Chapter 4

Preparedness and Response to Nuclear and Radiological Emergencies in Animal Production Systems in the Context of IAEA Safety Standards

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4.1 Relevant IAEA Publications on Emergency Preparedness and Response for Animal Production Systems

The IAEA has published Safety Standards and Scientific and Technical Publications to assist in developing an adequate level of preparedness and response for a NRE and includes:

- General Safety Requirements No. GSR Part 7 – Preparedness and Response for a Nuclear or Radiological Emergency (IAEA 2015)
- General Safety Guide No. GSG-2 – Criteria for Use in Preparedness and Response for a Nuclear or Radiological Emergency (IAEA 2011)
- Safety Guide No. GSG-2.1 – Arrangements for Preparedness for a Nuclear or Radiological Emergency (IAEA 2007a)
- General Safety Guide No. GSG-11 – Arrangements for the Termination of a Nuclear or Radiological Emergency (IAEA 2018a)

This chapter outlines how these requirements and guidelines apply to animal production systems to protect the food chain and water supply, prevent the ingestion of contaminated or potentially contaminated food and protect international trade. The generic criteria at which protective actions and other response actions to be taken in response to a NRE are described and the actions that can be implemented during each phase of any NRE for animal production systems are summarised.

The goals of emergency preparedness and response to a NRE are outlined in the IAEA's General Safety Requirements Part 7 (IAEA 2015). These goals include avoiding or minimising the occurrence of severe health effects due to chronic

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radiation exposure, reducing the risk of stochastic effects (e.g. increased cancer) and mitigation of the consequences of an emergency.

4.2 Phases of a Nuclear or Radiological Emergency

The arrangements, protective actions and other response actions outlined in this publication are implemented at various phases of a nuclear or radiological emergency to ensure there is adequate preparedness and response to a NRE. The stage at which the protective actions and other response actions are implemented is important to ensure their maximum effectiveness in emergency preparedness and response. Figure 4.1 outlines the various phases and exposure situations for a nuclear or radiological emergency. The phases of the emergency exposure situation are defined only for planning purposes to ensure adequate provisions are in place for an effective response in an emergency. However, during the response to a NRE, it is difficult to clearly distinguish between these various phases, especially between the early response phase and transition phase (IAEA 2015).

4.2.1 The Preparedness Stage

The preparedness stage is the stage at which adequate capabilities are in place for an effective emergency response in a nuclear or radiological emergency. This capability consists of a set of elements that include but are not limited to:

- Authority and responsibilities
- Organisation and staffing
- Coordination
- Plans and procedures
- Tools, equipment and facilities
- Training drills and exercises and
- A management system

Fig. 4.1 Temporal sequence of the various phases and exposure situations for a nuclear or radiological emergency (IAEA 2018a)

This is the time to ensure an emergency management system is established and maintained and that roles and responsibilities for preparedness and response for a nuclear or radiological emergency are clearly specified and clearly assigned. This can be achieved through the fulfilment of various requirements outlined in the IAEA GSR Part 7 (IAEA 2015).

4.2.1.1 Hazard Assessment

Requirement 4 of GSR Part 7 (IAEA 2015) requires that a hazard assessment is conducted to provide a graded approach to a nuclear or radiological emergency. The purpose of the hazard assessment is to identify facilities, activities or sources that would require appropriate response actions in the event of an emergency. These facilities are grouped based on their threat level and their potential consequences from Categories I to V (IAEA 2015). For animal production systems, the categories of primary concern are:

- Category I – Facilities that could give rise to severe deterministic effects off the site
- Category II – Facilities that could give rise to stochastic effects off the site
- Category V – Areas within emergency planning zones and distances of a facility in Category I or II located in another state

These are typically nuclear power plants, research reactors and nuclear-powered vessels.¹ A severe accident at Category I or Category II facilities can result in the distribution of radioactivity over a wide geographical area, leading to contamination of the environment and subsequent contamination of the food chain. For example, the Chernobyl and Fukushima Daiichi accidents are Category I facilities that gave rise radioactive contamination of the environment and food. Hazard assessments should be conducted periodically and bring together information at a national, regional, local and, where appropriate, international level. The results of hazard assessment should be coordinated and shared at a national level with representatives of all organisations that have a role in response to a nuclear or radiological emergency. This is to ensure that all governmental bodies and organisations, including those responsible for agriculture and food production, are in engaged in the hazard analysis.

¹Category III facilities are those that would not warrant actions off-site, for example, industrial irradiation facilities or hospitals.

Category IV are activities or acts that are at an unspecified location, for example, the transport of nuclear or radioactive material.

4.2.1.2 Development, Justification and Optimisation of a Protection Strategy

A protection strategy is developed, justified and optimised based on the hazards identified and on the potential consequences of a nuclear or radiological emergency. Optimisation of the protection strategy can be assisted with the setting of generic criteria. The generic criteria are typically expressed in terms of the dose to humans that would be received if no actions were taken (projected dose) or dose that has been received. The generic criteria are within a range of 20–100 mSv (IAEA 2015) and are set at these levels to avoid the occurrence of severe health effects due to radiation exposure and to reduce the risk of stochastic effects. If the generic criteria are exceeded, protective actions and other response actions are implemented. Table 4.1 outlines the generic criteria for protective actions and other response

Table 4.1 Generic criteria for protective actions and other response actions for food, milk and drinking water to reduce the risk of stochastic effects through the ingestion of contaminated food, milk or drinking water (IAEA 2015)

Generic criteria		
Urgent protective actions:		
Effective dose	100 mSv in the first 7 days	Restrictions on food, milk and drinking water and restrictions on the food chain and water supply
Equivalent dose in foetus	100 mSv in the first 7 days	
Early protective actions:		
Effective dose	100 mSv in the first year	Restrictions on food, milk and drinking water and restrictions on the food chain and water supply
Equivalent dose in foetus	100 mSv in the first year	
Protective actions:		
Effective dose	10 mSv in the first year from ingestion of food, milk and drinking water	Restrict consumption, distribution and sale of non-essential food, milk drinking water and water and other commodities including animal feed. Restrict the use and distribution of other commodities. Replace essential food, milk and drinking water as soon as possible or relocate the people affected if replacements are not available
Equivalent dose in foetus	10 mSv for the full period of in-utero development from ingestion of food, milk and drinking water	
Response actions to restrict international trade:		
Effective dose	1 mSv per year	Restrict non-essential international trade of food and other commodities such as animal feed
Equivalent dose in foetus	1 mSv for the full period of in-utero development	

actions related to food, milk, drinking water and nonfood commodities such as animal feed in an emergency to reduce the risk of stochastic effects.

Generic criteria are based on doses that need to be determined in the preparedness phase taking into account a large number of factors (IAEA 2015). The generic criteria can contain considerable uncertainties; therefore, they cannot be used directly in emergency response where urgent actions are required. Instead a set of operational criteria are derived, in advance, from the generic criteria that can be used directly in an emergency to allow the effective implementation of protective actions including food milk and drinking water restrictions and their associated arrangements. The operational criteria are:

1. The observables at the scene of the nuclear or radiological emergency: Observables can include an unshielded, damaged or potentially damaged source; a major spill from a potentially damaged source; a fire, explosion or fumes from a dangerous source; an earthquake or a suspected radiological dispersal device.
2. Emergency Action Levels (EALs): These are specific, predetermined and observable criteria based on abnormal facility conditions. For Category I and II sites, certain EALs will lead to the declaration of a general emergency, with off-site consequences.
3. Operational Intervention Levels (OILs). OILs are operational criteria that allow the prompt implementation of protective actions and other response actions on the basis of monitoring results that are readily available during a nuclear or radiological emergency.

The relationship between generic criteria and operational criteria are outlined in Fig. 4.2.

Fig. 4.2 The system of generic criteria and operational criteria

Table 4.2 Codex guideline levels for radionuclides in foods with contamination following a nuclear or radiological emergency for use in international trade (CODEX STAN 2006)

Product name	Representative radionuclides	Guideline level (Bq/kg, fw)
Infant foods	^{238}Pu , ^{239}Pu , ^{240}Pu , ^{241}Am	1
	^{90}Sr , ^{106}Ru , ^{129}I , ^{131}I , ^{235}U	100
	^{35}S , ^{60}Co , ^{89}Sr , ^{103}Ru , ^{134}Cs , ^{137}Cs , ^{144}Ce , ^{192}Ir	1000
	^3H , ^{14}C , ^{99}Tc	1000
Foods other than infant foods	^{238}Pu , ^{239}Pu , ^{240}Pu , ^{241}Am	10
	^{90}Sr , ^{106}Ru , ^{129}I , ^{131}I , ^{235}U	100
	^{35}S , ^{60}Co , ^{89}Sr , ^{103}Ru , ^{134}Cs , ^{137}Cs , ^{144}Ce , ^{192}Ir	1000
	^3H , ^{14}C , ^{99}Tc	10,000

4.2.1.3 International Trade of Food Following a Nuclear or Radiological Emergency

The trade of food internationally following a nuclear or radiological emergency is governed by the Joint FAO/WHO Codex Alimentarius Commission Guidelines for radionuclides in food (CODEX STAN 2006). Similar to the generic criteria for the restriction of food traded internationally outlined in Table 4.1, the guideline levels are based on a reference level of 1 mSv per year. Assuming 10% of the diet consumed is from imported food, guideline values have been determined for 20 radionuclides for infant foods and other foods other than infant foods. The 20 radionuclides have been divided into four groups based on their radiotoxicity and are outlined in Table 4.2. If food traded internationally are below the guideline levels, then they are deemed safe for human consumption. As these values are only guideline levels, if they are exceeded, national governments will need to determine whether these foods can be traded and consumed within their jurisdiction.

4.2.1.4 OILs for Triggering Food, Milk and Drinking Water Restrictions

The IAEA have derived default OILs for use in a nuclear or radiological emergency based on generic criteria (IAEA 2011). Default OIL values need to be established in the preparedness phase in order to make decisions quickly in the urgent and early phases of an emergency when information is limited.

In the early phase of an emergency, surface contamination measurements are relatively easy to obtain using field survey instruments. OIL 1, OIL 2 and OIL 3 are measurements of ground contamination calling for urgent protective actions, early protective actions and restrictions to be implemented to keep the dose to any person below the generic criteria (for examples of generic criteria, see Table 4.1). This includes the implementation of the appropriate restrictions on food, milk and

Table 4.3 Default OILs for deposition (IAEA 2011)

OIL	OIL value	Protective action for food restrictions if exceeded
OIL 1	Gamma 1000 $\mu\text{Sv/h}$ at 1 m from a surface or a source 2000 count(s) direct beta surface contamination measurement 50 count(s) direct alpha surface contamination measurement	Stop consumption of local produce, rainwater and milk from animals grazing in the area
OIL 2	Gamma 100 $\mu\text{Sv/h}$ at 1 m from a surface or a source 200 count(s) direct beta surface contamination measurement 10 count(s) direct alpha surface contamination measurement	Stop consumption of local produce, rainwater and milk from animals grazing in the area until they have been screened and contamination levels have been assessed using OIL 5 and OIL 6
OIL 3	Gamma 1 $\mu\text{Sv/h}$ at 1 m from a surface or a source 20 count(s) direct beta surface contamination measurement 2 count(s) direct alpha surface contamination measurement	Stop consumption of non-essential local produce, rainwater and milk from animals grazing in the area until it has been screened and contamination levels have been assessed using OIL 5 and OIL 6 Screen local produce, rainwater and milk from animals grazing in the area out to at least ten times the distance to which OIL 3 is exceeded and assesses samples using OIL 5 and OIL 6 Consider providing iodine thyroid blocking for fresh fission products and for iodine contamination if replacement for essential local produce or milk is not immediately available Estimate the dose of those who may have consumed food, milk or rainwater from the area where restrictions were implemented to determine if medical screening is warranted

drinking water. Table 4.3 outlines the default OILs for ground/surface contamination and the response action for food, milk and drinking water if the OIL is exceeded.

If ground/surface contamination measurements indicate the exceedance of generic criteria, food, milk and drinking water, restrictions may be put in place. Further analysis will be required to confirm or lift these restrictions. This requires the analysis of food, milk and drinking water samples. OIL 5 is a screening of potentially contaminated foodstuffs for gross alpha and beta activity. If the gross alpha and beta screening levels are below the OIL 5 values, then the foodstuff is safe to consume in the emergency phase. If the screening level is exceeded, then additional analysis is required to determine the radionuclide-specific concentrations in the food, milk or drinking water; this analysis is based on the use of OIL 6. The collection and analysis of food, milk and drinking water sample analysis of specific radionuclides and comparison with their corresponding OIL 6 values are very time-consuming and complex. Comprehensive activity concentrations in

Table 4.4 Default OILS for contamination of food milk and drinking water (IAEA 2011)

OIL	OIL value	Response action if exceeded
OIL 5	Gross beta, 100 Bq/kg Or Gross alpha, 5 Bq/kg	Assess using OIL 6
OIL 6	$\sum_i \frac{C_{f,i}}{\text{OIL}_{6i}} > 1$ <p>Where $C_{f,i}$ is the concentration of radionuclide i in the food, milk or water and OIL_{6i} is the radionuclide specific OIL for radionuclide i</p>	<p>Stop consumption of non-essential food, milk or water and conduct an assessment based on realistic consumption rates. Replace essential food, milk and water promptly, or relocate people if replacement of food, milk and water is not possible</p> <p>For fission products (e.g. containing iodine) and iodine contamination, consider providing iodine thyroid blocking if replacement of essential food, milk or water is not immediately possible</p> <p>Estimate the dose of those who may have consumed food, milk or rainwater from the area where restrictions were implemented to determine if medical screening is warranted</p>
For an emergency at a light water reactor (IAEA 2013a)		
OIL 7	1000 Bq/kg of I-131 Or 200 Bq/kg of Cs-137	<p>Within days: Stop the consumption, distribution and sale of the affected food, milk or drinking water. If the food, milk or drinking water is essential, replace it</p> <p>Within weeks: Estimate the dose from all exposure pathways for those who may have consumed food, milk or drinking water with activity concentrations greater than OIL 7 to determine if medical screening is warranted</p>

food, milk and drinking water may not be readily available in the timeframes required for effective decision-making in the early stages of an emergency. Therefore, the IAEA has defined an additional OIL 7 but for light water reactor emergencies only (IAEA 2013a) (Table 4.3). The OIL 7 values are defined through ^{131}I and ^{137}Cs as marker radionuclides (but they consider all other radionuclides that are likely to be discharged as a result of an emergency at a light water reactor).

Table 4.4 outlines the default OILs for food milk and water along with the response action if the OIL is exceeded.

Restrictions on food, milk and drinking water can be implemented based on generic criteria or OILs only if they are non-essential and there are alternative sources of food, milk or drinking water available. These restrictions cannot be implemented if they would result in severe malnutrition, dehydration or other severe health impacts (IAEA 2015).

For nonfood commodities, for example, animal feed response actions such as restrictions on its use or trade can be developed using OIL_C values. Methods for the derivation of OIL_C values are outlined in IAEA GSG-11 (IAEA 2018a).

Table 4.5 Suggested sizes for emergency zones and distances for light water reactors (IAEA 2013a)

Emergency zones and distances	Suggested maximum radius (km)	
	≥1000 MW(th)	100–1000 MW(th)
Precautionary action zone (PAZ)	3–5	
Urgent protective action planning zone (UPZ)	15–30	
Extended planning distance (EPD)	100	50
Ingestion and commodities planning distance (ICPD)	300	100

4.2.1.5 Emergency Planning Zones and Emergency Planning Distances

In accordance with the development of a protection strategy as outlined in IAEA’s GSR Part 7 (IAEA 2015), arrangements need to be made in the preparedness stage to ensure effective decision-making in the taking of urgent protective actions, early protective actions and other response actions. Given the limitations on the information available in the urgent and early phases of an emergency, the response actions are assisted through the establishment of specific off-site emergency planning zones and emergency planning distances (IAEA 2007a). These emergency planning zones and distances are applicable to facilities in Emergency Preparedness Categories I and II and in areas in Emergency Preparedness Category V.

The emergency planning zones and distances include a precautionary action zone (PAZ), an urgent protective action planning zone (UPZ), an extended planning distance (EPD) and an ingestion and commodities planning distance (ICPD). These zones and distances range from a few up to hundreds of kilometres and are contiguous across country borders. Table 4.5 outlines the suggested sizes for the emergency planning zones and emergency planning distances for light water reactors, based on their power levels, but the actual boundaries of these need to be defined by local conditions and landmarks (e.g. roads and rivers) so that they are easily identified during an emergency. An example of these zones and distances for light water reactors can be seen in Fig. 4.3 (IAEA 2013a).

4.2.2 Emergency Exposure Situation

A nuclear or radiological emergency can be declared as a result of an actual or potential release of radioactivity.

Once a nuclear or radiological emergency has been declared, prompt action is required during the emergency exposure situation. The emergency exposure situation can be divided into three phases as outlined in Fig. 4.1. The timeline of these phases is dependent on the nature and scale of the nuclear or radiological emergency. The sequence of protective actions as a result of a nuclear or radiological emergency is outlined in Fig. 4.4.

Fig. 4.3 Emergency planning zones and emergency planning distances (IAEA 2013a)

Fig. 4.4 Temporal sequence of various types of protective actions and recovery options for a nuclear or radiological emergency (IAEA 2018a)

4.2.2.1 The Urgent Response Phase

The urgent response phase is the period in which actions must be taken within hours or days to be effective; these are the precautionary and urgent protective actions that have been predetermined in the preparedness phase and are based on observables and conditions at a facility (e.g. the declaration of a general emergency).

Precautionary urgent protective actions are implemented before or shortly after a release of radioactive material to avoid severe deterministic effects. For Category I facilities, the precautionary urgent protective actions include the consumption of an ITB agent, the safe evacuation of the PAZ beyond the UPZ and food, milk and drinking water restrictions. These precautionary urgent protective actions should take place within an hour of the declaration of a general emergency (IAEA 2013a).

Urgent protective actions need to be implemented within hours or days of the declaration of an emergency to maximise their effectiveness. These actions include evacuation, short-term sheltering, actions to reduce inadvertent ingestion, decontamination of individuals and protection of the food and water supplies, restrictions on significantly contaminated food and water supplies and the provision of

instructions to protect agricultural products. These urgent protective actions are implemented within the predetermined emergency planning zones and distances.

Within the UPZ, urgent protective actions can include sheltering or evacuation, administering of ITB agents, actions to reduce inadvertent ingestion and instructions to the public not to consume food that may have been directly contaminated or to consume milk from animals that may graze on contaminated ground.

The principle urgent protective action within the EPD is to take actions to reduce inadvertent ingestion by keeping hands away from the mouth, not to drink, eat or smoke until hands are washed, and to avoid activities that could result in the creation of dust that could be ingested.

The urgent protective actions within the ICPD are to place grazing animals on protected feed if feasible, to protect food and drinking water sources and to stop the consumption and distribution of non-essential local produce, wild-grown produce, milk from grazing animals and animal feed until the levels of contamination have been assessed.

Environmental monitoring should also begin as soon as practicable to implement the appropriate restrictions on food and drinking water from rainwater where they may be contaminated to levels requiring restrictions. In practice, it may only be feasible to conduct ground/surface monitoring in the PAZ and UPZ to determine whether OIL 3 has been exceeded and food restrictions are required. Further and more comprehensive environmental monitoring will be required during the subsequent phases of the emergency.

Following the declaration of an emergency, specific urgent protective actions can be implemented before and shortly after the release of radioactivity to the environment to reduce the risk of contamination of animals. Such actions include (Nisbet et al. 2015):

- Short-term sheltering of animals
- Provision of clean feed
- Covering of harvested fodder
- Closure of air intake valves at food processing plants

These urgent protective actions are applicable for areas in threat Categories I, II and V.

4.2.2.2 The Early Response Phase

At the early response phase, the radiological situation has been sufficiently characterised to enable the implementation of actions that are effective within days or weeks; these are the early protective actions.

Early protective actions are those pre-established in the preparedness phase and are based on operational criteria, such as OILs, until more detailed characterisation of radioactivity in the environment and laboratory analysis of food, milk and water samples are conducted in the transition phase.

The environmental monitoring, sampling and laboratory analysis can be used to start adjusting the initial protective actions implemented in the urgent response phase to confirm the adequacy of the controls in place, to provide for additional protective actions or to remove restrictions. This could lead to:

- Longer-term restrictions on food, milk and drinking water
- Relocation of people if they are living in areas where essential food and drinking water is contaminated and replacements cannot be provided
- Actions to prevent contaminated food and animal feed from entering the food chain

There may also be a need to revise the OIL values and to extend monitoring and assessment beyond the initial emergency planning zones and distances to take into account the conditions during the emergency. This could lead to additional restrictions or the lifting of restrictions on food, milk and drinking water in certain areas.

Consideration also needs to be given to the protection of international trade and commercial interests, and restrictions can be placed on food and commodities from affected areas until it has been verified that they do not exceed internationally agreed criteria for trade (IAEA 2013b).

The early response phase is the time where other agricultural countermeasures can begin to be implemented in order to protect the food chain and to avert dose over longer time periods. In addition to the early protective actions listed above, the other protective actions considered most effective for animal production systems in the early phase are (Nisbet et al. 2015):

- Slaughtering of animals or dairy livestock shortly after deposition
- Restrictions on the gathering of wild foods, hunting and fishing
- Suppression of lactation before slaughter to avoid the production of contaminated milk

4.2.2.3 The Transition Phase

The transition phase commences once the radioactive source is under control, the situation is stable and the radiological situation is well understood. Once this occurs there is a progression to the point at which the emergency can be terminated through the reduction of long-term exposures and the improvement of living conditions in the affected areas (IAEA 2018a).

At this phase of the emergency the actions implemented are, in a large part, remedial or recovery actions as the more disruptive protective actions have been implemented in the urgent and early response phases. Furthermore, the actions in the transition phase are not driven by urgency and can be justified and optimised through consultation with interested parties, whereas in the earlier phases of an emergency, consultation with interested parties is limited.

A number of aspects need to be considered at the preparedness phase when establishing arrangements for the transition phase. Three key elements to be considered for animal production systems are:

- The lifting or adapting of protective actions
- Radioactive waste management
- Dealing with non-radiological affects

The protective actions that were implemented in the urgent and early response phases are based on operational criteria that were predetermined in the emergency preparedness phase and on the limited environmental monitoring that is conducted in the early response phase.

OILs can be used to consider which specific protective actions can be lifted or adapted. For example, restrictions on food, milk and drinking water in the urgent and early response phases were based on EALs and OIL3. OIL 5, OIL 6 and/or OIL 7 can be used to adjust any restrictions imposed. In the transition phase, a comprehensive sampling and monitoring programme is carried out to determine the levels of radioactivity in the environment and in food, milk and drinking water. This detailed radiological characterisation can be used to determine the dose in the future after protective actions have been lifted, i.e. the residual dose. The residual dose can be determined once the exposure pathways have been characterised and the urgent and early protective actions are known.

The final decision on the adapting or lifting protective actions are based on these residual dose assessments. In order to terminate an emergency, the residual dose should be in the order of 20 mSv effective dose in a year (IAEA 2015). In the transition phase, after more comprehensive sampling and monitoring of food, milk and drinking water, the actual dose from ingestion can be calculated, and its contribution to the residual dose can be estimated to determine whether this protective action can be adapted or lifted (IAEA 2018a).

The lifting or adapting of protective actions may also be possible through the implementation of decontamination and dose reduction techniques. In animal production systems, the techniques that can be used in the transition phase for dose reduction are (Nisbet et al. 2015):

- Selective grazing whereby animals are restricted from grazing on highly contaminated land and moved to pastures with lower contamination
- The addition of additives to animal feed to inhibit the uptake of radionuclides
- Decontamination or processing of milk to reduce the radioactivity levels
- Live monitoring of animals to determine whether clean feeding or the addition of additives to feed can be implemented before slaughter to reduce levels of significant contamination

4.2.2.4 Radioactive Waste Management

The management of radioactive waste increases in importance in the transition phase of an emergency response as, earlier in an emergency, the focus is primarily on implementing protective actions. Large-scale nuclear or radiological emergencies can generate large volumes of radioactive waste capable of overwhelming national capabilities for radioactive waste management and delaying the termination of an emergency. The waste generated during a nuclear or radiological emergency can be as a result of the emergency situation or could arise from the protective actions or other response actions implemented during the emergency (IAEA 1987, 2013b).

Before the disposal of any waste arising from a nuclear or radiological emergency, it needs to be identified, characterised and categorised taking into account the various radiological and non-radiological (chemical, biological, physical and mechanical) aspects of the waste. This should be based on regulations on radioactive waste management that should be developed in the preparedness phase. Methodologies also need to be developed in advance for the identification of appropriate storage options and sites and the predisposal management of radioactive waste through segregation, packing, transport and storage. Arrangements should also be made to minimise the amount of waste declared as radioactive waste through the introduction of clearance levels for waste materials or through the reuse or recycling of the waste.

Consideration should also be given to obtain international assistance in waste management.

In animal production systems, the management of animal remains also needs to be given special consideration. For animal production systems, management options need to be identified for the disposal of animal carcasses. Workers handling the animal carcasses need to be trained in basic radiation protection principles, and they need to be provided with the appropriate equipment to ensure their exposure to radioactivity is kept to a minimum (IAEA 2013b).

The disposal options that can be considered in the transition phase include (Nisbet et al. 2015):

- The biological treatment of contaminated milk through aerobic and anaerobic digestion
- The disposal of contaminated milk to sea
- The burial or burning of animal carcasses following slaughter
- Disposal of contaminated food to landfill with an option of incineration beforehand to reduce the volume being disposed
- Landspreading of contaminated milk and/or contaminated slurry
- Rendering of animal carcasses to reduce volumes before disposal

4.2.2.5 Dealing with Non-radiological Consequences

In the early stages of emergency response, the radiological issues typically outweigh non-radiological consequences, but in the transition phase, as doses tend to decrease with the effective implementation of protective and recovery actions, non-radiological factors become increasingly important. These non-radiological consequences include psychosocial, economic and political factors and require the active participation of the public and other interested parties in the transition phase. This can include the psychosocial impact of farm and veterinary workers in areas affected by radioactive contamination. For example, farmers concern about growing or selling produce (Takebayahi et al. 2017).

A nuclear or radiological emergency and the protective actions implemented in the emergency response phase can have a detrimental impact on the economy, trade and people's livelihood. Therefore, compensation for the damage caused by nuclear or radiological emergencies may be required in these instances. This was demonstrated in the United Kingdom in the wake of the Chernobyl accident in 1986 where farmers were compensated for market losses incurred on sheep sold at auction (Kerr and Mooney 1988; IAEA 2018a).

4.2.3 *The Termination of a Nuclear or Radiological Emergency*

The termination of a nuclear or radiological emergency is based on a formal decision that is made public and is made in consultation with interested parties. The termination of the emergency takes into consideration both radiological and non-radiological consequences and can be implemented at different times and in different geographical areas depending on the nature and scale of the emergency (IAEA 2015).

A nuclear or radiological emergency can only be terminated once a number of general and specific prerequisites have been met. The source of the nuclear or radiological emergency should be under control, the future development of the situation is well understood and no further significant releases or exposures should be expected. All of the urgent and early protective actions should be implemented, with the possibility that some may already be lifted or adapted, and the radiological situation should be well characterised with doses assessed for the affected populations. This includes the dose ingested through the consumption of food from animal production systems. The radiological situation should be assessed against the appropriate reference levels, generic criteria and operational criteria to determine whether the residual dose of the affected population is at or below approximately 20 mSv per year (IAEA 2018a).

Once all the prerequisites for the termination of an emergency have been met, the emergency exposure situation ends, and the end of the emergency can be declared.

4.2.4 Planned or Existing Exposure Situation

Once the emergency has been terminated the situation moves to either a planned or existing exposure situation (Fig. 4.1).

Nuclear or radiological emergencies that do not result in a significant release of radioactivity into the environment and do not result in long-term exposure of individuals due to residual radioactive material can transition to a planned exposure situation. In these circumstances, these situations are not expected to result in an exposure situation that differs from one that existed prior to the emergency (IAEA 2018a).

An emergency that has resulted in a significant release of radioactive material to the environment, typically a nuclear emergency, will result in exposure during the emergency and in the long term due to residual radioactivity in the environment. For these situations, once the end of an emergency has been declared, the situation transitions to an existing exposure situation (IAEA 1987, 2013b, 2018a).

The IAEA requirements and guidance for planned and existing exposure situations are governed by additional IAEA safety standards series publications and include but not limited:

- General Safety Requirements No. GSR Part 3 – Radiation Protection and Safety of Radiation Sources: International Basic Safety Standards (IAEA 2013b)
- General Safety Guide No. GSG-8 – Radiation Protection of the Public and the Environment (IAEA 2018b)
- Safety Guide No. WSG-3.1 – Remediation Process for Areas Affected by Past Activities and Accidents (IAEA 2007b)

4.2.4.1 Restrictions on Food, Milk and Drinking Water After the Termination of an Emergency

Once the end of an emergency has been declared, any restrictions implemented on food, milk or drinking water are no longer governed by the requirements for emergency exposure situations (IAEA 2016). Instead, for existing exposure situations, the framework is governed by the WHO Guidelines for Drinking-Water Quality (WHO 2011) and the IAEA GSR Part 3 (IAEA 2013c). The WHO Guidelines for drinking water quality sets a reference level of 0.1 mSv per year for consumption of drinking water from all sources of radioactivity. Requirement 51 of GSR Part 3 requires regulatory bodies to establish reference levels for exposure due to food, feed and drinking water based on a dose that doesn't exceed a value of about 1 mSv per year.

For food used in international trade, the Codex Alimentarius guidelines outlined above still apply in an existing exposure situation (CODEX STAN 2006).

Following any nuclear or radiological emergency, it is important that arrangements remain in place to reassure the public and interested parties (such as trading partners) that the food meets international standards. This can be achieved through

a testing and certification system that can verify that food products are safe and do not exceed the reference levels and internationally agreed criteria for trade (IAEA 2013a).

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