be taken into account, which poses a particular challenge. After the protective actions have been taken, their effectiveness must be assessed and, if appropriate, adapted to the situation or discontinued.

Publication ICRP 109 [5] suggests a reference level in the range of 20–100 mSv per year (per emergency or per year).

Optimised levels below 20 mSv per year are reasonable if they are feasible and if exposure is low from the beginning, which is of this order of magnitude (a few tens of mSv/year) or less. Optimisation also takes into account the justification of respective protective actions, especially those that have a significant impact on a person’s life. For example, the justification of relocation in order to reduce exposure by “only” a few mSv or even a few tens of mSv per year is questionable. The justification in such case is particularly questionable if the relocation is for a long period of time. The vulnerability of individual groups in terms of health, psychological, economic and social factors, and [[8]](#footnote-8) their interaction, must also be taken into account in determining the justification of relocation.[[9]](#footnote-9) The possibility of reduced life expectancy due to stress associated with resettlement, the possible effects of inadequate care for the sick and vulnerable people, etc., should also be taken into account.

## Consultation with the interested public

Consultation with the interested public (e.g. people living in the vicinity of category I nuclear facility, company owners in the area) is most intensive at the preparedness stage (prior to an emergency). In the urgent response phase, consultation is limited or almost abandoned, but continues in the early response phase, when the protection and response forces have finished their work, and then intensifies in the transition phase. The manner, intensity and involvement of groups of the interested public depends on the type and scope of the emergency, its potential consequences, the diversity of the groups involved, the available time and the procedures to be followed. During the preparedness stage, participation is not strictly time-limited, but during an emergency it is important that consultations do not interfere with the implementation of the Protection strategy.

It is important that, during the preparedness stage, organisations with defined duties and responsibilities for the implementation of the Protection strategy and the public directly affected by its implementation (the general public, non-governmental organisations, etc.) are engaged in the drafting of the planning documents, both the strategy and other operational documents, during the preparedness stage. The method of their participation will be determined in relation to the situation (the publication of the document on the Internet and the gathering of comments, face-to-face meetings, workshops, public announcements, public presentations, etc.). It is important to inform and actively engage with the public, as this is an important mechanism for better and more legitimate decisions.

## Nuclear accident in Slovenia

A nuclear emergency is an accident that may involve a significant release of radioactive material to the environment. The Protection strategy in the event of a nuclear accident in Slovenia deals in detail specifically with two types of accidents which may result in a significant release of radioactive material to the environment, namely a reactor accident at category I nuclear facility [[10]](#footnote-10) and an accident in a spent fuel pool, which in Slovenia is an integral part of category I nuclear facility , so that the two can be treated in a comprehensive manner, as both are managed by the same organisation, with an emergency response plan that covers both.

### Reactor accident at category I nuclear facility in Slovenia

In the event of a reactor accident at category I nuclear facility in Slovenia, different emergency levels are defined in relation to the different consequences of the accident and are declared by the personnel of category I nuclear facility

One of potential accident scenarios at category I nuclear facility is the failure of the containment when a significant amount of radioactive material may be released to the environment and protective actions must be taken to protect the public. The characteristics of the release of radioactive material depend on many factors: the extent of core damage, the rate of containment leakage, and whether it is a dry or a wet release. The concentration and pathway of radioactive material in the air are also influenced by weather. In the event of a release to the environment, protective actions will be coordinated in advance, as appropriate.

The emergency planning zones around category I nuclear facility are:

* a precautionary action zone (PAZ) is an area with a radius of 3 km around category I nuclear [[11]](#footnote-11)facility in which, on the basis of the conditions at the facility upon the declaration of a general emergency, all of the protective actions are taken before or immediately after the release of radioactive material in order to protect the public against deterministic effects (e.g. immediate preventive evacuation);
* an urgent protective action planning zone (UPZ) is an area with a radius of 10 km around category I nuclear facility in which urgent protective actions are taken in a timely manner, on the basis of an expert assessment by the competent services and measurements, in order to protect the public against the negative consequences of radiation;
* an extended planning distance (EPD) is an area with a radius of 25 km around category I nuclear facility which is, as appropriate, divided into sectors (separate geographical areas), to facilitate the taking of actions. Protective actions are taken on the basis of an expert assessment by the competent services and field measurements;
* an ingestion and commodities planning distance (ICPD) is a wider area which encompasses the entire territory of the Republic of Slovenia. Protective actions are taken primarily on the basis of field measurements.

It is important that protective actions are taken rapidly, in particular in the immediate vicinity of category I nuclear facilitywithin the PAZ and UPZ. According to the IAEA’s recommendations, urgent protective actions within the PAZ and the UPZ are to be taken within an hour of establishing the occurrence of an emergency. The most effective protective action is a safely conducted preventive evacuation (evacuation before a release) from the PAZ and the UPZ and simultaneous iodine thyroid blocking carried out on the basis of the emergency level (a general emergency in the present case). Protective actions within the PAZ have priority over those within the UPZ. Evacuation from the PAZ and the UPZ is more effective than sheltering, even when carried out during a release of radioactive material to the environment, especially when carried out rapidly. If it is not possible to carry out an evacuation promptly, sheltering up to 24 hours and simultaneous iodine thyroid blocking are appropriate protective actions [13]. Iodine thyroid blocking is a protective action which is never taken independently but always simultaneously with evacuation or sheltering [14].

The period during which urgent protective actions are taken starts based on the situation at category I nuclear facility , with the declaration of an emergency in accordance with the procedure for the declaration of an emergency class. This phase normally lasts several hours.

Protective actions in the surroundings of a facility are not envisaged if an emergency level lower than “general emergency” is declared. The main initial activities are:

* Within about 15 minutes after the conditions for declaring an emergency level are established, the operator declares an emergency class (unusual event, alert, site emergency) on the basis of the predefined criteria (EALs), i.e. the triggers.
* Category I nuclear facility activates its emergency response management organisation.
* In the event of a site emergency, personnel not involved in the emergency response is evacuated. Emergency workers start taking protective actions in order to prevent the consequences of an emergency and to return the facility to a stable state. The radiation measurement unit starts with measurements on-site or in the vicinity of the nuclear facility. If there is a probability of a release of radioactive material to the surrounding area, protective actions are taken within the PAZ and the UPZ and those parts of the EPD where a potential radioactive cloud is expected to spread [14].
* Depending on the situation, the preparation of protective actions and other response measures may be ordered, including the preparation of units and equipment to carry out evacuation, the notification of the public of an emergency through information channels where information and instructions are available and advice is provided to establishments with special collective responsibilities, the preparation of iodine thyroid blocking, etc.

The recommendations of international organisations (IAEA, HERCA) on the size of the emergency planning zones and distances around category I nuclear facility are only general guidelines, on the basis of which the state defines specific sizes according to specific analyses of the facility concerned, emergency conditions, the core inventory, the topography of the local area, meteorology and other local conditions [14].[[12]](#footnote-12)

When a general emergency is declared, the Protection strategy is implemented in two phases, the urgent protective actions phase and the early protective actions phase. In these two phases, other response measures are also taken, for example: the mitigation of non-radiological consequences, the registration of inhabitants, health screening, decontamination, and radiation protection of emergency workers.

#### Urgent protective action phase based on the conditions at a nuclear facility in category I

This phase starts with the declaration of a general emergency at a nuclear facility in category I in accordance with the procedure for declaring an emergency class. It normally lasts a few hours.

On the basis of the existing analyses of the consequences of a severe nuclear emergency and the effectiveness of protective actions, actions must be taken rapidly in this phase, i.e. within a few hours, particularly in the immediate vicinity of the facility. Any delay has a significant impact on the effectiveness of actions. Urgent protective actions and other response measures are carried out, which include evacuation, iodine thyroid blocking, short-term sheltering, actions to reduce inadvertent ingestion, the decontamination of people, restriction of contaminated food consumption, and the identification of persons in need of a medical examination and medical care.

#### 2.4.1.2 Early protective action phase based on environmental measurements of radioactivity

The early protective actions phase starts with the availability of measurements of radioactivity in an area affected by the accident (i.e. ranging from a few hours to approximately one day after the declaration of a general emergency). This phase may last for a few days or weeks or even months. The duration is limited until sufficiently reliable measurements are available for the entire affected area and early protective actions have been taken.

The main purpose of this phase is to obtain accurate data on contaminated areas, which requires measurements. The first priority areas for measurements, where dose rates are measured, and soil and food samples (locally produced food, drinking water, milk) are taken, are populated areas that have not been evacuated in order to determine whether they need to be evacuated or people relocated. Food measurements (locally produced food, drinking water and milk) provide data to guide decision-making on restrictions along the food chain. This phase also includes the extension of protective actions compared to the first phase.

Based on predetermined operational criteria, such as operational intervention levels [9, Appendix 4], areas are identified where early protective actions and other response measures are justified. The objective is to identify areas where the predetermined operational intervention levels are exceeded and which warrant the following early actions:

* relocation;
* restrictions on the use of local products, milk from grazing animals, drinking water and feed in contaminated areas not included in the first phase.

If it turns out that the operational intervention levels were not exceeded, restrictions may be lifted under the condition that the situation is stable. Medical examinations and medical care must be provided to the public also during this phase.

In the early protective actions phase, the situation generally does not change significantly over a short period of time (within days or even weeks). As there is more time, it is useful to engage all of the relevant stakeholders in the decision-making process on protective actions and decontamination methods. However, subsequent, potentially more significant, releases to the environment should not be completely ruled out. A decision on protective actions is taken and environmental radiation measurements are coordinated. The database of these measurements serves as the main basis for decision-making.

Any area subject to evacuation and relocation in the event of a nuclear emergency must be adequately secured and controlled. The closure of an area must be publicly announced and implemented by physical barriers, so that access to areas at risk by road is closed and check points are set up. Closed areas, entry to these areas and exit from them are also controlled. The check points are also points of entry for emergency workers. At the same time, people must be registered in order to have an overview of the situation, i.e. who has and who has not undergone control and, if needed,decontamination. Such controls include material entering or exiting a contaminated area. Control over radioactive waste must also be ensured.

A restriction on the use of contaminated food (locally produced food, drinking water and milk) and feed, and relocation, have priority over other response measures. As the success of actions depends on the timely provision of the relevant information to the public and emergency workers, the establishment of an information network is a priority.

It is essential that all actions be documented when they are taken. This is the only way to ensure long-term control over people’s movements, their doses and the doses of emergency workers, and, as appropriate, long-term medical follow-up. Documenting all actions also ensures that all environmental interventions are monitored, allowing for long-term spatial planning, appropriate management of radioactive waste and the mitigation of the damage caused by a nuclear emergency.

During the emergency, protective actions must also be adapted to the prevailing social conditions and developments, taking into account the effects of ionising radiation. When mitigating the consequences, it may become clear that many actions cannot be foreseen. Operational intervention levels must also be optimised.

Effective management of an emergency with transboundary consequences requires cooperation with states that are or could potentially be affected by the emergency. Such cooperation includes the exchange of information on the nature of the nuclear emergency, exposure, actions and their coordination, and information transmitted to the public through bilateral or international information exchange and coordination systems [7]. It is reasonable that emergency planning zones and distances are coordinated between the states if they extend beyond national borders into the territory of another state.[[13]](#footnote-13)

### Spent fuel pool accident

Although a high level of safety in spent fuel management is provided by the relevant national regulations [16], in addition to a reactor accident at a nuclear facility in category I with light-water reactors, an accident may also occur in a spent fuel pool when[[14]](#footnote-14), for a variety of reasons, the cooling of the spent fuel is no longer ensured, and, due to radioactive decay, the spent fuel continues to release residual heat after the chain reaction has stopped.

Due to the loss of cooling in the spent fuel pool, spent fuel may be exposed, which, depending on the course of events, leads to an early or subsequent release of radioactivity from the spent fuel. The dose rate from fuel radiation depends on the water level in the spent fuel pool, while an early or subsequent release of radioactivity from the spent fuel depends on the damage to the spent fuel elements, the heating dynamics (the rate of evaporation or water vaporisation due to the events in the technological process, fire, internal flooding, earthquake, etc.) and the rate of the emptying of the pool (e.g. in the event of the loss of coolant due to the damaged pool structures).

In the entire history of nuclear energy, there has never been a major accident in a spent fuel pool with a significant release of radioactive material to the environment, as large quantities of water in the pool provide sufficient time before the water would evaporate, so that emergencies can be brought under control in time [17], and appropriate actions (such as adding water to the pool and shutting down the power plant [18]) can be taken during an emergency, depending on the scenario and the level of water in the pool. While the probability of an accident in a spent fuel pool is extremely low, the environmental consequences of such an accident are comparable to those of a reactor accident [19]. Both the consequences and the fact that the spent fuel pool is located on the site of a nuclear facility, the same actions are taken, based on the declared emergency level, to protect the public and the environment as in the event of a reactor accident (Section 2.4.1). In doing so, the identified emergency planning zones and distances , the taking and optimisation of the foreseen actions, and cooperation with the states that are or could be affected by the emergency must be taken into account.

## Nuclear accident abroad

In the event of a nuclear accident abroad, significant radiation levels that would warrant urgent protective actions in the territory of the Republic of Slovenia are not expected. The envisaged set of protective actions mainly concerns restrictions on non-urgent travel to affected areas and actions along the food chain – mainly measures concerning the import of food and commodities from the area at risk. Slovenia must exercise control over the import of food and commodities at the entry points on the European Union’s external borders.

For the control of food and commodities, “sleeping” regulations are activated, such as Council Regulation (Euratom) 2016/52 of 15 January 2016 laying down maximum permitted levels of radioactive contamination of food and feed following a nuclear accident or any other case of radiological emergency, and repealing Regulation (Euratom) No 3954/87 and Commission Regulations (Euratom) No. 944/89 and (Euratom) No 770/90, and similar regulations and other acts to be adopted by the European Commission for the control of goods and food in the event of an emergency, as was the case with the accidents in Chernobyl and Fukushima.

Environmental monitoring must also be carried out as a major nuclear emergency abroad can have transboundary impacts and consequences in the territory of the Republic of Slovenia. A part or all of its territory may be at risk. In addition, Slovenian citizens in the affected area must also be taken care of. For evacuees returning to Slovenia from the affected area , contamination measurements and, if necessary, decontamination must be carried out at the national border and other entry points (e.g. airports). Contamination measurements and decontamination must also be carried out for means of transport returning from the affected area.

## Radiological accident

Protective actions and areas are not planned in advance for a radiological emergency. The potential scale of the accident in terms of area and number of people at risk is small or negligible compared to a nuclear emergency.

The same criteria and a similar set of protective actions as for a nuclear emergency apply to a radiological emergency. As in the event of a nuclear emergency, the principle of saving lives first applies to radiological emergencies, taking into account that the normal protective equipment of emergency workers provides adequate protection against contamination. Actions taken rapidly further reduce the dose from external exposure. The conventional (non-nuclear) hazards for the public, not excluding irradiation, injury or risk arising from the accident, must be highlighted.

The set of protective actions is much smaller in the event of a radiological emergency. Evacuation is the most appropriate action (iodine thyroid blocking and sheltering are not foreseen), and restrictions on food, feed and commodities are practically negligible, even considering the extent of the area or the quantity of commodities. Evacuation or potential permanent relocation does not affect a significant number of people and therefore no advance planning is necessary. In the event of open sources, decontamination is almost always required.

The response to radiological emergencies caused by criminal acts (theft, sabotage, extortion, the use of a "dirty bomb") and otherwise unlikely [1], is specific particularly when there is a threat and the nuclear or radioactive material must be located. In such case, the cooperation of units conducting radiation measurements with the police is crucial. However, when there is a threat and nuclear or radioactive material must be located, intelligence is also important. The most serious threat, albeit the least likely, is a "dirty bomb" or any other dispersal of dispersible radioactive material. The approach is the same as for a radiological accident, but with the additional consideration of the possibility of an explosion. Protective actions taken to protect the public against any radiation hazard are accordingly adapted.

### Possible scenarios of radiological accidents

#### Accident involving the use of radioactive material

The possible causes of an accident are manifold (human factors, technical and organisational aspects). Due to the improper use of radioactive material or the inadequate design of a package or device containing a radiation source, the leakage or spillage of the source may occur, leading to inadvertent inhalation and/or the inadvertent external exposure of a person and/or the environment. The scale of an emergency in such cases is usually smaller than in a nuclear accident. However, practical examples from abroad have already shown that, due to a combination of circumstances, the scale of an emergency can be larger if the source is dispersed (e.g. from a sealed form, a capsule), thus contaminating a larger area and a higher number of people. Similarly, there could be a major emergency if a fire or explosion were to occur at the same time as a spillage or leakage. Timely action by the competent organisations can prevent the contamination of people and the environment. The general public is not normally at risk in such cases, but care must be taken to secure the area of the accident and at the same time to prevent access to the area and the spread of contamination.

#### Accident caused by a malicious act

An emergency involving radioactive sources can be caused by theft, sabotage, extortion, the intentional release of radioactive material, irradiation or terrorism. Such emergency can range from unintentional irradiation due to ignorance of the radioactive material, to the intentional irradiation of people, leading to planned health consequences. In this type of emergency, the intervention measures must be timely and well thought out in order to protect human health. In addition to acting timely and efficiently, intervention personnel must also cooperate with the security authorities, as it is necessary to anticipate potential subsequent consequences and recurrences. Despite the situation at the crime scene, people must be quickly removed from the site to prevent further contamination or to avoid re-exposure to the hazard. A larger area must be protected as there is no way of knowing what further attempts may be made. The nuclear safety authority and the security authorities, the neighbouring states and international organisations must be notified as soon as possible to prevent any recurrence at other sites.

## Other accidents

In addition to the abovementioned emergencies at nuclear facilities in Slovenia and abroad, and radiological emergencies, the hazard assessment [1] includes the following scenarios: a satellite containing radioactive material falls to the ground, an accident at a nuclear-powered vessel, and damage to the tailings repositories at the former Žirovski Vrh mine.

***Fall of a satellite*** If a satellite falls to Earth, provisions must be made in particular for food, the identification of "hot spots" and decontamination.

***Nuclear powered vessels***

The probability of an accident on a nuclear-powered vessel in Slovenia is very low, hence no emergency planning zones and distances are planned in the coastal area. All actions envisaged in the event of a radiological emergency are applied accordingly.

***Damage to the tailings repositories at the former Žirovski Vrh mine***

The long-term status of the Jazbec and Boršt repositories is determined by the project for the final arrangement of the repository and the as-built design. If, due to an accident, remediation of the repository is needed, the area must be secured so as to prevent employees from entering the area. Visual inspection and measurements of the situation will determine the nature, extent and significance of damage and, once the situation is stable, remediation must be carried out. The remediation of damage is based on the detailed project for the implementation of works and the project of implemented works, in which all details and norms for the implementation of works and the status after the implementation of the final arrangements must be specified. The quality of the implemented works and the performance of any necessary decontamination of the surfaces [20, 21, 22] must be verified by measurements.

## Radiation protection of emergency workers

Radiation protection is provided by taking the following protective actions:

1. dose limits for emergency workers are not exceeded and their exposure is optimised [9];
2. the exposure of emergency workers is assessed (radiological control), including personal dosimetry, as appropriate;
3. emergency workers are qualified for their work and familiar with protective actions against radiation and potential risks [18];
4. if necessary, emergency workers use appropriate personal protective equipment;
5. if necessary, personal decontamination is carried out, including the decontamination of equipment used by emergency workers;
6. emergency workers meet the health requirements of their job[19];
7. when an emergency worker may have received an effective radiation dose exceeding 20 mSv, he or she must be referred to an authorised practitioner of occupational medicine for an extraordinary medical examination after he or she finishes the intervention. If it is suspected that an exposure has occurred which could cause deterministic effects, blood samples for biodosimetry must be taken as soon as possible.

Where members of the public (helpers[[15]](#footnote-15)) may also be involved in taking protective actions, the described actions for radiation protection must also cover them, as appropriate and considering the type of work they perform and the associated risks.

Operators of nuclear and radiological facilities whose activities could cause an accident must, in accordance with their protection and response plans, ensure that the abovementioned radiation protective actions are provided to their workers in an emergency. It must be taken into consideration that the employees at the facility will normally be the first on the scene of the accident and directly involved in the management of the radiation sources and the resulting situation, and will therefore normally be among the most exposed.

In accordance with their instructions for emergency response, other operators of radiation activities must ensure that radiation protective actions are taken, thus protecting their workers and other persons involved in an accident, taking into account the abovementioned actions, as appropriate and in relation to the type of activity and the risk level.

In planning protective actions, care must be taken that the effective doses received by individuals do not exceed the reference levels.

## Registration of inhabitants and medical care

In the event of a nuclear or radiological emergency, inhabitants in the area must be registered, and the received doses and needs for health screening, counselling and medical follow-up assessed as soon as possible. To this end, emergency workers may use the central register of evacuated and relocated persons.

It is important that the evacuees in accommodation centres are provided emergency medical care and psychosocial assistance. Control over doses and medical follow-up must be introduced, as appropriate.

# PROTECTION STRATEGY – PREPARADNESS FOR RESPONSE (INFRASTRUCTURE)

For the efficient implementation of the protection strategy, preparedness must be at an optimal level, and the required infrastructure, including procedures and methodology for taking protective actions, must be in place. All of the main elements of preparedness, which must be in place before an emergency and used or implemented during an emergency, are described below.

The goals of response times for actions that must be taken according to the different emergency preparedness categories, are defined in more detail in Annex 2. Protective actions and other response measures to be taken to protect the public in the event of a nuclear emergency in the emergency planning zones and distances – in the event of a declared general emergency due to a reactor accident at a category I nuclear facility in Slovenia – are defined in Annex 3. Legislation governing protection against natural and other disasters and other areas associated with taking actions (health, agriculture, forestry and food, public safety, infrastructure, finance, foreign affairs, the economy, social welfare, education, etc.) defines in detail emergency workers and targeted times (including the provision of adequate qualifications) and taking protective actions and other response measures in the event of a general emergency at a category I nuclear facility in Slovenia.

## Measurements of radioactivity in the environment

The aim of emergency monitoring (measurements) of radioactivity is to provide timely information on the quantities and type of external radiation and radioactive contamination in the event of a nuclear or radiological emergency. Decisions on the required protective actions to be taken for the public and emergency workers are based on these data. Information obtained with measurements is needed to notify the public of the emergency level and to define persons requiring medical follow-up, and for the international exchange of information.

It is necessary to (Figure 2):

* take actions to protect the public in the newly defined contamination areas (P1 areas);
* ensure the continuation of the already taken protective actions (P2 areas);
* discontinue protective actions that have already been taken (P3 areas).

All of the three possible statuses of areas before and after environmental monitoring are shown in Figure 2. After monitoring, areas are redefined and accordingly joined.

 

**Figure 2:** Areas where protective actions are taken [23]

Emergency monitoring at sites and of environmental samples is carried out, as appropriate, for example measurements of the contamination of drinking water where the water is used for drinking or where there is a risk of the contamination of the environment from a spill of contaminated water. Environmental monitoring may be carried out over a short period of time, for example two months, or for several years or even decades. After a major accident, measurements of food contamination may need to be carried out over several decades.

Emergency monitoring of radioactivity consists of measurements of radioactivity at the source and in the environment, and measurements of individuals. The scope of emergencymonitoring is determined on an ongoing basis in relation to the type and scale of the accident. The programme of such monitoring is prepared in the initial stages of the accident and is continuously updated in relation to the development of events. A framework programme for different types of accidents is prepared prior to an emergency, defining in advance the types of measurements envisaged, and their purpose, frequency, location, and material sampling. In the event of an accident, a large number of measurements are expected, such that increased capacities of the measurement equipment are required for emergency monitoring. In addition, emergency workers must have suitable radiological personal protective equipment, and must be trained to work under elevated radiation and stress. They must upgrade the protection of measuring equipment at their premises and access to these premises to prevent contamination [24].

Based on the monitoring, an analysis of all three areas (P1-P3) is performed and protective actions are proposed. If areas are small, additional protective actions are taken or discontinued later, after environmental monitoring has been carried out.

Before a protective action is taken on the basis of environmental measurements, including radiation exposure, it is sensible to analyse the projected doses that will be incurred by emergency workers and members of the public (helpers). Following an action, the received doses must be analysed and measures taken accordingly.

The public must be notified of data and information on the emergency monitoring and briefed about the situation on an ongoing basis.

## Reference level

In the event of an emergency, all protective actions are designed to minimise the radiation exposure of the public, to minimise any other damage, and to enable people to return to their place of residence as soon as possible and to continue living as before the emergency. In planning the emergency response, the overall objective is that the annual radiation dose does not exceed the reference levels determined by law.

 In Slovenia, the reference level for effective doses is set in the applicable legislation in accordance with international guidelines [9] at 20 mSv per year for existing exposures and 100 mSv for emergency exposures. In certain cases and depending on the phase of the accident, reference levels lower than those already set may be used:

* for emergency exposure, a reference level of less than 100 mSv or even less than 20 mSv may be recommended, if adequate protection can be provided or no excessive costs incurred;
* for specific cases of existing exposure connected with ionising radiation sources or exposure pathways, a reference level of less than 20 mSv per year, including less than 1 mSv per year, may be set if economically and socially justified.

In addition, appropriate reference levels may also be set for the transition from emergency exposure to existing exposure, in particular at the end of the early protective actions phase, such as relocation. Prevailing conditions and social criteria must be taken into consideration and may include:

* for exposure up to and including 1 mSv per year: general information on exposure levels without specific consideration of individual exposures;
* for exposures up to and including 20 mSv per year: specific information to enable individuals to manage their own exposure where possible;
* for exposures up to and including 100 mSv per year: an assessment of individual doses and specific information on radiation hazards and available actions to reduce exposure.

The following reference levels [6] are used to optimise radiation protection in the event of an emergency exposure and existing exposure. These depend on the type of exposure and should take into account the requirements of radiation protection and other social aspects. Exposures above the reference levels are given priority in the optimisation of radiation protection, but the optimisation of protection is also carried out below the reference levels.

## Operational intervention levels

Operational intervention levels (hereinafter: OIL) are expressed in terms of a directly measurable quantity, such as the external radiation dose rate, surface contamination or the concentration of radioactive material in air and food (locally produced food, drinking water and milk). OILs are used for adopting decisions on intervention measures. In Slovenia, OILs are defined by the applicable legislation [9] on the basis of the reference level of 100 mSv. When lower reference levels are used, OILs must be reduced proportionally by optimisation.

For operative decision-making on protective actions and thus for meeting the general criteria, OILs with predefined values must be used.

OIL1, OIL2 and OIL3 for the dose rate from sediment are used to identify where evacuation, relocation or restrictions on the use or distribution of local products, forest fruits (wild mushrooms, etc.), milk from grazing cows, rainwater and feed that may be contaminated, are required due to fallout.

OIL4 is used to assess whether levels of radioactive contamination of the skin require medical examination or additional medical measures.

OIL5 and OIL6 are not available for historical reasons [9].

OIL7 values, expressed as concentrations (Bq/kg) of two typical radionuclides (131I in 137Cs), are used as indicators to determine whether food (locally produced food, drinking water and milk) is safe for human consumption without a full spectroscopic (radionuclide) analysis.

OIL8 is used to assess whether the concentration of radioactive iodine in a human thyroid gland requires an additional medical examination and medical follow-up.

Emergency workers are usually the first to arrive at the scene of an accident, except at nuclear and radiological facilities, where employees are the first responders. The planning and implementation of each type of intervention measure and its scope and duration must ensure that the protection of the public in the intervention area is optimised so that they are exposed to ionising radiation at as low a level as possible, taking into account the economic and societal benefits of intervention measures.

Individual doses must not exceed the dose limits for professionals working with sources of ionising radiation, unless taking action would protect the lives and health of a large number of people or prevent the development of events with catastrophic consequences.

If it is possible that individuals may have received significant doses in a short period of time as a result of a nuclear or radiological emergency, it is essential to take action regardless of any circumstances, as this is the only way to prevent deterministic effects. The generic criteria for absorbed doses received in a short period of time for which action must be taken in any case in order to prevent deterministic effects are the basis for decontamination, medical care and urgent actions, and are applied, if possible, before release.

In the event of a nuclear or radiological emergency, protective actions must be taken to reduce the risk of stochastic effects from exposure to ionising radiation. The risk to the public from the ingestion of contaminated food and the use of contaminated commodities must also be reduced. It must be ensured that the received effective dose, taking into account all exposure pathways, does not exceed one tenth of the value set out in the generic criteria for action to be taken in the event of a nuclear or radiological emergency to prevent stochastic effects [9], which means that a diet must be provided which meets this criterion (if the contribution from the food chain exceeds one tenth of the value, replacement must be provided). If replacement cannot be provided, the consumption of contaminated food is allowed until replacement is provided under the condition that the projected doses do not exceed the values set out in the generic criteria for action to be taken in the event of a nuclear or radiological emergency to prevent stochastic effects [9].

The risk from the use of contaminated vehicles, equipment and other commodities must also be reduced.

## Protective actions for the public

In the event of a nuclear or radiological emergency, protective actions for the public must also be taken. Urgent actions are taken in the precautionary action zone and the urgent protective action planning zone (PAZ, UPZ), while early protective actions are taken in the area of the extended planning distance (EPD), such as relocation and food measures (restrictions on contaminated food), while food measures and restrictions on the use of certain commodities are expected and implemented mainly in the food and commodities restriction zone (ingestion and commodities planning distance - ICPD, which covers the entire territory of the Republic of Slovenia). Other suitable actions are also taken in all zones, including the following:

* the area is secured and under control;
* the prevention of inadvertent ingestion[[16]](#footnote-16);
* use of personal protective equipment;
* the decontamination of people, animals and equipment, including food and feed processing;
* care is provided to injured and irradiated persons.

In order to avoid the deterministic and stochastic effects of ionising radiation, the following must be taken into consideration when ordering protective actions [34]:

* the reference levels for the exposure of the public and occupational exposure [9];
* a strategy for the protection of the public potentially exposed in the event of different events and associated foreseen scenarios;
* generic criteria for each protective action [9];
* OILs for taking protective actions [9].

The OILs are defined in such a way that, when complied with, they ensure that the public is exposed below the reference levels.

Protective actions can be classified into:

* urgent protective actions designed to prevent the deterministic effects of radiation, and
* early protective actions and other response measures taken to prevent the stochastic effects of radiation.

They can be taken within a few days or several weeks or even over a longer period of time. For a long lived radionuclide, individual actions may take decades. The objective of all of the protective actions is to minimise the exposure of the public to radiation.

### Sheltering

Sheltering means that people and animals stay in closed premises in the event of an emergency in order to provide shielding against external radiation exposure and intake. Closed premises are, for example, shelters and buildings with closed windows and a switched-off ventilation system. Sheltering can last up to a few days.

### Iodine thyroid blocking

The consumption of potassium iodide tablets or iodine prophylaxis is the consumption of stable iodine before or immediately upon the occurrence of a nuclear emergency in order to protect the thyroid against the uptake of radioactive isotopes of iodine. Potassium iodide tablets are administered in combination with sheltering or evacuation.

In the event of a nuclear accident at a category I nuclear facility , establishments where a number of persons gather (schools, kindergartens, community healthcare centres, homes for the elderly, other institutions, companies and organisations) and which are located in the precautionary action zone and in the urgent protective action planning zone, must be supplied with potassium iodine tablets prior to an emergency pursuant to the Rules on the use of potassium iodine [13]. For all other Slovenian citizens, potassium iodine tablets may be stored at suitable competent organisations (e.g. hospitals and other healthcare organisations) and distributed according to the need for iodine prophylaxis.

### Evacuation

In the event of a nuclear emergency, evacuation is usually ordered before radioactive material is released to the atmosphere.[[17]](#footnote-17)The same actions are taken in the event of a radiological emergency involving the release of radioactive material to the atmosphere, or based on field measurements when the soil is contaminated (e.g. a radioactive liquid spill).

In the event of a nuclear emergency at a nuclear facility with an impact on the public (upon release), check points are set up on evacuation routes at exits from the evacuated areas to supervise evacuation and short-term returns to the closed areas or areas at risk during and after the accident. If the evacuees are likely to be contaminated, measurements of individual contamination and decontamination are carried out at the reception centres where the members of the public are registered, provided that they report to the reception centres immediately upon evacuation as requested.

### Early protective actions and other response measures

The early protective actions phase based on the environmental radiation measurements starts with the availability of these measurements for the affected area (i.e. from a few hours to approximately one day after a general emergency is declared). This phase may last for a few days or weeks, or even months, until sufficiently reliable measurements are obtained in the entire area at risk and early protective actions are taken. In planning early protective actions, the main guiding principle is to ensure that the residual dose is below the reference level, taking into account the full range of sensible protective actions and all exposure pathways.

Based on predefined OILs, areas are identified where additional protective actions and other response measures are justified. The goal is to identify areas where the predefined OILs are exceeded and which warrant the following early actions:

* relocation;
* restrictions on the use of local products, milk from grazing animals, rainwater and feed, for contaminated areas not included in the first phase.

The main goal of this phase is to obtain accurate data on contaminated areas. In the first phase, dose rate measurements are carried out, after which areas are identified where radionuclide concentrations in soil samples and food (locally produced food, drinking water and milk) must be measured. In order to establish where relocation is required, the first priority measurement areas are populated areas that have not been evacuated. Food measurements provide data to guide decision-making on restrictions along the food chain.

If it turns out that the OILs have not been exceeded, restrictions may be lifted under the condition that the situation is stable. This means that radioactive release is no longer possible, and contamination is below the regulatory threshold.

A representative person is used in dose assessment [25]. It is taken into consideration that a representative person belongs to one of the following three categories: 0-5 years (infant), 6-15 years (child) or 16-70 years (adult). For the practical implementation of this recommendation, dose coefficients and lifestyle data (diet, time spent indoors or outdoors) must be used for a one-year-old infant, a 10-year-old child and an adult, so that all of the three age categories are covered. A representative person can also be defined in a probabilistic way, by having a probability of less than 5% that a member of the public selected at random will receive a higher dose than estimated. Dose calculations also consider certain vulnerable groups, such as children and pregnant women, which requires a good knowledge of the situation (assumptions in the calculations).

#### 3.4.4.1 Relocation

Once an emergency is under control and a release to the environment or environmental contamination is no longer expected, emergency environmental monitoring is used to identify areas that are too contaminated to live in, due to soil radiation or contaminated water, milk and food. Relocation is not a timely action and is carried out after the end of the response phase, during the transition phase when the protection and response forces are no longer present. Special attention must be paid to the evacuees who cannot return home because their area is designated for relocation.

#### 3.4.4.2 Protective actions in relation to food, feed, livestock and other commodities

Food, feed, raw material and livestock may be contaminated due to a nuclear or radiological accident. Contamination can also occur in the different phases of food production and processing, e.g. during cultivation and to some extent in greenhouses, warehouses, production facilities and shops.

After a nuclear or radiological emergency, radioactive material can be transmitted to food in the food chain. Depending on the type of emergency, only surface water may be contaminated, while groundwater remains uncontaminated.

Livestock may remain in the contaminated area, but they must be cared for as appropriate for the animal species and category concerned (feeding, watering, milking and the cleaning of stables). If animal feeding systems are automated, a power supply must be provided with generators. Grazing animals do not have to be cared for over a longer period of time, if they have access to feed and water. Animals can also be evacuated but a place must be provided to house the animals and, very likely, for decontamination before they leave the area.

When animal lives are endangered or irreversibly affected by ionising radiation or they are ill or injured, emergency veterinary care (treatment or euthanasia) must be provided.

It is essential to set maximum permitted levels of radioactive contamination for food and feed, as this reduces the potential for contamination by ingestion. If the permitted levels are exceeded, products must not be used. Restrictions must also apply to food production, including locally produced food, drinking water and milk, and feed. It should be recognised that actions can also be taken to reduce the amount of radioactive material in food and feed. These actions allow products and drinking water to be used safely and production to continue.

Protective actions targeting food reduce the risk of stochastic effects due to the ingestion of contaminated food. Restrictions on the consumption of contaminated food, especially milk and drinking water, protect the public from ingesting radioactive material in food and drink. Intervention actions targeting food last from a few days to a few weeks for short lived isotopes and up to several decades for long-lived isotopes.

Protective actions targeting food are taken in relation to:

* **the source** – the food chain
* the use of drinking water;
* the use of fresh feed;
* the use of crops.
* **consumption** – distribution and ingestion
* drinking water;
* milk and dairy products;
* fruit and vegetables;
* forest fruit, wild mushrooms, etc.;
* game/wild meat.

Tap water will be contaminated after some time has elapsed from the release, whereas crops, for example, are contaminated immediately. Milk is contaminated after two days, which can be prevented if animals are confined to stables and fed uncontaminated feed.

Restrictions on other products refer to the use of local products, which can also be contaminated, either directly (e.g. handicrafts and building materials stored outdoors) or indirectly through the use of contaminated raw materials (e.g. woodenware).

The objective is that the total dose to the public from the consumption of contaminated food in the first year after the accident is less than 1 mSv. In the event of a major accident, where dose levels below 1 mSv cannot be maintained, care must be taken to keep the dose in all cases below 10 mSv during the first year.

For natural products on the market, including venison, wild mushrooms and wild-caught fish from lakes and rivers, a concentration level is set above which products may not be traded (e.g. the current European Commission recommendation is that the accumulated concentrations of 134Cs in 137Cs in products must not exceed 600 Bq/kg in intra-EU trade).

Restrictions on the use of drinking water may:

* be introduced due to contamination;
* or connected with a shortage of adequate water as the water source must be used in a wider area or for decontamination.

#### 3.4.4.3 Other response measures

The public must be notified of an emergency in a timely and comprehensive manner. It must also be informed of the situation and the anticipated development of events, and the required self-protective actions. Hence, those who have comprehensive information and communication skills must communicate with the public. The aim of such communication is to quickly convey to the domestic and international public accurate information about an emergency, its causes, possible consequences and the development of events, activities carried out by the competent institutions to deal with the situation and mitigating consequences. Protective and mitigation actions can only be taken in cooperation with the public. Only informed members of the public will be able to cooperate in taking actions. The public must receive:

* instruction on the implementation of protective actions;
* information on the effects of radiation and contamination on health and the environment;
* an explanation of the accident, and nuclear and radiological safety;
* compensation and subsidies;
* notices issued by the local authorities;
* information on psychological assistance;
* advice for foreigners.

Based on environmental monitoring, the projected spread of contamination and actions taken to protect the public, it is possible to predict economic damage not yet inflicted. To this end, the key economic activities in P1 and P2 areas must be identified (Figure 2, P1 – an extension of the area where actions are taken, P2 – the continuation of actions), the risk of damage assessed, i.e. damage caused by the accident and by protective actions, for example erosion caused by the removal of topsoil. A priority list of economic activities where damage must be prevented first is drawn up.

The limitation of economic damage must also be considered in the transport of radioactive material to or from the contaminated area. In this respect, legal provisions must be taken into account [26].

A damage inventory and the payment of compensation in the event of a nuclear emergency are determined by law – in Slovenia, by the Act on Liability for Nuclear Damage [27]. Economic damage is not only connected with direct damage to economic facilities, but includes damage caused by protective actions and actions related to decontamination or the restoration of the environment to its previous state. The law regulates the keeping of records on the parties that suffered damage, the methods of assessing nuclear damage and the system for informing parties that suffered damage. Records on the limitation of economic damage are also kept.

In the event of a radiological emergency, the costs of remediation or the omission of the prescribed handling of radioactive material are borne by the user of the radiation source or by the state, if the user of the radiation source is unable to carry out remediation, if the entity that caused the accident is not in the territory of the Republic of Slovenia or if the latter cannot be determined [6, Article 166].

## Radioactive waste management

Waste generated as a result of a nuclear emergency has specific physical, chemical and radiological properties and therefore poses a major challenge for treatment, packaging, storage, transport, conditioning for disposal and disposal. As significant quantities of waste may be generated in an emergency, close cooperation between all stakeholders throughout the period of remediation is essential.

After urgent protective actions have been taken and the emergency response phase has ended, the management of radioactive waste starts. This is when remediation starts, including the cleaning and decontamination of radiologically contaminated areas, waste management and activities to return a nuclear facility or other infrastructure to the planned exposure situation or the transition to a new existing exposure situation. An inventory of the contaminated areas, types and categories of contamination must be taken, and a person or an organisation responsible for taking and assessing inventory resulting from contamination must be designated [28].

Once decontamination procedures are carried out, different types of radioactive waste are created. Radioactive waste may warrant treatment to reduce its volume and/or mass. Radioactive waste can be classified into different classes according to its aggregate state or its level and type of radioactivity [29].

The responsibility for radioactive waste under the Ionising radiation protection and nuclear safety act lies with the entity that caused the accident, the owner of the source or the operator of the facility, or, if the latter is unknown, the responsibility lies with the state. The management and disposal of waste generated in a nuclear or radiological emergency is the responsibility of the provider of the service of general economic interest of radioactive waste management [6] that to this end prepares detailed guidelines on radioactive waste management in the context of different accidents.

# TRANSITION PHASE

The transition phase is a period of de-escalation and a controlled transition to either an existing exposure situation or to a planned exposure situation. Which exposure situation is reached (existing or planned) has no significant impact on the main actions in the transition period, but this does not mean that it does not matter which situation is reached. Wherever possible or reasonable, the objective should be to reach a planned exposure situation.

The main actions in the transition phase are:

* Integrated radiation monitoring in the environment with an adequate sampling frequency and number of measurement points, including for the sampling of food and feed. Such monitoring must contain enough reliable data to verify calculations, which must match, within the margin of accuracy, the expected received dose for the calculated periods, otherwise it must be improved. It also shows which exposure pathways contribute the most to the received dose. It must be checked at regular intervals if actions still in place can be discontinued or additional actions must be taken to be able to discontinue a protective action (e.g. the decontamination of an area based on the risk assessment, the lifting of restrictions on food consumed in negligible quantities (e.g. spices), the processing of food (milk processed into cheese)).
* Long-term medical follow-up: medical examinations of the members of vulnerable groups and exposed emergency workers.
* The mitigation of non-radiological consequences: financial compensation and compensation for nuclear damage; finding jobs and other activities enabling an active life for relocated members of the public; psychological counselling; explaining protective actions and how to carry them out in an effective manner; informing the public not directly involved in taking protective actions but who have concerns; reviving economic and other activities in the affected areas.
* Comprehensive care for the relocated members of the public, the provision of education, jobs, housing, and psychosocial assistance.

Detailed planning during this phase is considerably more difficult because of the many possibilities and situations, not all of which can be foreseen. The risk itself (projected and actually received doses) is much lower than during the phase in which protective actions are taken. It is also important to be aware that people and the environment will be stigmatised, and that self-protection will play a major role in this area, as people will be taking actions themselves.

## Primary objective of the termination of an emergency

The primary objective of the termination of an emergency is to restore social and economic activity. Once this objective and all of the general prerequisites for the termination are met, the termination of an emergency is declared. The general prerequisites for the termination of an emergency are general and specific. The specific prerequisites are of two types: 1. the transition to a planned exposure situation, and 2. the transition to an existing exposure situation. The termination of an emergency must be declared in a formal and public manner.

It must be taken into consideration that the transition from an emergency exposure situation to an existing exposure situation does not necessarily occur simultaneously across the entire area. Certain parts of an area may have already transited to an existing exposure situation or a planned exposure situation (i.e. the accident is over), while in others, the situation may still be that of an emergency exposure (i.e. the accident is not yet over).

In accordance with a graded approach, and pursuant to the existing hazard assessment [1] and past experience with accidents, the assumption is that upon the termination of an emergency:

* in the event of a general emergency at a nuclear facility in category I leading to a significant release of radioactive material to the environment (e.g. the Fukushima accident), the transition to an existing exposure situation is made;
* in the event of a site emergency at a nuclear facility in category I or in a research reactor, the transition to a planned exposure situation is made and followed by normal operation, taking into consideration that in such case the planned exposure situation may include remediation, decommissioning or the end of the facility’s operation. Following an accident of this category, the exposure situation of the public is not expected to differ from the situation prior to the accident;
* in the event of an unusual event and the alert at a nuclear facility in category I or in a research reactor after the accident, normal operation will be re-established, and the transition to a planned exposure situation made;
* in the event of other category IV accidents,[[18]](#footnote-18) which may occur at an unknown location, the transition to an existing exposure situation or a planned exposure situation is made, for example an accident in which radioactive material was not released to the environment is terminated upon the transition to an exposure situation equal to the one before the accident. The identified source may be reused or its use is stopped. In both cases, even when the source becomes radioactive waste, the transition is made to a planned exposure situation. An accident involving a significant release of radioactive material to the environment is terminated upon the transition to an existing exposure situation.

Taking a hazard assessment into consideration when procedures for the transition phase are being prepared facilitates the determination of the time frames within which the transition phase of an emergency is terminated. It should be noted that time frames primarily depend on:

* the inability to foresee the time and location of a nuclear or radiological emergency and its actual effects;
* the complexity of potential exceptional measures after an accident, and
* the potential impact of non-radiological consequences, such as the concerned public and the impact of the political situation on decision-making in an emergency.

New risks may be identified after an emergency, which must result in changes to response procedures in an emergency. Before the termination of an emergency is declared, hazards must be thoroughly re-assessed in accordance with requirement 4 of GSR Part 7 [4] and emergency response plans accordingly amended.

### General prerequisites for the termination of an emergency

Once all of the general prerequisites in Table 1 are met, the termination of an emergency is declared. Due to the specifics of individual emergencies, the general prerequisites listed below are not an absolute but a relative set, which means that they are always adjusted to the actual situation and circumstances in an emergency.

**Table 1:** General prerequisites for the termination of an emergency

| **GENERAL PREREQUISITES FOR THE TERMINATION OF AN EMERGENCY** |
| --- |
| **(1) the discontinuation of urgent protective actions and early protective actions**The required urgent and early protective actions were taken. |
| **(2)** **the situation is under control**The exposure situation is well understood and stable, which means that the hazard source is under control, no additional release or exposure is expected due to this event, and the expected development of the event is well understood; in such case protective actions are discontinued and the termination of the emergency is declared. |
| **(3) assessment of the radiological situation in the environment**The radiological situation or the environmental contamination must be carefully analysed, the control of doses and dosimetry must be introduced, the exposure pathways and doses received by the affected population (including doses received by members of vulnerable groups, such as children and pregnant women) must be identified. The decision to discontinue or adjust certain actions that were taken at the start of an emergency is made on the basis of an assessment of the radiological situation. The possible future uses of land and water in the affected areas must be defined, if necessary (e.g. restrictions on the use of these areas or alternative uses). |
| **(4) a new hazard assessment is carried out**A detailed hazard assessment is carried out, both in relation to the current state of an emergency and to future developments, in accordance with the Instructions for drafting hazard assessments [30]; the hazard assessment thus prepared is the basis for preparedness and response in the event of new emergencies.Events and areas that may require protective actions and other response measures, including those that may mitigate the consequences of future emergencies, are defined in the hazard assessment. An overview of the existing emergency response procedures must be prepared, and procedures revised or replaced by new ones, as appropriate. |
| **(5) coordination of the revised and new procedures**Revised or new emergency response procedures must be coordinated with all organisations involved in the response to an emergency. As the coordination of revised or new procedures can be a lengthy process and in order to avoid unnecessary delays in the termination of an emergency, the existing resources and means for emergency management must be at least minimally supplemented (e.g. training is introduced, only part of the procedures are revised) until the new or revised procedures come into force. |
| **(6)** radiation **protection of emergency workers**Care must be taken that in the area of the planned exposure situation the radiation protection of intervention personnel in that area can be consistently carried out; care must also be taken that the source is protected in accordance with international recommendations for nuclear security. |
| **(7) assessment of radiological consequences**The radiological situation is assessed in relation to reference levels, generic criteria, OILs and dose limits to determine whether the appropriate criteria have been met for the transition to an existing exposure situation or to a planned exposure situation. |
| **(8) assessment of non-radiological consequences**Non-radiological consequences (e.g. psychological, social and economic consequences) and other factors (e.g. land use options, resource availability, community resilience or how quickly the community can recover from an emergency, the availability of social services), and measures to eliminate these consequences are defined. |
| **(9) register for medical follow-up**A register of individuals who require long-term medical follow-up due to the consequences of an emergency. |
| **(10) radioactive waste**Proper management (temporary repositories, contaminated soil is covered so that wind or animals cannot spread contamination) of all radioactive waste arising from an emergency. |
| **(11) consultations with the interested public**Consultation with the interested public is carried out in order to increase public trust in the decision to terminate an emergency and facilitate their acceptance of this decision, without unreasonably hindering the timely implementation of the competent authority’s decision to terminate the emergency.The interested public and other interested parties are consulted with regard to the basis on which to declare the termination of an emergency, which protective actions were taken and which restrictions were imposed during an emergency; possible adjustments of restrictions, the continuation of protective actions or the introduction of new protective actions, the expected duration of these actions and restrictions; the necessary changes in the behaviour and habits of the public, the possibility of taking (where appropriate) one’s own protective actions – self-protection, e.g. a shorter stay in an area, changes to agricultural work and land use, restrictions on the consumption of certain foods; the need for permanent environmental monitoring and source monitoring following the termination of an emergency; further efforts to restore services and jobs; and the dangers of ionising radiation in the exposure situation after an emergency. |

### Specific prerequisites for the termination of an emergency

### 4.1.2.1 Specific prerequisites for the transition to a planned exposure situation

In addition to the general prerequisites, the following specific prerequisites (Table 2) must also be met in order to declare the termination of an emergency and enable the transition to a planned exposure situation.

**Table 2:** Specific prerequisites for the transition to a planned exposure situation

| **SPECIFIC PREREQUISITES FOR THE TRANSITION TO A PLANNED EXPOSURE SITUATION** |
| --- |
| **(1) analysis of an emergency and the preparation of exceptional measures**Upon the termination of an emergency, the circumstances leading to the accident must be analysed, corrective measures defined and an action plan for their implementation drawn up by the relevant competent authorities and the operator of the nuclear facility or irradiation installation. In accordance with the law [6], the analysis must include an exceptional review of the safety report. As the analysis can be time-consuming and in order to avoid unnecessary delays, it is advisable to introduce appropriate administrative procedures to restrict or prevent the use or handling of the source until the circumstances leading to the accident are clarified. Depending on the type of activity and the field of application, initial corrective measures or exceptional measures [6] must be imposed by the competent authority on the radiation service operator using the radiation source or operating the facility or installation which caused the accident. |
| **(2) assessment of criteria for the safety of a source and its safe management**Upon the transition to a planned exposure situation, the safety criteria for a source must be assessed in terms of the protection of a source against intentional threats and for the safe management of a source involved in an accident (radiation source) and in accordance with the requirements defined for the planned exposure situation in question. The planned exposure situation depends on the type of accident: it may concern routine operation after decontamination and after the radioactive waste generated during the accident has been properly taken care of, or it may concern the termination of the use of the source, in which case the user of the source must comply with the relevant legislation. |
| **(3) the requirements for dose limits and reference levels are met**Before the transition to a planned exposure situation, the requirements for dose limits and reference levels in relation to the exposure of the public must be met in accordance with the law [6]. |

### 4.1.2.2 Specific prerequisites for the transition to an existing exposure situation

The specific prerequisites defined in Table 3 must be met to enable the transition to an existing exposure situation.

**Table 3:** The specific prerequisites for the transition to an existing exposure situation

| **THE SPECIFIC PREREQUISITES FOR THE TRANSITION TO A PLANNED EXPOSURE SITUATION** |
| --- |
| **(1) the general prerequisites for the termination of an emergency**All of the actions required to meet the general prerequisites for the termination of an emergency must be taken. It must be verified that the estimated avertible doses are below the reference levels defined for the protection and response phase. |
| **(2) the identification of areas at risk**Areas at risk which are not suitable for resettlement and where social and economic activities can no longer be performed must be identified. In the protection and response phase, people were evacuated and/or relocated from these areas and/or special restrictions were introduced in these areas which will remain in place also after the termination of the emergency. The area is defined by the competent authority. Exposure in this area is monitored in accordance with implementing acts [31].Administrative measures and other actions to monitor the implementation of all of the imposed restrictions in this area must be introduced in the at-risk (contaminated) areas. |
| **(3) the preparation of a restoration strategy**Before the termination of an emergency is declared, a strategy must be prepared to restore infrastructure, workplacesand public services (e.g. public transport, shops, schools, kindergartens, community healthcare centres, the police and firefighters), which are a prerequisite for normal life in the affected areas and in the areas where evacuation or relocation has been carried out. |
| **(4) communication**A mechanism and means for continuous communication and consultation with all interested parties, including local communities, must be put in place. |
| **(5) the transfer of authority**All required changes must be made or the authority and liability transferred from the organisations responsible for emergency response to those responsible for comprehensive remediation. Information and data collected in an emergency and relevant for long-term planning must be exchanged between the appropriate organisations and authorities. |
| **(6) long-term monitoring**The preparation of a programme for the long-term monitoring of the remaining at-risk (contaminated) areas is initiated. |
| **(7) long-term medical follow-up programme**A long-term medical follow-up programme of registered persons is prepared (the register must be set up before the termination of the emergency). |
| **(8) psychological and social assistance**A strategy of psychological and social assistance for the affected public is prepared. |
| **(9) compensation**The legislation on nuclear damage [27] which governs compensation to victims for the damage caused by an emergency is taken into consideration in order to assure the public that compensation procedures will be carried out, notwithstanding the fact that they may continue after the termination of the emergency. |
| **(10) remediation**In the event of an existing exposure due to an emergency, a remediation regime is prepared or its preparation initiated, taking into account the applicable legislation and including the allocation of the required financial, technical and human resources. |
| **(11) dose assessment**It is, in principle, not necessary to control individual doses at the end of an emergency. As the doses received by individuals can vary considerably depending on their lifestyle, these doses must be assessed and the protection of these individuals addressed in a strategy for the long-term protection of the public. |
| **(12) exceptional circumstances**When exceptional circumstances arise during an emergency due to which it has not been possible within a reasonable amount of time to take all actions required to meet the general prerequisites for the termination of the emergency and to verify that the estimated residual doses are below the reference levels for the protection and rescue phase, the decision to terminate the emergency may still be made, if it has been established that no further protective actions and other response measures are foreseen, and that none of the generic criteria for taking early and other protective actions have been fulfilled. |

### Time frames for the termination of an emergency

The time frame within which an emergency is expected to end must be envisaged in the preparedness stage. Because the development of an accident is inherently unpredictable and, despite careful planning, certain circumstances cannot be foreseen, it is not possible to predict in advance exactly when an event will end. However, it is possible and necessary to define a strategy in the preparedness stage to declare within a reasonable amount of time that an emergency is terminated despite the unpredictability.

Experience has shown that in order to end a large-scale emergency (e.g. an accident at a nuclear facility in category I causing significant contamination in the environment), a timeframe ranging from a few weeks to a year can be envisaged, while for a small-scale emergency (e.g. an accident during the transport of radioactive material or an accident involving most radioactive sources), this timeframe ranges from one to a few weeks.

# REMEDIATION AND REVITALISATION

The lifting of protective actions is the first precondition for the termination of an emergency. The termination of an emergency is declared when the situation is under control and stable. All of the prerequisites for the lifting of protective actions must be met simultaneously. The prerequisites must be defined and described in detail.

## Remediation

In the event of an existing exposure, an integrated remediation regime must be defined, which is not only extremely demanding after such emergencies, but also requires significant financial resources. As the extent of remediation may vary considerably, the remediation objectives must be defined and a remediation programme drawn up, taking into account that it will be necessary to adjust the planned activities or even change them substantially during implementation. Cooperation with the party that caused the accident will be required. In drawing up the remediation programme, special attention must be paid to the exposure of the public and the environment to sources of ionising radiation and the provision of ionising radiation protection. Remedial actions must be taken on the basis of measurements, an assessment of their justification, and optimisation requirements. The programme is subject to approval by the regulatory authority responsible for ionising radiation protection. Communication during remediation is specific. Relevant information that is transparent, consistent, clear and as complete as possible must be communicated to the public quickly. It is also important to consult the interested public (as described in Section 2.3). Procedures must be established for reporting to the competent organisations any non-routine circumstances relevant to protection against ionising radiation.

Based on the actual situation, the remediation strategy must identify actions, those responsible for them and those taking actions. It must also include the financial aspect of actions and potential assistance from other states or the international community. If those responsible for actions or those taking actions are institutions or persons that in normal situations do not take such actions, professional supervision by a competent institution is required. This is the only way to avoid further damage that might result from an action not taken properly.

The implementation of remediation must be supervised, which means that data on the implementation of remediation must be collected and monitored. To this end, it is important to have data on:

* contaminated areas (identified on the basis of environmental measurements; see Section 3.1);
* the radiological monitoring of the public and the associated actions needed to reduce individual doses (a record of individual doses);
* the health surveillance of the public with an emphasis on radiation exposure;
* the monitoring of doses received by emergency workers and other personnel, and actions needed to reduce individual doses (a record of emergency workers);
* the training of emergency workers and other personnel in relation to radiation protection;
* the health surveillance of emergency workers and other personnel, with an emphasis on exposure to radiation;
* analyses of dose fields and individual doses after an emergency;
* the planning procedures of individual and environmental radiation exposure, including radioactive waste management (the costs of transport and the management of waste, the exposure of waste management workers and the public arising from waste management);
* documentation on the communication system, evacuated and relocated persons;
* the verification of the results of actions taken, as they are the only performance indicators of remediation.

## Revitalisation

During remediation or after remediation is completed, an area is revitalised, taking into consideration that the results of monitoring are one of the decisive factors. The monitoring of contamination and radiation loads will certainly continue in the revitalisation phase, even if remediation is completed. The revitalisation of areas is conducted on the basis of a programme that defines who implements an activity. Potential international financial and other assistance provided for the elimination of the consequences should be taken into consideration.

The extent of revitalisation may vary, and may involve the permanent resettlement of specific areas, i.e. people live 24 hours a day in areas with economic and other infrastructure where no restrictions and measures are in place or only to a limited extent (the transition to an existing or planned exposure situation). When the objective is economic revitalisation, areas where people do not live permanently or where they stay only during working hours are planned.

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# Abbreviations

|  |  |
| --- | --- |
| BSS | Basic safety standard |
| EAL | Emergency action level |
| EU | European Union |
| GSR | General Safety Requirements |
| IAEA | International Atomic Energy Agency |
| ICRP | International Commission on Radiological Protection |
| OIL | Operational intervention level |
| PAZ | Precautionary action zone |
| ICDP | Ingestion and commodities planning distance |
| UPZ | Urgent protective action planning zone |
| EPD | Extended planning distance  |

**Appendix 1:** **Categories of sources of hazard [1]**

* **Category I:** Reactors with a power greater than 100 MWth; spent fuel pools from reactors with a power of 3,000 MWth; facilities with an inventory of dispersible radioactive material where the total activity of the inventory is such that the ratio[[19]](#footnote-19) A/D2 exceeds 10,000.
* **Category II:** Reactors with a power greater than 2 MWth; spent fuel pools from reactors with a power between 10 MWth and 3,000 MWth; facilities with an inventory of dispersible radioactive material where the total activity of the inventory is such that the ratio of A/D2 exceeds 10.
* **Category III:** Reactors with a power lower than 2 MWth; the potential danger of a dose rate of 100 mSv/h at a distance of 1 m and with an unprotected source; facilities with an inventory of dispersible radioactive material where the total activity of the inventory is such that the ratio of A/D2 exceeds 0.01.
* **Category IV:** Activities that may cause a nuclear or radiological emergency at an unknown location; uncontrolled (lost or stolen) dangerous radiation sources; an accident during transport of radioactive material, fall of a satellite, dangerous radiation sources in scrap metals; as well as nuclear or radiological emergencies in foreign countries that do not fall into category V. Category IV represents a risk to be considered at all levels for the entire state (at the national level and in all local communities), and
* **Category V:** Areas in a state bordering a state with category I and II facilities, whose emergency planning zones and distances extend to the area of the first state.

**Appendix 2:** **Response time goals in relation to the hazard source category[[20]](#footnote-20)**

| **Actions that must be taken within the timeframe starting at t0[[21]](#footnote-21)** | **Category I** | **Category II** | **Category III** | **Category IV** | **Category V** |
| --- | --- | --- | --- | --- | --- |
| **Declaration of an emergency and the classification of emergency level**  | < 15 min | < 15 min | < 15 min | < 15 min | / |
| **A notification is sent to the organisations responsible for notifying the public** | < 15 min | < 15 min | < 15 min | < 15 min | < 15 min |
| **The activation of on-site response personnel** | < 15 min | < 15 min | < 15 min | / | / |
| **Emergency procedures to control an emergency and mitigate its consequences are initiated** | < 15 min | < 15 min | < 15 min | < 15 min | / |
| **The regulatory body for nuclear safety is activated** | < 15 min | < 30 min | < 30 min | < 30 min | / |
| **Protective actions are initiated (evacuation, etc.) to manage an emergency** | 15 min < 1h | 15 min < 1h | 15 min < 1h | 15 min < 1h | < 1h following notification |
| **The competent institutions are notified of an event** | < 15 min | < 30 min | < 30 min | < 30 min | < 30 min |
| **The notification of the public in the PAZ and the UPZ**  | 1h < 2h | 1h < 2h | 1h < 2h | 1h < 2h | 1h < 2h following notification |
| **The notification of neighbouring states and international organisations** | < 1h | / | / | / | / |
| **Technical assistance is provided to protection and rescue personnel** | < 1h | < 1h | / | / | / |
| **The provision of environmental monitoring at the site of an emergency is assured (environmental radiation measurements)** | < 2h | < 2h | < 2h | < 2h | < 2h |
| **The public is notified of urgent protective actions** | 1h–2h | 1h–2h | 1h–2h | 1h–2h | 1h–2h following notification |
| **The activation of mobile units**  | < 1h | < 1h | < 1h | < 1h | < 1h |
| **Advice provided to local authorities** | < 1h following notification | < 1h following notification | < 1h following notification | < 1h following notification | < 1h following notification |
| **An information centre for communication with the public is activated** | 1h < 2h following notification | 1h < 2h following notification | 1h < 2h following notification | 1h < 2h following notification | 1h < 2h following notification |
| **Reception centres are set up** | < 2h | < 4h | < 2h | < 4h | / |
| **Emergency monitoring operates at full capacity** | < 4h | < 4h | < 4h | < 4h | < 4h |
| **Food and commodities restriction** | < 2h | < 2h | < 2h | < 2h | < 2h |
| **Actions in relation to international trade are taken** | < 24h | < 24h | < 24h | < 24h | < 24h |
| **A request for international assistance** | < 24h | < 24h | < 24h | < 24h | < 24h |

**Appendix3: Protective actions and other response measures to protect the public in the event of a nuclear emergency – in the event of a declared general emergency due to a reactor accident at category I nuclear facility in Slovenia**

| **Protective actions and other response measures taken** | **Precautionary action zone (PAZ)** | **Urgent protective action planning zone (UPZ)** | **Extended planning distance (EPD)** | **Ingestion and commodities planning distance (ICPD)** |
| --- | --- | --- | --- | --- |
| **Evacuation** | X | X | X(if OIL1\* is exceeded, an action similar to relocation must be taken immediately, whereas more time is available for relocation) | X(if OIL1\* is exceeded, an action similar to relocation must be taken immediately, whereas more time is available for relocation) |
| **Iodine thyroid blocking** | X(action combined with sheltering or evacuation) | X(action combined with sheltering or evacuation) | X(action combined with sheltering) | X(action combined with sheltering) |
| **Sheltering** | X(when evacuation is not possible) | X(for the duration of evacuation from the PAZ) | X(if sheltering is ordered due to a radioactive cloud outside the UPZ) | X(if sheltering is ordered due to a radioactive cloud outside the EPD, which is not very likely) |
| **Area secured and under control** | X | X | X |  |
| **The decontamination of people and equipment** | (the decontamination of vehicles only at the exit from the area, as appropriate. As decontamination must not hinder evacuation, it is carried out at reception centres.) | (the decontamination of vehicles only at the exit from the area, as appropriate. As decontamination must not hinder evacuation, it is carried out at reception centres.) | X(based on measurements, OIL4\*\*\*\*) | X(in principle, carried out at reception centres outside the PAZ, the UPZ and the EPD, OIL4\*\*\*\*) |
| **The decontamination of surfaces** |  (in the transition phase only: the washing of roads, the removal of soil, mowing grass, resurfacing, etc.) |  (in the transition phase only: the washing of roads, the removal of soil, mowing grass, resurfacing, etc.) | X(based on measurements and the assessment of justification, and taking into account optimisation) | X(not very likely) |
| **The reception of and care for evacuees** |  |  |  | X |
| **Relocation** | (not an option, the public is evacuated) | X(OIL2\*\*)(when the entire UPZ is not evacuated) | X(OIL2\*\*) | X(OIL2\*\*)(not likely, but it cannot be ruled out) |
| (based on OIL2\*\* in the transition phase, check if conditions for the return of the public evacuated from the PAZ and/or the UPZ are met) |
| **Healthcare provided to injured and irradiated persons** | X(immediate care, medical treatment provided outside the PAZ, the UPZ and the EPD)  | X(immediate care, medical treatment provided outside the PAZ, the UPZ and the EPD)  | X(immediate care, medical treatment provided outside the PAZ, the UPZ and the EPD)  | X(medical treatment) |
| **Food (locally produced food, drinking water and milk) and feed restrictions** | X(OIL3 and/or OIL7\*\*\*)(this restriction is immediately imposed in the PAZ and the UPZ after a general emergency is declared; it is lifted on the basis of OILs) | X(OIL3 and/or OIL7\*\*\*)(this restriction is immediately imposed in the PAZ and the UPZ after a general emergency is declared; it is lifted on the basis of OILs) | X(OIL3 and/or OIL7\*\*\*)(if there is a risk of contamination (e.g. the passage of a radioactive cloud, considering meteorological forecasts), this action is taken quickly and discontinued on the basis of OILs) | X(OIL3 and/or OIL7\*\*\*)(if there is a risk of contamination (e.g. the passage of a radioactive cloud, considering meteorological forecasts), this action is taken quickly and discontinued on the basis of OILs) |
| **Commodities restrictions**  | X(a general restriction, which is lifted on the basis of measurements and dose assessment) | X(a general restriction, which is lifted on the basis of measurements and dose assessment) | X(based on measurements and dose assessment) | X(based on measurements and dose assessment) |

**Notes:**

\* OIL1: evacuation within the first day, iodine thyroid blocking (sheltering when evacuation is not possible).

\*\* OIL2: safe and organised relocation, the most contaminated areas have priority (where dose rates are close to OIL1).

\*\*\* OIL3 and/or OIL7: a restriction on the use of fresh, locally produced, food and milk and unprotected sources of drinking water on the basis of dose rate measurements (OIL3) or specific analyses (OIL7). The two OILs may also be used for the purposes of lifting a general restriction.

\*\*\*\* OIL4: measurements of skin contamination (the gamma dose rate at a distance of 10 cm from the skin), if the value is exceeded, decontamination must be carried out.

In the urgent protective action phase (coloured grey in the Table), actions focus on evacuation, iodine thyroid blocking and sheltering in the PAZ and the UPZ. In the EPD and the ICPD, the combined action of sheltering and iodine thyroid blocking may be taken on the basis of an estimate of the time of release and the properties of the possible spread of a radioactive cloud, if such an estimate can be madeaktivac.

1. The term *emergency* in this document differs from the term accident in regulations governing protection against natural and other disasters (An accident is an event or series of events caused by uncontrolled natural and other forces that affect or threaten the life or health of people, animals and property, cause damage to cultural heritage and the environment to such an extent that for their control and management it is necessary to use special measures, forces and means, because the measures of regular activities, forces and means are not sufficient. [2]). [↑](#footnote-ref-1)
2. The term *protective actions* in this document differs from the same term in regulations governing protection against natural and other disasters (see, for example, the provisions on protective actions in [2, Articles 59–69]. [↑](#footnote-ref-2)
3. The hazard assessment in the event of a nuclear and radiological emergency in the Republic of Slovenia [1] distinguishes between five categories of sources of hazard (Appendix 1). [↑](#footnote-ref-3)
4. A dirty bomb is a radiological dispersion device that combines radioactive material, e.g. Cs-137, Sr-90, Am-241, Ra-226 or other radionuclides, with conventional explosives. It is intended to contaminate or “dirty” the area around the explosion with radioactive material. [↑](#footnote-ref-4)
5. The term dose is used in a general sense and refers to any dose (effective or equivalent). The projected dose is the calculated dose to the population of interest over a given period of time if no protective actions are taken. [↑](#footnote-ref-5)
6. Generic criteria [2, Annex II]. [↑](#footnote-ref-6)
7. The residual dose is the dose expected to be received after protective actions have been taken and until the end of exposure. [↑](#footnote-ref-7)
8. A person at midlife with about 40 years to live will receive an additional 400 mSv over the rest of their lifetime (assuming that a given set of actions represents a reduction of 10 mSv/year in relation to another set of actions). This extra 400 mSv for the rest of his or her life can be compared to the approximately 2.5 mSv that a person receives each year from natural sources. Also taking into consideration that the risk of cancer is equivalent to receiving 0.05/Sv. Such a person "accumulates" the risk linearly over a time period of 40 years, so their average risk is ½ x 0.4Sv x 0.05/Sv = 0.01. Such risks may be acceptable for certain population groups. Furthermore, if one also takes into account the decrease in contamination due to radioactive decay and the fact that contamination moves into deeper layers or is leached and diluted, then even a few tens of mSv of additional dose in the initial phase cannot be the basis for such an action as relocation. [↑](#footnote-ref-8)
9. An example of the interaction between a health and a social factor: a family, i.e. parents at midlife with young children, live together because the parents have to take care of the children, even though the health risk is acceptable for the parents but not for the children. [↑](#footnote-ref-9)
10. The Protection strategy does not specifically address nuclear accidents where no significant release of radioactive material to the environment is foreseen, such as an accident at a dry storage of spent fuel, where even for the worst case scenario it is not foreseen that off-site protective actions would be necessary. [↑](#footnote-ref-10)
11. The size of emergency planning zones and distances is defined in accordance with the guidelines of the IAEA [11] and based on the conclusions of the Report of the working group for the preparation of hazard assessment bases for a nuclear emergency at the Krško Nuclear Power Plant [14]. [↑](#footnote-ref-11)
12. In 2015, the potential consequences of a significant release of radioactive material from category I nuclear facility were analysed for Slovenia by simulating a large number of releases [15] to determine distances for scenarios in which the values for the occurrence of stochastic effects are exceeded. The simulation results for a release of 10% of the radioisotopes from the core under different weather conditions showed that the releases are relatively evenly distributed around the power plant due to the weather conditions (indicating that this area should be treated homogeneously, without any geographical divisions) and that for very significant releases (the maximum imaginable composition of radioisotopes through filters), a precautionary action zone of 10 km is sufficiently large; even its reduction would be justified. However, for unfiltered releases past the containment, the probability of which is extremely low in the two scenarios (5.2·107), response would be required within a 25 km radius around category I nuclear facility or even beyond. According to the analysis, preparedness for response is not justified [14] for these events due to their extremely low probability of occurrence (less than once in a million years). [↑](#footnote-ref-12)
13. This applies to the extended planning distance around category I nuclear facility in Slovenia (the Krško Nuclear Power Plant), which is envisaged to extend into the territory of the Republic of Croatia. [↑](#footnote-ref-13)
14. To a lesser extent for category I facility in Slovenia, radioactive gases in the decay repository also pose a risk to the environment [19, Chapter 3.0]. [↑](#footnote-ref-14)
15. Helpers are members of the public who willingly and voluntarily help in the response to a nuclear or radiological emergency, while being aware of their potential exposure to radiation. Actions for radiation protection must also cover helpers, as appropriate and considering the type of work they perform and the risks to which they are exposed. Response actions in which they will be engaged and what exactly they will do must be defined in an emergency so that at the time they receive instructions for their work and how to perform it safely and effectively [4]. [↑](#footnote-ref-15)
16. Radioactive material (radionuclides) released to the environment in the event of a nuclear emergency are deposited on the ground and other surfaces, e.g. vehicles. Thus, people may inadvertently ingest significant quantities of radioactive material, which is not a negligible source of internal irradiation. This is especially important in the first few days following a release. Activities resulting in inadvertent ingestion include for example: the consumption of food, drinking and smoking with contaminated hands; children playing on the ground and in sandboxes; gardening and other outdoor activities for professional or recreational purposes. It is therefore important to limit access to the contaminated area. [↑](#footnote-ref-16)
17. Studies have shown that an evacuation at a rate of 5 km/h which started upon the release of radioactive material is more effective than sheltering. If an evacuation can be carried out safely, it should not be delayed, as the release of radioactive material can take several days [11]. If the public cannot be evacuated immediately (due to e.g. limited road capacities), sheltering applies while waiting for evacuation. [↑](#footnote-ref-17)
18. In accordance with requirement 4 of GSR Part 7 [4], category IV emergencies involving radiation sources not under regulatory control (lost or stolen); the transport of radioactive material, fall of a satellite, dangerous sources in scrap metals, and nuclear and radiological emergencies not in category V that occurred in another state (category V includes areas within emergency planning zones and emergency planning distances in a state for a category I or category II facility located in another (usually neighbouring) state). [↑](#footnote-ref-18)
19. The ratio means A/D2, where A is the activity of the material and D2 is the D-value for dispersible material, which is denoted as D2 [32], [33]. [↑](#footnote-ref-19)
20. Hazard sources are all facilities, devices, machines and equipment containing nuclear or radioactive material that in an emergency cause an increase in radiation. In accordance with GSR Part 7, [4] hazard sources are classified in relation to a hazard and the potential consequences of an emergency (emergency preparedness categories). [↑](#footnote-ref-20)
21. t0 is the time when the occurrence of an emergency is established. [↑](#footnote-ref-21)