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Building a Framework for Post-Nuclear Accident Recovery Preparedness

National-Level Guidance

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Radiological Protection

Building a Framework for Post-Nuclear Accident Recovery Preparedness: National-Level Guidance

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The mission of the NEA is:

- to assist its member countries in maintaining and further developing, through international co-operation, the scientific, technological and legal bases required for the safe, environmentally sound and economical use of nuclear energy for peaceful purposes.
- to provide authoritative assessments and to forge common understandings on key issues as input to government decisions on nuclear energy policy and to broader OECD analyses in areas such as energy and the sustainable development of low-carbon economies.

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Foreword

The OECD Nuclear Energy Agency (NEA) has a long tradition of promoting co-operation and assistance among its member countries on preparedness for nuclear and radiological emergency exposure situations and consequence management in the short, medium, and long term. This service is effectively implemented through the forum provided by the Committee on Radiological Protection and Public Health (CRPPH), as well as its subsidiary Working Party on Nuclear Emergency Matters (WPNEM). These organisations facilitate the sharing and analysis of experience in policy, regulation, and implementation of the system of radiological protection, as well as addressing and solving emerging issues.

The area of recovery management has been of interest to the CRPPH and WPNEM for some time. This includes the issue of managing the medium-term consequences of protection strategies during the early transition phase after a nuclear or radiological accident. This topic was addressed by the 3rd NEA International Nuclear Emergency Exercise (INEX-3) in 2005-2006, the conclusions of which led to the establishment of the Expert Group on Recovery, Food Countermeasures and Agriculture, and the Expert Group on Countermeasures. These two groups produced a combined report on Strategic Aspects of Nuclear and Radiological Emergency Management, published in 2010, which identified the need for a recovery framework to improve the preparedness arrangements for emergency management.

A decade after the Fukushima Daiichi Nuclear Power Plant accident and 35 years after the Chernobyl accident, improving preparedness for recovery from a nuclear or radiological accident remains a priority for NEA member countries and many partners around the world. In this context, the Expert Group on Recovery Management (EGRM), was launched by the CRPPH in 2019. The group's remit was to develop a comprehensive and operational generic framework for preparedness for recovery management that could be easily adapted to national conditions. The group's ambition has now been realised with the publication of this report, based primarily on the many lessons learnt from the Fukushima Daiichi and Chernobyl nuclear power plant accidents, but also on the recent or ongoing development of national recovery preparedness arrangements in some countries. The NEA is confident that this framework will act as a reference document to assist countries in developing harmonised national plans and procedures for post-accident recovery preparedness.

Acknowledgements

This report was prepared by the Nuclear Energy Agency (NEA) Expert Group on Recovery Management (EGRM) held under the Committee on Radiological Protection and Public Health (CRPPH). It was discussed at a dedicated session during the CRPPH annual meeting in April 2021 and finalised by the NEA Secretariat after formal approval by the CRPPH. The NEA expresses its appreciation to the members of the EGRM for their dedicated work and valuable contributions to ensure the creation of this report.

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The NEA also thanks everyone involved in the organisation of the workshop on "Preparedness for Post-Accident Recovery: Lessons from Experience", held on 18-19 February 2020 in Tokyo, Japan. This event provided a unique opportunity for the EGRM to discuss and analyse the successes and remaining challenges in major recovery elements (e.g. food safety, monitoring, waste management, business, and well-being). This is in addition to discussions for the structuring of a nuclear post-accident recovery management framework to improve preparedness.

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CODIRPA	Steering Committee for the Management of the Post-Accident Phase in the Event of Nuclear Accident or a Radiological Emergency Situation (France)
CONDO	Software for estimating the consequences of decontamination options
CONFIDENCE	COping with uNcertainties For Improved modelling and DEcision making in Nuclear emergenCiEs
CRPPH	NEA Committee on Radiological Protection and Public Health
EGRM	NEA Expert Group on Recovery Management
ENGAGE	ENhancinG stAkeholder participation in the GovernancE of radiological risks for improved radiation protection and informed decision-making
EPR	Emergency preparedness and response
ERMIN	European model for inhabited areas
FEMA	Federal Emergency Management Agency (United States)
FSC	Food Safety Commission (Japan)
HERCA	Heads of the European Radiological Protection Competent Authorities
IAEA	International Atomic Energy Agency
IASC	Inter-Agency Standing Committee
ICRP	International Commission on Radiological Protection
INEX	NEA International Nuclear Emergency Exercises
MHLW	Ministry of Health, Labour and Welfare (Japan)
MHPSS	Mental Health and Psychosocial Support
MPL	Maximum permitted levels
NCRP	National Council on Radiation Protection and Measurements (United States)
NEA	Nuclear Energy Agency
NERHQ	Nuclear Emergency Response Headquarters (Japan)
NSC	Nuclear Safety Commission (Japan)
OECD	Organisation for Economic Co-operation and Development
PREPARE	Innovative integrated tools and platforms for radiological emergency preparedness and post-accident response in Europe
RODOS	Real-time Online Decision Support System for off-site emergency of nuclear power plants
TEPCO	Tokyo Electric Power Company (Japan)

TERRITORIES	To Enhance unceRtainties Reduction and stakeholders Involvement TOwards integrated and graded Risk management of humans and wildlife In long-lasting radiological Exposure Situations
WEST	Waste estimation support tool
WHO	World Health Organization
WPNEM	NEA Working Party on Nuclear Emergency Matters

Executive summary

Recovery from a nuclear or radiological accident is a long, complex and resource-intensive process. While the development of efficient response plans as part of preparedness is well supported by international guidance, limited material exists for preparing for long-term recovery. The purpose of this publication is to provide key considerations for the development of a national-level preparedness framework to manage recovery from a radiological or nuclear accident. All countries (including those with no nuclear facilities) should develop such a framework as it is key to ensuring that the recovery process is managed effectively, required resources are identified, and that the objectives of recovery are ultimately achieved.

Past experiences from nuclear, radiological, and other types of severe accidents have highlighted the difficulties that may be encountered if there is a failure to prepare adequately for recovery. In any recovery situation, the effectiveness of the operations carried out will be highly dependent on the resources that can be mobilised as well as the organisation of these resources. If the necessary resilience to deliver effective operations is not developed during the preparedness phase, the ability to deliver the best possible outcomes will be undermined. The process for establishing a framework for recovery preparedness proposed in this report follows a cyclical approach and is based on three aspects: 1) key elements of preparedness for recovery; 2) objectives of recovery, and; 3) strategies to achieve and assess these objectives.

Depending on national arrangements, the adoption of an all-hazards approach that makes use of a common framework to support recovery irrespective of the nature of the emergency should be used. Planning should be risk-informed, proportionate, flexible, scalable, and non-prescriptive, and should consider a large range of potential risks and impacts while considering the specificities for a nuclear or radiological accident. Governance, roles, responsibilities and co-ordination should be anticipated, legal requirements considered, and international and/or transboundary harmonisation facilitated within a framework for recovery preparedness. Since decisions covered by such a framework can have significant impacts on the population concerned, the integration of ethical principles such as prudence, justice, and dignity, is key to ensure that decisions made on the basis of the framework are far-sighted, and equitable, and that they respect individual autonomy.

When developing a recovery preparedness framework, it is important to set out the objectives of recovery. The recovery objectives proposed in this publication are three-fold: ensuring health and well-being, supporting the economy, and protecting the environment. It is recommended that these objectives are achieved in a holistic and inclusive manner in close co-ordination with relevant including key local stakeholders. Also, vulnerable populations need to be carefully considered in recovery preparedness strategies.

Experience from past nuclear accidents has shown that decision makers must consider non-radiological public health aspects in decision-making processes. This includes the anxiety caused by the presence of radiation as well as the harmful consequences of protective actions, both of which can result in poor mental health and psychosocial well-being. Recovery preparedness should aim to quickly enable:

- active dialogue with the affected population through different communication channels;
- the re-establishment of a functioning societal framework;
- the provision of training and education on radiological issues and on mental health and psychosocial support;
- the establishment of indicators for well-being with all stakeholders; and
- the preparation of a health surveillance strategy.

Investing in emergency and recovery preparedness is usually more cost-effective than implementation of unprepared emergency and recovery actions in the event of an accident. To support the economy, the recovery framework should enable efficient co-ordination of economic issues with recovery actions. This includes encouraging businesses in the proximity of nuclear facilities to consider risks associated with nuclear emergencies such as potential image loss of the region and regional commodities. In addition, mechanisms to encourage future economic activities in affected regions should be developed. Furthermore, existing compensation and economic support initiatives should be reviewed, and specific guidance for trade issues following a nuclear accident should be produced.

A framework for recovery preparedness should consider the protection of the environment as a key component in optimisation and decision-making. Environmental protection recovery objectives should be identified and, where possible, draw on all-hazards plans. To this end, specific arrangements for post-accident recovery should be aligned with national policy, strategy, and legislation for protection of the environment. Environmental recovery objectives should also be used as the basis for discussions with an extended panel of stakeholders and wider environmental protection issues considered.

Stakeholder involvement, public communication and dissemination of information are cross-cutting issues that need to be addressed in a recovery preparedness framework. Public communication is a two-way process and relationships with community stakeholders are integral in the "co-expertise process". Ensuring consistent messaging through the transition from emergency response to emergency recovery is vital. Thus, the development of recovery risk communication strategies and the planning for different communication channels should be included in the recovery preparedness framework. In addition, the identification and early involvement of stakeholders and the special consideration of vulnerable populations should be addressed.

There are a number of cross-cutting issues affecting preparedness for post-accident recovery which can be grouped under the concept of building resilience. These include planning, capacity and capability building, exercising, and education and training. A recovery preparedness framework should include the critical evaluation of capacity and capability, exercising and testing arrangements, and provision of education and training to people who will be involved in recovery management.

The management of contaminated goods in the months and years after a nuclear or radiological accident is an important factor with cross-cutting implications. A recovery preparedness framework should include international considerations while providing enough flexibility to incorporate national and regional specificities, rather than exclusively focusing on strategies at any one level. It should include the radiological criteria that might be applied, the preparation of an extended food monitoring strategy and plans for appropriate protective actions.

Remediation of inhabited areas and food production systems may take place over months, years or even decades after a nuclear or radiological accident. A remediation strategy should be developed as part of a recovery preparedness framework. Such a strategy should include the anticipation of infrastructure and resource requirements, the establishment of a process to accomplish remediation, and the collection of important data and information that will support decision-making on remediation.

Nuclear and radiological accidents have the potential to generate large volumes of radioactive waste. Therefore, specific arrangements need to be put in place to deal with the increased volume and types of waste. This should include a critical evaluation of national policy, strategy, and legislation as well as the adoption of a proportionate approach to waste management preparedness. Furthermore, modelling tools should be used to support decisions and inform plans for the management of waste. Radiological criteria for waste management should be evaluated and treatment and storage plans established. A recovery preparedness plan should also include preparations for staging and defining endpoints.

Following a nuclear accident, a comprehensive environmental monitoring programme will confirm the spatial distribution of the contamination, its radionuclide composition, physical and chemical properties, heterogeneity, and its evolution in time via various transport mechanisms (e.g. weathering, dispersion in the environment, plant and animal uptake). Human dose assessments will show the distribution of external and internal doses arising from various exposure pathways. The monitoring programme in the recovery phase will evolve as the radiological situation and the concerns and needs of stakeholders change. Similarly, dose assessment is continuously refined as a result of the increased availability of monitoring data and the re-evaluation of the radiological situation. As part of a recovery preparedness framework, an environmental monitoring programme and a human dose assessment programme should be planned.

Based on the strategies identified above, countries should implement national recovery preparedness frameworks, taking into account national requirements and specificities. In accordance with the cyclical approach of the proposed recovery preparedness framework, national frameworks should be continuously improved through feedback obtained from exercises or experience from real situations. As recovery exercises, especially those focusing on long-term recovery, are rare and not yet required by international standards, there is a need for more exercising in this area. The NEA could play a role in gathering countries together to exchange expertise and best practices in implementing recovery frameworks. Also, the organisation of a recovery exercise as part of the NEA International Nuclear Emergency Exercise (INEX) series could help improve recovery preparedness at the international, national and local levels.

More research is needed on the long-term direct and indirect consequences of nuclear or radiological accidents on the economy and international trade to complement the ongoing research activities on long-term Mental Health and Psychosocial Support (MHPSS). Another aspect that deserves further investigation is the optimisation of decision-making in the emergency response phase. In particular, stakeholder involvement and the balancing of protective actions taken during the emergency response phase and their long-term non-radiological consequences (i.e. mental health and well-being, environmental and socio-economic impacts).

Introduction – What is at stake?

There are different phases in the management of a nuclear accident – the early and intermediate phases of emergency response and the long-term phase where the recovery process is implemented (ICRP, 2020). Documents such as the IAEA's *Considerations in the Development of a Protection Strategy for a Nuclear or Radiological Emergency* (2021) underline the importance of the preparedness stage for the development of efficient plans for the response to a radiological or nuclear accident. However, there are limited international documents which extend to preparedness for the longer-term recovery. The recovery phase presents different challenges to the early and intermediate phases. Therefore, arrangements that specifically address recovery management must be developed and exercised as part of preparedness. The purpose of this publication is to provide key considerations for the development of a national-level preparedness framework to manage recovery from a radiological or nuclear accident (also referred to as "recovery management framework" in this report).

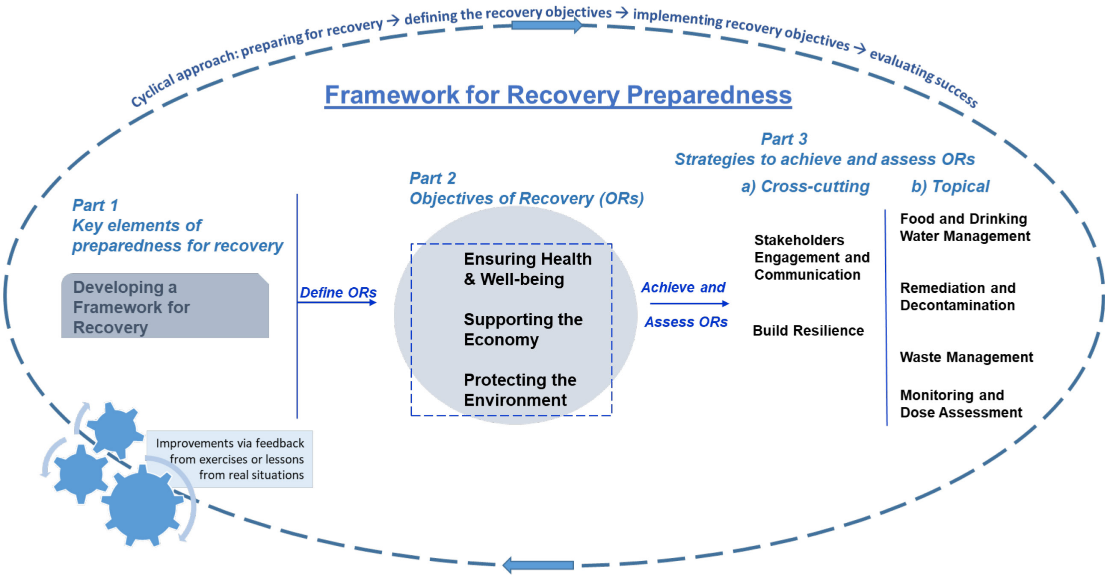
Radioactive substances released during a nuclear accident do not respect national borders. Therefore, all countries including those with no nuclear facilities should develop recovery management frameworks. The nature and level of detail included in such a framework should be commensurate with the outcomes of a national risk assessment that considers all possible nuclear and radiological accidents in terms of their origin, likelihood and magnitude of impacts (NEA, 2010). One of the lessons learnt from the Fukushima Daiichi accident is that risk assessments must not only address foreseeable events but also ensure flexibility to respond to an emergency beyond what had originally been foreseen (NEA, 2021a and 2021b).

Recovery following a nuclear accident is a long, complex and resource-intensive process. Since it is not feasible to have the range of diverse resources and commitment of the concerned stakeholders required for recovery in pre-accident "stand-by" mode, it is important to have processes and procedures in place to activate the resources needed and involve the relevant stakeholders at all levels in the recovery phase (NEA, 2017a). Developing a framework for recovery in preparedness is key to ensuring that the recovery process is managed as effectively as possible, that the required resources are available, and that the objectives of recovery are achieved.

There must be close links between preparing for response and recovery so that the implications of decisions taken in emergency response on long-term recovery are fully understood and the criteria for lifting urgent protective actions are considered. It is important to prepare sufficiently to avoid unexpected consequences of early decisions in the emergency or in the recovery phase. Past experiences from nuclear, radiological and non-radiological emergencies have highlighted the difficulties that may be encountered if there is a failure to prepare adequately (NEA, 2018a and 2021a). Not preparing adequately for recovery can lead to confusion regarding roles and responsibilities; poor co-ordination between organisations and people at local, regional and national levels; lack of legislation to facilitate the swift implementation of recovery actions and a failure to engage with key stakeholders. Any of these can seriously impede the success of the recovery, with negative consequences for affected communities. In addition, the financial cost of recovery may be far greater than would have been the case if a recovery management framework had been developed in preparedness.

The process for establishing a framework for recovery preparedness proposed in this report follows a cyclical approach as outlined in Figure 1. Following this approach, the core part of the report is segmented into three logical parts that cover several cross-cutting and topical issues associated with recovery from nuclear and radiological accidents. Each of the parts provides guidance on what steps should be taken to improve preparedness. The first part covers key elements of preparedness for recovery, with a chapter on guidelines for developing a recovery framework. The second part deals with the objectives of recovery, with chapters on ensuring health and well-being, supporting the economy, and protecting the environment. The third and final part examines cross-cutting and topical strategies to achieve and assess recovery objectives, with chapters on stakeholder engagement and communication, building resilience, food and drinking water management, remediation and decontamination, waste management, as well as monitoring and dose assessment. To underline the importance of establishing recovery preparedness in each of the different fields, this chapter provides a short overview of what is at stake if countries fail to prepare properly for recovery.

Figure 1: **The cyclical process of building a framework for recovery preparedness**



What is at stake?

A community is a complex web of interconnected people and organisations. If any part of this web is overlooked in planning, the process of recovery will be sub-optimal, and a community may experience difficulties in restoring an acceptable standard of life. An organisation or government acting without the public's trust can suffer severe long-lasting reputational harm (NEA, 2018b). It is essential that all parties be aware of, informed of and, to the maximum extent possible, involved in the recovery process as mentioned in ICRP Publication 146 (ICRP, 2020) through the "co-expertise" approach. The wider legal necessity to include certain groups (such as Indigenous peoples) in consultations through the recovery process needs to be considered on a regional and national level as indicated for example in the European Aarhus Convention (Aarhus, 1998). Overall, community members' buy-in to rebuild is essential and can only be achieved if they are provided with the information and the means to ensure a transparent, safe and sustainable process.

In any recovery situation, the effectiveness of the operations carried out will be highly dependent on the resources that can be mobilised as well as the organisation of these resources. If the necessary resilience to deliver effective operations is not built during the preparedness phase, the ability to deliver the best possible outcomes (for health, society, environment, the economy and so on) will be undermined. Leadership and co-ordination at local, regional and national levels are vital for the situation to be managed in an effective, collaborative manner. Without plans in place to adapt to the capacity and capability demands of a situation, timely recovery will be inhibited and the societal, economic and psychosocial consequences of the situation will be greatly increased.

The accidents at the Chernobyl and Fukushima Daiichi nuclear power plants have demonstrated the long-lasting nature of the disruption to the daily life of residents in the affected areas and beyond (WHO, 2005; Bromet and Havenaar, 2007; Hasegawa et al., 2015). This can result in a strong decline in the well-being of individuals and communities, leading to a number of health issues, especially mental health and lifestyle diseases (WHO, 2020). Evacuation and relocation can give rise to a multitude of stress factors that negatively influence well-being, including sudden disruption to family relations, potential separation of households and disruption of daily routines. Even people who remain in their homes can experience stress due to remediation actions, a lack of confidence, or uncertainties and fears about potential negative health effects (Fukasawa et al., 2017; Murakami et al., 2020). This can be reinforced by a loss of livelihood and a decline in infrastructure due to unemployment, contaminated land, closure or at least reorganisation of schools and hospitals, and a dearth of public transport. This is why the different facets of well-being have to be considered as part of the optimisation process within recovery preparedness plans to strike an important balance of doing more good than harm during recovery.

A nuclear accident also creates significant economic disruption that can have long-lasting direct and indirect economic impacts. Direct economic effects arise from decontamination and waste management. The agricultural and food sectors are affected by radioactive contamination of agricultural land and products, which leads to product bans, temporary cessation of agricultural activities and stigmatisation and image loss of products or territories (Bachev and Ito, 2014.; Schneider et al., 2021; NEA, 2021a). Indirect economic effects on the industrial and service sectors arise from demographic changes and loss of labour force. These indirect effects can undermine the economic fabric of the affected region, limit its attractiveness, and hamper its revitalisation (Schneider et al., 2021; NEA, 2021a; NEA, 2021b). Even the economy of areas or countries not directly affected may suffer reputational losses in the tourism and food sectors (Curits et al., 2016).

The Chernobyl and Fukushima Daiichi accidents have clearly shown that the environmental consequences of such accidents are complex and extensive in space and time (UNSCEAR, 2020). They can have important immediate and long-term, direct, and indirect consequences on ecosystems linked to the presence of radionuclides in the environment. These include damage to natural resources (e.g. fresh and marine waters, forests, air) and changes in biodiversity and ecosystem structure. Radionuclides released during past accidents have infiltrated all the components of ecosystems over very long periods of time (Steinhauser et al., 2014). Protection of the environment from the deleterious effects of exposure to ionising radiation or radioactive materials should form part of a risk assessment for a given situation. Preparedness on this issue is a means of ensuring adherence to the UN Sustainable Development Goals (SDGs) and alignment with the Sendai Framework for Disaster Risk Reduction 2015-2030 (UNDRR, 2015).

One of the major concerns of residents living in areas affected by nuclear and radiological accidents is food and water safety. While most of the potential internal doses to the affected population can be averted by taking protective actions to reduce the transfer of radioactivity to food products and restricting the sale of contaminated food, the implementation of a food management system based solely on activity concentrations does not prevent stigmatisation or negative attitudes from consumers or retailers. Larger quantities of contaminated waste are generated when agricultural and animal products must be disposed of due to food restrictions, although the implementation of agricultural protective actions can reduce the quantities of waste, particularly in the longer term. Consequently, there are many issues at stake when considering food and drinking water management with potential major economic consequences, particularly for agricultural businesses in the contaminated region.

Remediation of inhabited areas and food production systems may take place over months, years or even decades (IAEA, 2006), with the potential for some options to generate large volumes of waste (MoE, 2018a). Experience from past nuclear and radiological accidents has shown that authorities can be overwhelmed during the emergency phase, resulting in delays in initiating remedial actions (e.g. due to no timely availability of human, technical and financial resources) and thus impacting recovery. At the same time, experience indicates that the impact of remedial actions on non-radiological aspects, especially on well-being and the environment, should not be underestimated (IAEA, 2006; MoE, 2018a; Ohmura, 2014). Remediation can have positive and negative impacts on the health and well-being of affected people, the food chain, the environment, economy, and society. The positive impacts of remediation include reduced radiation exposure of those living and working in affected areas, reassurance for the public that contamination is reduced or removed, reassurance that food is safe to eat, and reinstatement of businesses and trade. The negative impacts of remediation include additional doses received by remediation workers, disruption to lifestyle and livelihoods while remediation work is being carried out, disruption to food supplies, and the generation of waste and economic costs of the remediation efforts. Additional challenges arise in situations where food restrictions are in place, but where decontamination is not being carried out. This not only requires a carefully planned risk communication strategy but also a long-term monitoring strategy to promote public understanding and acceptance.

Nuclear and radiological accidents have the potential to generate large volumes of radioactive waste, which predominantly comes from the implementation of protective actions or remedial measures as described above. Managing waste generated from nuclear and radiological accidents is a key component of recovery and can incur considerable costs and delays if executed poorly. Many activities, such as transport or setting up staging areas, are difficult to establish without prior planning and may require legal and political backing to be implemented. Without prior approvals or plans that cover such activities, it will be difficult to avoid delays and the associated impacts on people and the environment. Routine radioactive waste management arrangements come under extreme pressure after large emergencies. Experience from previous incidents has shown that a lack of preparedness resulted in arrangements for managing waste being developed from the time of the incident rather than in advance. This led to multiple economic, environmental and social challenges that could most likely have been reduced if there had been greater preparedness (IAEA, 1988; 2017). Member states who fail to consider the specific arrangements for the management of wastes in advance of an emergency are likely to experience similar challenges.

A well-considered monitoring and dose assessment programme provides information for decision makers to develop evidence-based recovery strategies and adjust them to the specific situation. It is a key element for efficient recovery as it allows decision makers and the public to gain a sound understanding of the radiological situation and associated risks. Environmental monitoring and dose assessment can reduce the risk of chronic exposure, identify areas that are free from radioactive contamination, and help to build trust, resilience, and maintain trade (NEA, 2021a). Understanding the evolution of the radiological situation is essential to optimise and eventually lift protective actions and proceed with recovery. Previous experience has shown that public trust is enhanced through empowerment and self-determination, which is additionally fostered by encouraging self-help monitoring and other individual actions related to the understanding of the radiological situation. However, benefits from individual monitoring depend on the thorough provision of support in interpreting monitoring results so that people understand the outcomes and any actions that they can take to improve their own situation. If this is not considered, individual monitoring might trigger adverse psychological consequences (NEA, 2021a). Thus, the preparedness phase is key to ensuring efficient plans for recovery.

Part 1: **Key elements of preparedness for recovery management**

Chapter 1. Developing a recovery framework

Introduction and definitions

Definitions

In this publication, a **recovery management framework** is a set of policies, procedures, principles, objectives, strategies, and/or tools identified and documented for the purpose of managing the process of recovery from an emergency. Throughout this report, the term "framework" without a qualifier should be interpreted as a recovery management framework.

For the purposes of this publication, a **nuclear or radiological accident** describes an event resulting in significant releases of radioactive material into the environment (ICRP, 2020).

The post-accident **recovery phase** (which corresponds in the long term to an existing exposure situation) begins when the radiation source at the origin of the accident is considered to be sufficiently secured and/or the exposure situation is adequately characterised to support long-term decision-making (for off-site accidents only the latter applies) (e.g. IAEA, 2018; ICRP, 2020).

The **all-hazards** approach assumes that hazards, independent of their source and nature, often result in challenges that are similar to a certain extent. Thus, responses to different hazards are often based on similar models where the resulting challenges and outcomes are comparable, and experience from hazards in different sectors might be used to optimise the overall preparedness and response to hazards. This is notwithstanding the specific requirements of a situation, e.g., nuclear or radiological accidents, that have to be considered on top of all-hazards-approach-based responses (NEA, 2018a).

The first step in developing a framework for recovery is identifying and agreeing with stakeholders on the overall objectives of recovery based on the principles of justification and optimisation and developing criteria that can be used to assess if the recovery has been successful (ICRP, 2020). Both radiological and non-radiological aspects of recovery must be considered (ICRP, 2020). The tools that can be used to achieve the objectives of recovery, such as remedial actions to reduce or remove contamination and food and drinking water protective actions, need to be discussed and agreed upon. The roles and responsibilities that are required to prepare for all aspects of recovery, the governance of and the co-ordination between these various roles, the engagement of civil society, legal requirements, international transboundary harmonisation, and ethical issues must also be addressed. Lessons learnt from preparing for and responding to other emergencies such as natural disasters, severe weather emergencies, industrial accidents and the COVID-19 pandemic can also be applied to nuclear recovery planning.

Guidance for developing a framework

The development of a national framework for recovery is challenging and could take many years to complete. Where possible and depending on national arrangements, the adoption of an all-hazards approach that makes use of common frameworks to support recovery irrespective of the nature of the emergency should be used in the development of arrangements for recovery from a nuclear or radiological emergency. The all-hazards approach can help to build resilience, enhance clarity of roles and governance, and ensure a more efficient use of resources by avoiding duplication of arrangements for different emergency types. In the United States, the

Federal Emergency Management Agency (FEMA) recommends that businesses adopt an all-hazards approach to the planning process since there are many different threats or hazards that may impact a business (FEMA, 2021).

The Sendai Framework for Disaster Risk Reduction 2015-2030 focuses on proactive disaster risk reduction rather than reactive disaster management and encourages a multi-hazard or all-hazards approach to disaster risk reduction at all levels as well as across all sectors. One of the guiding principles of the Sendai Framework is that decision-making is inclusive, risk-informed and in line with a multi-hazard approach (UNDRR, 2015). The Sendai Framework includes four priorities: understanding risk, improving risk governance, building resilience, and enhancing disaster preparedness. It offers practical guidance on the actions required to improve preparedness to ensure effective disaster response, rehabilitation, and reconstruction, and to use post-disaster recovery and reconstruction to "build back better".

Overall, planning for recovery should be risk-based, proportionate, flexible, scalable, and non-prescriptive (DECC, 2015b). While it may not be possible to plan in detail for every possible event, it is important to establish a framework for recovery that considers both a full assessment of the risks and the range of potential impacts including health, social, economic and environmental impacts. Learning from past events is important in avoiding "gaps" in risks or impacts that might not otherwise have been considered in the preparedness phase.

Some of the key findings of the NEA report on the challenges in nuclear and radiological legacy site management can inform the preparation of a post-accident recovery framework to ensure that there are measures in place to prevent the post-accident situation from becoming a legacy site (NEA, 2019a). These include the adoption of a holistic approach to the management and regulation of the hazards, the consideration of other hazards alongside the radiological hazards, the involvement of all stakeholders, and the use of a staged process to achieve an appropriate end-state.

Anticipate governance, roles, responsibilities, and co-ordination

The framework for recovery should facilitate a smooth transition between the emergency exposure situation and the existing exposure situation, particularly where different organisations or individuals are involved. It is therefore important to build relationships at the preparedness phase between the various organisations involved in the response. This has been demonstrated by Ireland's Government Task Force on Emergency Planning (DoD, 2017). The framework should also include an "exit strategy" to support decisions regarding the termination of recovery actions. The different roles and responsibilities of those involved in preparing for recovery together with the co-ordination and governance arrangements must be clearly set out in national frameworks. All organisations that have a role in preparing for recovery must have the necessary human, financial and other resources to be able to prepare for and undertake these roles and responsibilities. The co-ordination of decision-making processes among all the involved organisations at the local, regional, national and international levels is key and decision-making processes should be consensus-based, involving the populations who are likely to be affected, business communities, and elected officials (NEA, 2010).

Decisions in the recovery phase will directly affect the daily lives of affected populations and the overall quality of their living and working environment for an extended period. Engagement with affected communities enhances community resilience and supports the shared ownership of the outcomes of recovery management options, which is instrumental for building trust (WHO, 2020). In this context, local and regional aspects such as traditional land use, regional produce, tourism, and cultural practices must be considered. ICRP recommends that authorities, experts, and stakeholders co-operate in a "co-expertise process" to enable people to make informed decisions (ICRP, 2020). It is important that this "co-expertise process" is established in the preparedness phase so that trust can be established between authorities, experts, and stakeholders to enhance the efficiency of this "co-expertise approach" in the recovery phase. In France, a Steering Committee for the Management of the Post-Accident Phase in the Event of Nuclear Accident or a Radiological Emergency Situation (CODIRPA) was established in 2005 to develop the French policy for managing the post-accident phase of a nuclear accident (CODIRPA, 2012). One of the main reasons for the success of the CODIRPA process was that all relevant stakeholders and interested parties were included in decision-making.

Consider legal requirements

Following a nuclear or radiological emergency, the legal framework should not give rise to unnecessary delays in implementing urgent and longer-term protective actions due to legal and regulatory issues. Therefore, any legislation and regulations that will support the governance, at all levels, of the preparedness for recovery and recovery management should be considered. Consideration should be given to crafting guidance that may be useful as a starting point for drafting legislation in an emergency. This also highlights the importance of developing a flexible framework for recovery that can be adapted easily according to the situation following an emergency, and the benefit of adopting an all-hazards approach to preparedness for recovery management. When the Fukushima Daiichi accident occurred, the extent of the large-scale release of radioactive material into the environment exceeded the scale assumed in the risk assessment at the preparedness stage and highlighted the importance of having resilient arrangements in place for remediation and food safety management activities. This resulted in the clarification of these long-term recovery activities in the legal framework, as well as reinforced co-ordination between the organisations involved. One of the lessons learnt from the Fukushima Daiichi accident is that risk assessments must not only address foreseeable events but also ensure flexibility to respond to an emergency beyond what had originally been assumed (Annex C).

Facilitate international/transboundary harmonisation

More than one country may be affected by the same nuclear or radiological accident. Bilateral and international agreements developed in the preparedness phase should not be confined to emergency response provisions but should also include recovery management aspects such as cross-border trade of food and commodities. These bilateral and international agreements should include co-ordination mechanisms between neighbouring states during recovery to facilitate harmonisation of recovery actions across borders. The Heads of the European Radiological Protection Competent Authorities (HERCA) published guidance for bilateral arrangements in 2015 (HERCA, 2015). Although this publication deals with the emergency phase of an accident, there is some overlap in information that should be exchanged between the parties as part of their preparedness arrangements for recovery. An example of how neighbouring countries can work together to develop arrangements to promote harmonisation of response is demonstrated in the development of the "Nordic Flag Book on Protective Measures on early and Intermediate Phases of a Nuclear or Radiological Emergency" (STUK et al., 2014). While harmonisation is not mandatory, it could be advantageous, particularly for communities living close to national borders and for the protection of ethnic groups, as was the case with the Sami people in Finland, Norway and Sweden following the Chernobyl accident.

Integrate ethical principles

A recovery framework must be based on sound ethical principles. Ethical issues that need to be considered in the decision-making process under such a framework include the impacts that decisions may have on living conditions, life expectancy, mental health, well-being, and livelihoods. The following four core ethical values, based on those published in ICRP Publication 138 (ICRP, 2018), should be considered for use by a panel of stakeholders and decision makers in preparedness to ensure the robustness of the proposed framework with regard to ethical issues:

- **Beneficence/non-maleficence**: In determining whether recovery management options are justified, radiological aspects should be weighed against the impacts in other areas such as public health, society, the economy, and the environment.
- **Prudence**: Ensure there is a long-term review of the potential health and environmental effects for the population and territories affected by the accident.
- **Justice**: Ensure that the proposed framework treats all affected territories in an equitable manner with a fairly-balanced allocation of resources.
- **Dignity/autonomy**: Preserve the autonomy of decision-making and ensure the availability of resources to preserve this autonomy.

In addition to the core ethical values, the following "procedural values" should also be considered:

- **Stakeholder involvement**: Ensure a fair process and participation of all relevant stakeholders.
- **Transparency**: Ensure that the process for the development of the framework is well described and information is easily accessible.
- **Accountability**: Include an evaluation procedure to assess the robustness of the process itself and to provide regular feedback on the development of the process.

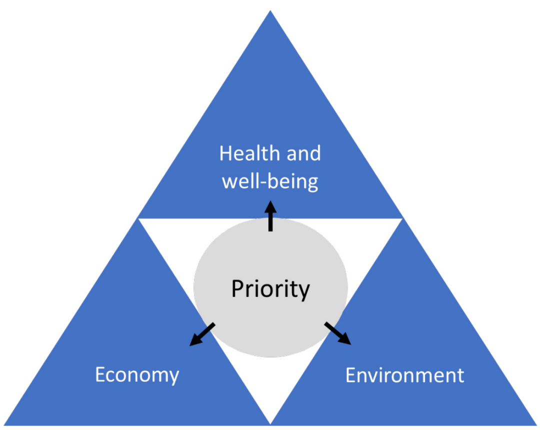
Part 2: Objectives of recovery

Background elements for weighting objectives of recovery in the framework

When developing a recovery framework, it is important to set out the objectives of what the recovery effort aims to achieve. The three proposed objectives of recovery reflect the holistic, cross-cutting nature of recovery from a nuclear or radiological accident, as well as the long-term implications of the protection strategy in meeting these objectives. The focus is on the re-establishment of decent living and working conditions in the affected areas and neighbouring sectors while recognising the fundamental role of the environment in re-establishing a sustainable quality of life in potentially affected areas.

Accordingly, the three interrelated objectives of recovery, i.e. supporting the economy, ensuring health and well-being, and protecting the environment, should be achieved in a holistic and inclusive manner and in close co-ordination with the relevant stakeholders. This co-ordination should start in the preparedness phase and consider all objectives together rather than one by one or independently from each other as they exhibit a complex interplay. The interrelated nature of the recovery objectives means that addressing one area will have consequences in other areas. For instance, remediation activities to address environmental impacts will also have social and economic consequences, such as the significant financial costs of restoring contaminated areas, and vice versa. Recovery objectives should be agreed upon by an extended panel composed of a diverse range of stakeholders, acknowledging their strong interdependency. Populations living in the vicinity of nuclear facilities play a particularly important role in this context and could help inform planning activities, reinforcing a risk-informed approach and community resilience. While all recovery objectives are interdependent and should be approached in a holistic manner, their prioritisation will shift and fluctuate throughout the recovery timeline, depending on the specific situation and context (Figure 2).

Figure 2: **The prioritisation of the recovery objectives will shift over time, depending on the situation and context**



Chapter 2. Ensuring health and well-being

Introduction and definitions

Definitions

Health: "Health is a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity" – Preamble to the WHO Constitution (WHO, 1948).

Well-being: "There is no consensus around a single definition of well-being, but there is general agreement that at minimum, well-being includes the presence of positive emotions and moods (e.g. contentment, happiness), the absence of negative emotions (e.g. depression, anxiety), satisfaction with life, fulfilment and positive functioning." – Centers for Disease Control and Prevention (CDC, n.d.).

MHPSS: The composite term "mental health and psychosocial support" (MHPSS) is used in the Inter Agency Standing Committee (IASC) Guidelines for MHPSS in Emergency Settings to describe "any type of local or outside support that aims to protect or promote psychosocial well-being and/or prevent or treat mental health condition". The global humanitarian system uses the term MHPSS to unite a broad range of actors responding to emergencies such as the COVID-19 outbreak (IASC, 2020b).

Nuclear or radiological accidents can result in a complex set of technical, radiological, environmental and socio-economic consequences that will promptly impact the lives of people in affected areas. Potential radioactive releases to the environment do not only represent a risk to the physical health of local inhabitants, but can also have considerable effects on their mental health and psychosocial well-being through associated consequences and constraints on daily life as well as fears and uncertainty. This effect is observed to be complex, long-lasting, and sometimes reinforced by the social, economic, and psychological challenges connected to protective measures and other radiological protective actions that are implemented to counteract radiation exposures for the population.

Guidance for developing the framework

While protecting the affected population and the environment from radiation exposure after a nuclear or radiological accident is the central rationale for radiological protection, experience from past nuclear accidents such as Fukushima Daiichi or Chernobyl has shown that decision makers have to bear in mind non-radiological public health aspects (WHO, 2020; IAEA, 2015a). The development of an appropriate set of criteria or a decision-making tool in the preparedness phase could be an important step in this context, as it could assist decision makers during recovery management to balance direct radiation-related health risks against the indirect consequences of protective actions. These indirect effects manifest as mental health and psychosocial well-being consequences for individuals and/or communities. In order to mitigate these indirect effects, appropriate countermeasures should be identified during preparedness, in consultation with local populations and a broad range of stakeholders.

Given that well-being is an issue that evolves over time and space, decision makers need to engage in a long-term participatory process with the local populations likely to be affected. It is indispensable to respect core ethical values like dignity and autonomy at all times to be successful in reducing health impacts and contributing to the well-being of the affected population

(Schneider and Maitre, 2020). One key factor to be considered for recovery preparedness in this context is community resilience. Existing resilience measurement tools should be integrated into health surveillance processes to enable monitoring of levels of resilience during the recovery process. Many of the below-listed recommendations should be applied with the goal of increasing or re-establishing community resilience during preparedness and recovery with respect to the local conditions and cultural circumstances, which are different for every community. In this context, non-governmental organisations also play an important part and should be involved in preparedness and planning activities, with their roles clearly described. They should also have their own disaster resilience plans in place for the response and recovery phases.

Actively seek dialogue with the affected population

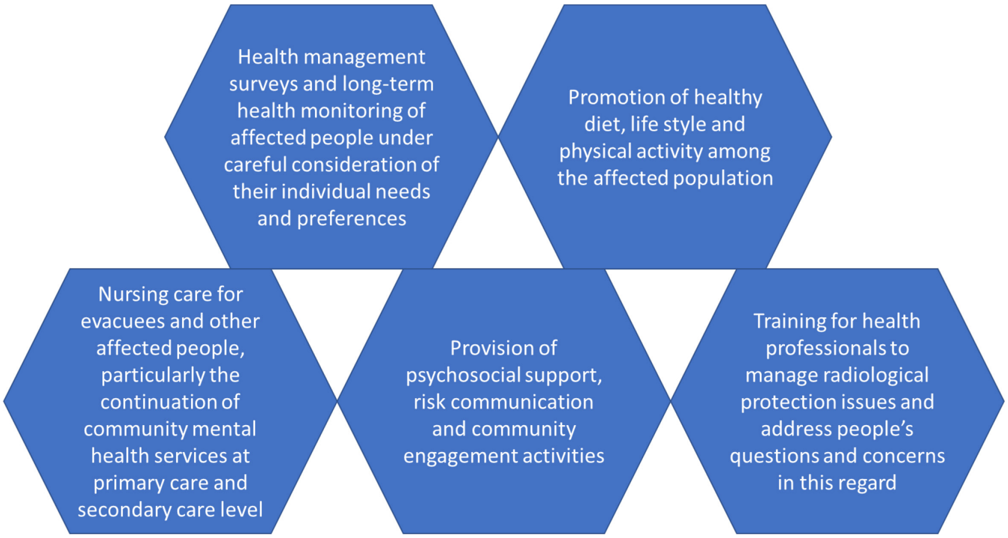
To achieve the goal of engaging in a long-term participatory process with the local population for recovery, counsellors deployed by the government could work towards establishing mutual trust relationships with local people by addressing their concerns and providing them with contacts for experts or local administrative officers. This approach was successfully tested after the Fukushima Daiichi accident (NEA, 2021a). The counsellors should be trained in the preparedness phase. Their main role should be that of facilitators for the potentially affected population, i.e., they should act as an interface between the public actors/institutions and the affected people. This could include providing referral pathways to (mental) health, administrative and legal services, as well as updates on protective or remediation actions and the radiological situation. In addition to dedicated public counsellors, the training of volunteers (e.g. in psychological first aid and radiological protection) in populations that are situated in the direct vicinity of nuclear power plants could potentially increase the acceptance of the counsellors' work and help it to be perceived as less intrusive. Volunteers and counsellors should co-operate closely and co-ordinate their work in the different communities, with volunteers acting in a complementary capacity. Both public counsellors and volunteers should benefit from continuous mental and emotional support opportunities to enable their sustainable engagement throughout the recovery phase.

Counsellors and volunteers should be trained in basic psychological support skills for emergency responders to help mitigate negative mental health and psychosocial well-being effects on the affected population and thus facilitate recovery (IASC, 2020a). These training initiatives should consider existing programmes at the local or national level to ensure co-ordination among organisations and consistency in the content (WHO, 2020). Other interventions over the long term could cover the establishment of inclusive self-help support groups with the aim of providing mutual emotional support by sharing problems and developing solutions or finding effective ways to cope with stress and anxiety (WHO, 2020). However, this should only be undertaken using approaches supported by evidence-based research. All the well-being interventions mentioned in this chapter should be accompanied by a carefully planned communication strategy that should be developed during the preparedness phase (as explained in Chapter 5 on "Stakeholder involvement and communications"). Similarly, plans should be set up for the nomination of voluntary citizen-ambassadors to represent the needs of the affected population in local liaison committees. Next to these ambassadors, local liaison committees for recovery management should be composed of representatives of the public authorities and radiological protection specialists (more information in Chapter 5 on "Stakeholder involvement and communications").

Re-establish a functioning societal framework

Over the long term, a health and social care response adapted to local needs has to be made available, including appropriate measures for health surveillance and monitoring of affected populations, taking into account lessons learnt from health surveillance programmes in Chernobyl and Fukushima. Some examples in this regard are listed in Figure 3. For these measures to be effective, they must be planned in advance. In particular, the training of health professionals, including nurses, can best be done during the preparedness phase. Training for nuclear or radiological emergency management should not only cover the direct physical effects of radiation, but emphasis should also be placed on the potential MHPSS effects in the population. This also includes the awareness of potential changes in the health services and in working practices of health professionals due to the impacts of a nuclear or radiological accident.

Figure 3: **Examples for actions to build a long-term health and social care response adapted to local needs**



Provide training and education on radiological and MHPSS issues

Training and education of the general population on radiological and MHPSS issues could be a further key to mitigating the effects of nuclear or radiological emergencies on their well-being. By supplying the affected population with comprehensive, easily understood information that is directly applicable to their situation, they can regain some autonomy in decision-making which will improve their perceived control over their lives (Schneider, 2021). Examples of educational information include day-to-day behaviour advice (e.g. encouraging activities that promote good mental health such as physical activity, connecting with loved ones, a good sleep routine, spiritual practices, and avoiding alcohol) as well as background information on radiological, mental health, and psychological well-being risks. Such educational programmes and MHPSS activities should be integrated into existing community structures, such as schools and community centres, which would also positively contribute to overall community resilience (NEA, 2020; WHO, 2020).

Establish indicators for well-being with all stakeholders

Establishing clear indicators of well-being during the preparedness phase could be based on exchange with people living near nuclear power plants and on experience from former nuclear accidents. These indicators could help ensure that ethical considerations such as dignity and autonomy, legitimacy, transparency and fairness are taken into account when establishing recovery priorities, including the selection of protective and remedial actions (Schneider, 2021). The agreement on indicators should be based on inputs available (e.g. resources, pre-existing services), processes, and outcomes (e.g. level of distress, functioning of beneficiaries, livelihoods) (WHO, 2020). Indicators should measure impact (e.g. ability to carry out essential daily activities; subjective well-being indicators like feeling calm, safe, strong and hopeful or adversely) and outcome (e.g. level of family connectedness or cohesion; level of cognitive and structural social capital) (WHO, 2020; IASC, 2017). The implementation of these indicators should be reviewed continuously by all stakeholders until the results show a satisfactory re-establishment of living conditions for the affected population. More information on MHPSS implementation measurement can be found in WHO, 2020 (pp. 22-23).

Similarly, milestones for a return to decent and sustainable living and working conditions could be set jointly between the affected population, radiological protection experts, and decision makers. This would provide people with clear objectives and transparency in how the recovery process is being managed. Decisions on the withdrawal of protective actions should involve the affected population and be communicated coherently and transparently. Radiological and non-radiological aspects need to be balanced and optimised. Furthermore, additional research should be conducted to inform the development of performance evaluation tools for recovery management during the preparedness phase.

Prepare a health surveillance strategy

As previously stated, the key factor in the successful management of mental health and psychosocial well-being after a nuclear or radiological accident is the support for the affected population. In this context, the development during the preparedness phase of a thorough health surveillance strategy, which can be adapted to the needs and preferences of the affected people during the recovery phase and is anchored in ethical considerations (e.g. respect for the dignity and autonomy of the people), should inform the set of well-being indicators. A health surveillance strategy should provide the necessary health care (mental or physical) to those in need, provide reassurance through its presence, and be inclusive of those who might not have been directly affected by the accident but would like access to health surveillance. However, health surveillance should not amplify stress and fear in the population (Ohba et al., 2021; Liutsko et al., 2021). Such a health surveillance strategy requires a holistic approach that addresses radiological and non-radiological impacts, given that the psychosocial aspects outlined in this chapter and Chapter 3, "Supporting the economy", could influence the effectiveness and the added value of health surveillance (Liutsko et al., 2021). Therefore, a health surveillance strategy should address radiological and non-radiological health impacts.

A health surveillance strategy should consist of a programme to survey individuals for their individual health care (e.g. screening programme) and the collection of health data for use in epidemiological studies. Both aspects require a comprehensive and well-maintained health registry for data collection. Furthermore, it would be appropriate to prepare meaningful communication and educational material that could be made available quickly to the affected population to help them understand the purpose and benefits of such health surveillance. Overall, health surveillance should not be perceived as being imposed on the affected population, but rather as an inclusive endeavour, whereby individuals and health care professionals meet on an equal basis to discuss the survey results and their implications (Liutsko et al., 2021). The extensive thyroid screening survey conducted after the Fukushima Daiichi accident to investigate potential increased thyroid cancer risk among children showed that results of such large-scale health surveillance programmes are not always to be interpreted unambiguously (UNSCEAR, 2020). This confirms the need to carefully communicate and explain the outcomes and purpose of such programmes and to involve local citizens in the definition and follow-up of this programme.

Chapter 3. **Supporting the economy**

Introduction and definitions

Definitions

Economic actors: In this chapter, the term "economic actors" refers to private economic actors such as businesses, entrepreneurs or industries and does not refer to public/governmental economic actors like regulators or ministries.

Nuclear accidents can result in a complex set of technical, radiological, and socio-economic consequences that will greatly impact economic activities in an affected territory over the short and long term. This can lead to the long-term depopulation of formerly thriving regions due to a negative feedback loop of poor economic conditions and lack of infrastructure, especially medical care (Schneider et al., 2021; Zhang et al., 2019; Bachev and Ito, 2014; Hasegawa et al., 2015; Fukasawa et al., 2017). The capacity of a region to recover economically depends on the efficient co-operation of public and private efforts, requiring appropriate preparedness on both sides to enable clear and effective responses (Schneider et al., 2021). However, economic recovery and the associated return to decent living and working conditions in an affected area largely depends on the prevailing circumstances, the recovery strategy and the decisions made in terms of protective strategy and remediation options. Much of the information regarding trade issues treated in this chapter also applies to the trade of foodstuffs. Please note that Chapter 7 "Food and drinking water management" focuses on all other aspects relating to food and drinking water.

Guidance for developing a framework

As experience from non-nuclear emergencies suggests, investing in preparedness for emergency response and recovery is usually more cost-effective than unprepared emergency response and recovery actions (MCC, 2005). The ambitious goal for the recovery framework should thus be to enable efficient co-ordination of economic issues with recovery actions and to elucidate how to engage industry, other activities, and the public in a sustainable socio-economic model adapted to the long-term vision for potentially affected areas.

Promote the consideration of nuclear risks for business in proximity of nuclear power plants

The preparedness phase should be used to implement co-operation between the different stakeholders, e.g., private business owners, radiological protection experts, national and local regulators, and local populations. Economic actors, especially those located in the vicinity of nuclear power plants, should be particularly concerned about creating holistic, all-hazards emergency response and recovery preparedness plans that include scenarios for nuclear or radiological accidents to safeguard their businesses (Schneider et al., 2021). Case studies from the Fukushima Daiichi accident show that those companies that were able to quickly adapt their activity, e.g. by addressing customer concerns, providing health security measures for workers adapted to their activity, or providing information on the situation, were particularly successful in maintaining their business activity in the new circumstances (Schneider et al., 2021). The overall decision about whether to continue economic activities in an evacuated area should be based on the implementation of the principle of justification, including consideration of ethical issues.

Anticipate image loss and anticipate mechanisms to build visions for future economic activities

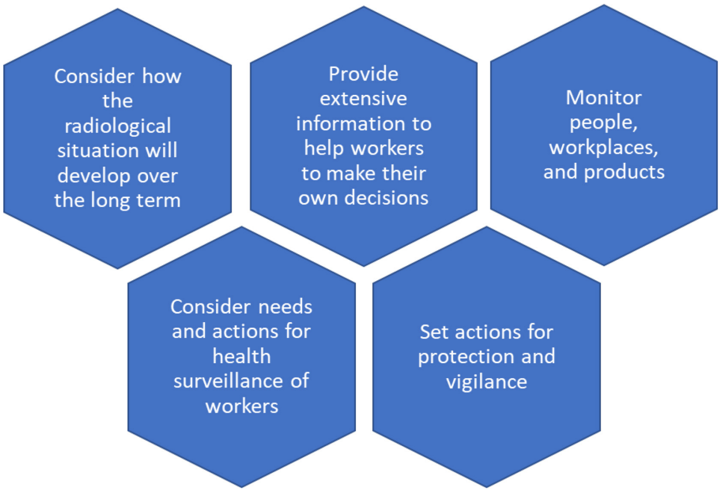
The impact of nuclear accidents on the image of the affected territories and local products is an important point that should be anticipated in the preparedness phase. Emphasis should be placed on possible levers to help in relaunching the attractiveness of the affected territories according to the long-term wishes and actual needs of the local population in the revitalisation process, as well as ethical values associated with long-term monitoring of these territories and the establishment of fair arrangements between the different actors. Concrete actions to effectively address the image loss of territories in economic terms after a nuclear accident could include:

i) information and communication campaigns on the regional, national and international level to provide information on the radiological state of the environment and local food products, as well as on the progress of the decontamination work; and/or

ii) national campaigns to re-invent the economic structure of territories, e.g. by establishing excellence centres for national and international research, offering favourable conditions for the sustainable installation of industries, and reinforcing infrastructure, including health care and education (Schneider et al., 2021). The strategic preparation of such actions and forward planning on effective engagement with stakeholders, including their identification and consideration of potential formats of engagement, should be addressed in the preparedness phase.

It is also important to focus on the health of workers and their families, who might be uneasy about working in an affected environment. In addition to the extensive protection afforded to all workers involved in business activities in the affected territories, targeted actions by authorities and employers could help to reduce these concerns (Figure 4). New approaches to limit stigmatisation and discrimination of local products by consumers and in international export chains should also be explored in addition to the application of clear standards for cross-border trade. Potential procedures that could be evaluated include ensuring quality improvement, the preparation of communications, assurance of consumers, certification of products, promotion, and maintaining or developing networks between the stakeholders.

Figure 4: **Objectives for targeted actions to help reduce worker concerns**



Review existing compensation and economic support initiatives

The issue of compensation and economic support activities after a radiological or nuclear accident should be further investigated during the preparedness phase to identify and assess already existing financial mechanisms that could rapidly contribute to economic recovery (NEA, 2012; NEA, forthcoming a and b). This should include opportunities to optimise these financial levers and clarify issues such as their evolution over time, especially with regards to their phasing-out.

Produce specific guidance for trade issues

To avoid trade barriers following a nuclear accident, clear and comprehensive international standards and trade policies are key. In this context, it is important to establish monitoring procedures and appropriate protective actions to guarantee the radiological quality of commodities and ensure the long-term protection of the population. Experience from the Chernobyl and Fukushima Daiichi accidents shows that systems for long-term monitoring and certification of commodities from natural resources like wood, as well as refined or processed high-tech commodities might be needed (Charron et al., 2016). Where levels of radioactivity comply with criteria set out in international standards, restrictions or regulatory controls for the purpose of radiological protection should be avoided. It appears favourable for neighbouring countries to co-ordinate their regulatory strategies and their implementation, including monitoring programmes for commodities. In this context, an internationally coordinated approach based on scientific criteria and taking into account the rights of Member countries guaranteed by the WTO Agreement on the Application of Sanitary and Phytosanitary Measures seems desirable, especially in the field of post nuclear accident food safety (WTO, 1995). Any measurement should be made by appropriate techniques and with equipment capable of measuring activity concentrations at the values specified. In view of these considerations, the complementary measures listed below should be considered during the preparedness phase:

- Develop strategies and prepare regulations for screening, control, and certification of commodities in accordance with international standards. The compliance of commodities with respective thresholds should be confirmed at the first point of entry into trade.
- Consider in advance which commodities might potentially exceed radioactivity criteria for exemption and clearance in case of an accident, due to possible surface contamination of raw material used in production. Establish a system to prevent these commodities from being traded without authorisation.
- Prepare monitoring programmes to assess the impact on the market of commodities containing radioactive substances and determine whether product restrictions or the redirection of the use of raw materials to commodities containing less radioactive substances may be necessary.
- Develop effective monitoring capability and contingency plans for major industries in co-operation with the relevant stakeholders.

Stimulate further analyses on direct and indirect economic effects of nuclear accidents

Overall, reliably predicting the possible economic consequences of a nuclear or radiological accident is extremely difficult. For that reason, continued investigation should be conducted on this subject in the preparedness phase to help better understand and anticipate the economic consequences of a nuclear or radiological accident. This should include direct economic effects, such as compensation issues, and indirect economic effects, such as image loss of local products and the decline in attractiveness of affected areas. The development of decision tools integrating potential economic impacts of protection strategies, e.g. decontamination strategies or food restrictions, would also help to better anticipate and limit economic impacts over time.

Chapter 4. Protecting the environment

Introduction and definitions

Definitions

Protection of the environment: as defined in ICRP Publication 103 (2007), the objective of environmental protection is "to prevent or reduce the frequency of deleterious radiation effects to a level where they would have negligible impact on the maintenance of biological diversity, the conservation of species or the health and status of natural habitats, communities and ecosystems".

Linking to the Sustainable Development Goals, this definition extends to the protection of **ecosystem services**. As defined in the Millennium Ecosystem Assessment (2003), these are ecosystems and the services they provide, such as provisioning and regulating water, food, forest and fishery products, natural resources, supporting cultural and ethical values.

More recently, to reinforce the importance of **natural capital** (defined by the United Nations as "the stock of renewable and non-renewable resources [e.g. plants, animals, air, water, soils, minerals] that combine to yield a flow of benefits to people"), the UN adopted a new statistical framework (System of Environmental-Economic Accounting) to better integrate biodiversity and ecosystems into national economic planning and policy decision-making (United Nations, 2021).

With regard to nuclear or radiological accidents, international recommendations to protect the environment against deleterious effects of exposure to ionising radiation and radioactive substances have gradually moved from the implicit paradigm "if human beings are protected, so is the environment" to the explicit objective of protecting the environment (ICRP, 2007; ICRP, 2008). However, there is still a need to improve protection in this area (Clement et al., 2021). In Europe and worldwide, many regulations to protect the environment attempt to respond to growing public awareness of the importance of the overall quality of environmental resources and biodiversity. Environmental protection recovery objectives should be identified at the preparedness stage for nuclear and radiological accidents and, where possible, draw on plans and prevention strategies that can be applied to a range of incidents under an all-hazards approach.

Guidance for developing a framework

The guidance provided here builds upon the international recommendations of the ICRP (ICRP, 2007), and is completed with some ideas on the potential evolution of the system in this area, on the International Basic Safety Standards and some related technical reports (e.g. IAEA, 2014 and 2020). Overall, the protection of the environment is a relatively new area in the field of radiological protection, all relevant international organisations being aware of the need for a clearer and stronger integration into the system (e.g. Copplestone and Garnier-Laplace, 2018).

Consider protection of the environment as key component in optimisation and decision-making

The environment should be considered an integral element of the optimisation process when deciding on the protection strategy (ICRP, 2014). Preparedness for a holistic optimisation process that integrates environmental protection should be based on prospective human and ecological risk assessments where scenarios should be relevant, realistic, comprehensive in terms of stressors/hazards, incident-scalable, and linked to any protective actions and their associated medium- and long-term consequences (e.g. food and drinking water safety management, waste management including disposal and/or recycling options, option of natural mitigation). This should be based on clear mapping and characterisation of natural resources and protected areas for wildlife and habitats not only locally but also on a wider geographic scale (e.g. by reference to national or regional inventories of protected areas).

During the long-term phase, it should be possible to consider actions to protect species that may be threatened by chronic radiation exposure and special provisions may be needed to maintain the quality of the environment impacted by protective actions. These actions should be considered within a holistic approach, including the abundance and diversity of threatened or endangered species, the spatial extent of the impact, and the inherent value of the environment (NCRP, 2018). Specific preparedness should include an additional step to examine whether the specific arrangements for the response and recovery phases are in line with national policy, strategy and legislation to protect the environment as a whole (e.g. nature conservation; environmental resource use; air, soil and water quality; biodiversity). This may require reference to the concept of natural capital designating important values of the natural environment that have not always been fully considered in decision-making (DEFRA, 2020; United Nations, 2021).

Align specific arrangements for post-accident recovery with national policy, strategy and legislation directed to protection of the environment

Environmental regulations, including those developed for radioactive waste, are often developed for routine operations (planned exposures) where discharges to the environment can be heavily controlled and monitored. In this context, legislation will need to be able to adapt to changing circumstances. During the preparedness phase, it is important that national policy, strategy, and legislation are reviewed to ensure that they are applicable to emergencies. Article 73 of the Euratom Basic Safety Standards Directive (Council of the European Union, 2013) and Requirement 49 of IAEA GSR Part 3 (IAEA, 2014) set out the requirements for dealing with contaminated areas from past activities and accidents. It is important that national policy and legislation addresses such requirements and that they are considered as part of the overarching emergency and recovery frameworks.

Convene an extended panel of stakeholders to discuss environmental recovery objectives

Environmental protection goals should be agreed with all affected stakeholders. These goals will aim to not only protect individuals of all species, but also to protect the structure and function of the ecosystem itself, depending on the aim of the risk assessment carried out. The protection goals need to be well defined, measurable and feasible. The most commonly used approach for radiological protection of wildlife is to protect at the population level, which will, by definition, ensure a sustainable ecosystem function. By taking this approach, it could be acceptable for a fraction of individuals to be severely affected, provided this did not threaten the viability of the population. Since a range of protection goals can be pursued, a range of benchmark values may need to be derived to ensure compliance with those goals (Real and Garnier-Laplace, 2020).

Consider wider environmental protection issues in the preparedness phase

It is important that information about the local environment and ecology is understood and documented within emergency and recovery plans during the preparedness phase. This task is more applicable to emergency and recovery plans developed for areas surrounding nuclear facilities as the fixed location provides an opportunity to model impacts to the environment relative to the range of potential accident scenarios. Where possible, recovery plans should identify sensitive environmental receptors, including parts of the ecosystem that are particularly radiosensitive. Having easy access to this information at the time of a radiological or nuclear emergency will ensure environmental risks are incorporated into the decision-making and optimisation process and potentially decrease the time taken to decide and implement protective and remedial actions. Such preparedness arrangements will help to achieve the overriding objective to protect the environment. Figure 5 provides an overview of aspects to be considered for preparedness for the protection of the environment.

Figure 5: **Aspects to be considered for recovery preparedness for the protection of the environment**

Part 3: **Strategies to achieve and assess recovery objectives**

Chapter 5. Stakeholder involvement and communications

Introduction and definitions

Definitions

"**Stakeholder involvement** is a process or a tool to reach a decision that is better-informed, sound and widely accepted". Stakeholder involvement can also be referred to as stakeholder engagement. (NEA, 2017b; ICRP, 2020)

In above context, "'**Stakeholder**' is intended to be taken in its broadest sense and should include inter alia the public, businesses, economic actors, non-governmental organisations, local, regional and national authorities." (NEA, 2017b)

Stakeholder involvement, public communications and the dissemination of information are cross-cutting issues that affect recovery management. Stakeholder involvement is necessary to ensure all those affected by a nuclear or radiological emergency are included in the decision-making and planning process, beginning in the preparedness phase (NEA, 2021d). These stakeholders include organisations that have roles and responsibilities assigned to them in planning for recovery as well as members of the public and community organisations. Building relationships with the community during preparedness facilitates effective engagement in recovery (DECC, 2015a; Health Canada, 2020; NCRP, 2014).

Public communication is a two-way process whereby information is disseminated to members of the public and the public have the opportunity for their concerns to be heard and addressed (NEA, 2017b). While topics for communication in the recovery phase will include the cause of the accident, responsibilities, long-term health consequences, compensation, living with contamination and legal issues, there will be links to the initial crisis communications strategy. Ensuring consistent messaging through the transition from emergency response to emergency recovery is vital. As demonstrated during the response to the COVID-19 pandemic, the public debate over mask use and the safety of vaccinations highlights how essential consistency is in maintaining trust and fostering public understanding and compliance (Sarukhan et al., 2020).

Relationships with community stakeholders are integral in the "co-expertise process" described by the ICRP (ICRP, 2020). This process helps develop a practical radiation protection culture and build community resilience; enabling citizens to make well-informed choices and behave wisely in situations involving potential or actual exposures to ionising radiation.

Overall, it should be noted that there are important differences between stakeholder engagement during the preparedness, response and recovery phases of a nuclear or radiological emergency. Techniques employed to engage with stakeholders will need to adapt to changing demands and manage the varying levels of confidence in public authorities, especially during the recovery phase (existing exposure situations) where confidence may been have lost through preceding events.

Guidance for developing a framework

The preparedness work should ensure readiness for recovery and to engage, inform and involve the public and other stakeholders. These preparations should have the flexibility to evolve and adapt according to the emergency.

Predefine stakeholders and early involvement

The identification and understanding of stakeholders who will be involved in recovery should be developed in preparedness (TERRITORIES, 2020; Raskob et al., 2016; Duranova and Raskob, 2020). This will require outreach to local communities to gain awareness of specific vulnerabilities, such as the existence of communities where communicating in the dominant national language may be limited or where there is a prevalence of consumption of local foodstuffs. The involvement of community-level stakeholders should be encouraged through exercises, recognising that there may not be one single approach for the involvement of all stakeholders. Projects such as France's CODIRPA (CODIRPA, 2012) and Europe's TERRITORIES (TERRITORIES, 2020), PREPARE (Raskob et al., 2016), CONFIDENCE (Duranova and Raskob, 2020) and ENGAGE (Duranova and Turcanu, 2020) include examples of different approaches. The evaluation of France's CODIRPA process confirmed that there is a need to involve and integrate local stakeholders and disseminate information in the local areas.

The categories of stakeholders that should be considered during preparedness for recovery are shown in Table 1:

Table 1: **Categories of stakeholders that should be considered during preparedness for recovery**

Stakeholder	Description
Local liaison committees	Local or community liaison committees around nuclear installations are often comprised of private community members, representatives of nuclear operators, special interest groups or other community-level organisations and can play a key role in the dissemination of information in the local area.
Journalists and traditional media organisations	These organisations are important for disseminating information to the public. They have a pre-established audience and often an in-depth awareness of the lives of those within the community which will also help with the assessment of the status of recovery. During preparedness, media organisations should be identified and included in exercises to help build trust between decision makers and the media.
Socio-economic actors	Understanding the types of businesses that may be affected during the preparedness phase will allow targeted communication strategies to be established to effectively promote positive messaging and avoid reputational harm.
Food producers and consumers	Food producers are integral to the recovery of a community. In the preparedness phase, networks of food producers, agriculture experts and consumers should be established to identify trusted sources of information and the needs of stakeholders (NEA, 2011; NEA, 2018b). Experience has shown that mutually beneficial remediation strategies can be developed with joint involvement of local authorities, farmers and consumers in a "co-expertise process" (NEA, 2021a). Outreach during preparedness will help define what strategies will be acceptable to local stakeholders and where to focus planning activities.
Health professionals	Health professionals are a trusted source of health advice for individuals (NEA, 2011; NEA, 2018b; CODIRPA, 2012). Local health professionals are well-positioned to provide information and personalised healthcare advice. Preparedness work should consider developing information that will assist health professionals in addressing radiological concerns and making use of or establishing health professionals' networks.
Education professionals	Local education professionals are an established, trusted source of expert information and advice (Health Canada, 2020). During preparedness, links can be established with professionals at local institutions, such as universities or laboratories, who already possess expertise essential to recovery (e.g. radiation protection). Formal networks of these experts can support groups such as health professionals in addressing concerns of stakeholders. Community information centres, for instance the reception and information centres (CAIs) defined in France's CODIRPA (CODIRPA, 2012), may be established for the recovery phase as a means of engaging with the public.

Table 1: **Categories of stakeholders that should be considered during preparedness for recovery** *(cont'd)*

Stakeholder	Description
Citizens	Citizens have been shown to be a valuable source of scientific information (NEA, 2018b; Duranova and Turcanu, 2020). The Fukushima Daiichi accident led to an unprecedented upsurge in citizen science initiatives in and around the affected areas including the "Safecast" international volunteer-driven, not-for-profit organisation. Citizen science can help build feelings of empowerment in a population. In the preparedness phase, modern communications and data sharing infrastructure can be established and planned.
Neighbouring countries	To expedite harmonisation of cross-border recovery, the participation of stakeholders from neighbouring countries is essential to give due consideration to recovery management aspects such as cross-border trade of food and commodities.
Non-governmental organisations/Environmental protection groups	Non-governmental organisations and environmental protection groups can be part of local liaison committees described above. They may also represent a wider community, e.g. international and/or focus on specific interests.

Provide special consideration for vulnerable populations

Certain populations may be particularly vulnerable to a nuclear or radiological accident and protective actions taken during the different phases of the management of such an accident due to age, disability, health, socio-economic factors, language, culture and geography. These populations may require additional support as their way of life may be disproportionally affected. Vulnerable populations are not homogeneous and there may be considerable overlap between groups. Outreach programmes established during preparedness that target populations known to be vulnerable are valuable for ensuring these groups' needs are taken into consideration. Table 2 lists examples of such vulnerable populations.

Table 2: **Examples of vulnerable populations that may require additional support in the aftermath of a nuclear or radiological accident**

Population	Description
Elderly residents	Elderly residents may live on their own, with family or in an assisted living facility. They may require additional support during the implementation of recovery actions. Community support functions may be affected or diminished in the recovery phase, which could affect their independence or well-being. Following the Fukushima Daiichi accident, the elderly population were among those most likely to wish to return to a recovering area and changes during the evacuation period could lead to a worsening of their health conditions (NEA, 2021a). In Minamisoma city this resulted in an increase of 30% in the average cost of nursing care per elderly individual (NEA, 2021a). Therefore, possible demographic shifts in recovering populations should be considered in preparedness.
Persons living with disabilities	Persons living with a physical or cognitive disability may require additional assistance during recovery. Preserving the highest level of independence possible for members of this group should be one of the targets of recovery. Preparedness should consider the accessibility and impact of any recovery action, including relocation and evacuation, on members in this group. Outreach to people living with disabilities in the community during preparedness can help identify accessibility needs and the variety of supports required.
Indigenous peoples	Nations have an ethical and moral obligation to consider the local Indigenous peoples' way of life in the decision-making process for recovery from a nuclear or radiological accident (Government of Canada, 2011). The earlier engagement to identify their specific needs in the preparedness phase occurs, the more likely the results of recovery will be just and inclusive. Indigenous peoples' lifestyle may be especially vulnerable to protective actions that limit the harvest of wild game or edible plants. This was demonstrated by the consequences of the Chernobyl fallout in Norway for the indigenous Sami population (NEA, 2021a).
Pregnant women and children	Experience from past nuclear or radiological accidents has shown that pregnant women and children (as well as parents concerned about the long-term impacts on their children's health) can be particularly at risk for MHPSS impacts (WHO, 2020).

Develop recovery phase risk communication

Lessons learnt from previous nuclear or radiological accidents have clearly shown that effective risk communication is essential for responding effectively to the short- and long-term consequences of accidents (NEA, 2021a and 2021d; Raskob et al., 2016; SHAMISEN, 2017). This requires the preparation of a transparent, clear, consistent, and credible communication strategy that includes participation and dialogue throughout recovery. An effective risk communication strategy informs the affected population about the risks of long-term radiation exposure, strengthens community resilience, and increases confidence in official measures (NEA, 2013 and 2021d; IRPA, 2020). The public needs to understand the risks associated with low-level contamination/ radiation exposure.

Trust is an important factor in the public perception of risks. Trust must be earned, and it is usually built up over long periods of time (NEA, 2017b; USNRC, 2004). Building trust can be achieved by involving stakeholders in decision-making processes, the use of sound scientific evidence, transparency in decision-making, the careful selection of spokespersons and the use of non-scientific language. However, experience has demonstrated that a proportion of the population will never trust the activities or information provided by recovery organisations (NEA, 2021a). This is best mitigated though the continual broad dissemination of trusted and credible information.

Plan communication channels

While established information channels will be used to supply the population with information, communication channels which facilitate a two-way dialogue and take account of a region's cultural and linguistic diversity should be established during preparedness (NEA, 2021d). Due to a variety of socio-economic factors, there may be communities unable to communicate in the dominant language of a nation. Information should, where possible, be available in the primary language of a community and in a form accessible to persons with disabilities, such as braille and sign language. This is particularly important for information where immediate clarification by a trained expert is not practicable.

Dialogue that addresses the concerns of affected populations is essential in building trust and empowerment. This can be facilitated by:

- call centres, staffed by trained personnel, that offer direct contact with authorities for the affected population;
- online forums that are monitored by trained personnel;
- local information events or citizen meetings with interactive sessions between citizens and experts;
- community information centres staffed by trained local personnel; and
- public and voluntary counsellors to actively seek dialogue with the affected population (see more information in Chapter 2 "Ensuring health and well-being").

France's plan to set up local reception and information centres in the contaminated area shortly after an accident, with the potential to maintain them for years as a central contact point for the affected population, is an example of good practice in communication with an affected community (CODIRPA, 2012).

It is essential to include modern internet-based communications within both information and dialogue channels (NEA, 2019b and 2021d). The use of social media is widespread and is therefore a valuable means of supporting the exchange of information with the public. It should be noted that misinformation can spread very quickly through social media and recovery organisations must have a social media strategy to deal with this.

Chapter 6. **Building resilience**

Introduction and definitions

Definitions

Capability is the power or ability to respond.

Capacity is the ability to respond at the necessary scale.

Resilience is the ability to resist, absorb, accommodate to and recover from the effects of a hazard in a timely and efficient manner.

The Sendai Framework acknowledges that "Disaster risk reduction requires an all-of-society engagement and partnership" (UNDRR, 2015). Fostering national and community resilience should be viewed as a key element of risk management (DoD, 2017). Moreover, it is recognised that community volunteers and voluntary organisations are an important element of community resilience. Subsequently, there is an opportunity to develop resilience by involving these groups in discussions on preparedness and inviting them to participate in building capacity and capability of communities (ANNCLI, 2020). One of the recommendations of the NEA workshop on Preparedness for Post-Accident Recovery is that preparedness strategies "should include actions targeting the resilience of societies and engaging local communities" and that "the co-expertise process could largely help in meeting this goal" (NEA, 2021a).

There are multiple cross-cutting issues affecting preparedness for post-accident recovery which can be grouped under the concept of building resilience. These include planning, capacity and capability, exercising, and education and training.

Guidance for developing a framework

Evaluate capacity and capability

An important early step in ensuring preparedness is to critically evaluate the current national capacity and capability to respond through appropriate studies and stakeholder engagement (ANCCLI, 2020). In a review of UK national nuclear emergency recovery capabilities, a questionnaire-based approach was used which allowed qualitative and quantitative information on each aspect of recovery capability to be gathered in a relatively short period of time (a few months) from approximately 20 organisations (PHE, 2016).

Baseline resources required should be clearly identified and, where necessary, legislation put in place to secure these. Increasing the existing levels of capacity and capability to cover larger scale events may not be straightforward due to costs and other restrictions. By adopting an all-hazards approach, some resources may be applicable to multiple types of hazards to achieve greater cost effectiveness.

Raising levels of capacity and capability does not come without cost, but there is evidence that investment in disaster preparedness leads to reduction in costs not only in humanitarian terms but in economic terms as well (Idris, 2018). The data available is not specific to nuclear accidents or recovery actions, but it is expected that the findings would translate to some degree. Some studies have estimated that every US dollar spent on overall disaster mitigation equates to four US dollars in future benefits in the event of a disaster occurring (MCC, 2005).

Exercising

Exercising is an important step in testing planned arrangements and increasing familiarity and experience in applying those plans. A planned programme of exercises should seek to test the resilience of plans and arrangements across a range of scenarios and scales. Recovery exercises provide a vital route through which key players in recovery can learn and gain experience outside of a real event. However, not all stakeholders (e.g. political leadership) are involved in exercises and so the possibility of expanding involvement in exercises to include more diverse stakeholders should be explored. The approach taken and the design of exercises can strongly influence their success in meeting their objectives. Some recommendations for actions and options to consider when designing a recovery exercise are given in the Checklist for Organising a Recovery Exercise (Annex A).

In general, national exercises are carried out frequently, but these tend to focus on the emergency rather than the recovery phase. It can be constructive to consider the internal drivers/motivators for carrying out exercises. The cost-savings in a real event because of thorough preparedness can be significant, and proper practice and determination of roles and activities is a key part of this.

Some national arrangements for carrying out recovery exercises are described here:

- *Canada*: Following participation in the IAEA Emergency Preparedness Review (EPREV) programme, recovery has become an area of focus for exercises, and operators have begun to voluntarily include recovery actions in their exercises. One exercise (Synergy Challenge, 2018) used a “time jump” device in the exercise programme to exercise some early recovery actions in what would have been the transition phase. Another exercise (Huron Resilience, 2019) included Business Continuity Plan recovery on-site. National standards (CSA N1600-2021) and regulations (CNSC REGDOC 2.10.1, 2016) will be updated to further encourage the inclusion of the recovery phase in emergency exercises.
- *France:* Several nuclear exercises have been and will continue to be organised to focus on the post-accident phase, although this is currently not required by European nor international regulations (Council of the European Union, 2013; IAEA, 2014; IAEA, 2015a). Post-accident phase exercises can be separate entities or extensions to national emergency phase exercises. Where the post-accident phase is played as an extension to national exercises, working groups are set up to handle different issues around implementing protective actions such as the implementation of food restrictions. A large-scale exercise (SECNUC, 2021) is planned to test the national response to a major nuclear incident (including co-ordination between ministries) and to test new arrangements regarding the post-accident doctrine.
- *United States:* Post-emergency phase inter-agency exercises are required by regulation in the United States for nuclear power station communities, although less frequently than emergency phase exercises (every eight years and every two years, respectively). There is increased focus on developing modular, table-top exercises for key recovery practices. Recommendations for exercise design include setting a battle rhythm to help move play along. Exercises are designed to include aspects such as legal expert input, economic analysis and simulation of external pressures.

Additionally, there are international initiatives that seek to develop understanding and share national practices including the NEA International Nuclear Emergency Exercises (INEX) series. INEX-3 included recovery management and medium- and longer-term decision-making as a key area of focus (NEA, 2007). The 14 participating countries conducted table-top exercises independently (or, in some cases, jointly with neighbouring countries) and then evaluated their experiences so that the national approaches could be shared and analysed. The outcomes of the exercise included a number of recommendations for areas of improvement and highlighted the importance of certain issues such as “stakeholder involvement aspects in later phase consequence management, and the interaction and interdependency of decision-making and approaches to stakeholder communication, agriculture, food and other countermeasures, recovery management, waste and compensation". The focus of INEX-6 will be on planning and preparedness for the transition and/or the recovery phase.

Provide education and training

Education and training of people who will be involved from the local to the national level in recovery management is important. There is a general concern that a downward trend in the recruitment, training and education of radiation protection professionals exists and, if unaddressed, is likely to impact the level of expertise in nuclear and radiological recovery situations. This suggests a continued need for serious consideration of the pipeline for skilled people in the relevant fields, both nationally and internationally. Part of the solution may be to train existing experts so that they may work across different situations and/or hazards.

Beyond technical expertise, one skill that is sometimes neglected is that of managing people and other experts, particularly during post-accident recovery. Clearly, the situation in the recovery phase is different from that in normal times and yet there are distinguishing characteristics which also separate it from the initial emergency phase. As a result, while involvement in emergency response might often be perceived as a duty, perceptions around involvement in the subsequent recovery may be more complicated, and challenges in resourcing and management can flow from this. In terms of building on existing expertise, there are international frameworks, such as the NEA Working Party on Nuclear Emergency Matters (WPNEM), that provide opportunities to test, collect and share national experiences. Initiatives such as these are recognised as important tools in assisting experts in their fields to be as effective as possible.

An area that perhaps did not receive the focus it should have in the past is education of the public and other stakeholders who are not directly involved in managing the response and recovery operations. Better education and other forms of engagement with the public may increase the likelihood of public buy-in to decisions taken on their behalf. Operators and other institutions that would be involved in recovery should look to establish programmes for public engagement before any accident or emergency occurs. In France, diverse working groups are reflecting on the establishment of a culture of safety and radiation protection for the populations living near nuclear facilities and throughout the territory (ASN, 2021). One group is working to find capacities/capabilities to implement this culture during preparedness and another group is dedicated to the recovery phase. The US Centers for Disease Control and Prevention (CDC) have had success with promoting awareness of real-world preparedness issues based on those that apply to science fiction hazards (a concept also known as "zombie preparedness") (CDC, 2021).

It is also important to recognise that initiatives such as citizen science (e.g. Safecast [Safecast, n.d]) exist and can potentially present both challenges and opportunities. Data sharing and two-way learning between institution-led and citizen-led projects is preferable to the two groups acting, or being perceived to be acting, in opposition to one another.

Chapter 7. Food and drinking water management

Introduction and definitions

Definitions

Radiological criteria are quantitative values for the practical implementation of the radiological protection system. Expressed in terms of dose or derived quantities (ICRP, 2020).

Experience from the Chernobyl and Fukushima nuclear power plant accidents has clearly emphasised the importance of managing contaminated goods in the days, months and years after a nuclear or radiological accident. Management strategies for food and drinking water are complex and need to consider the radiological impact from ingestion of contaminated foodstuffs, the setting of appropriate radiological criteria for the control of contaminated foodstuffs, the establishment of environmental monitoring programmes, and the selection and implementation of appropriate protective actions. Other important aspects to be considered for food and drinking water management are psychosocial issues, the need for stakeholder involvement, and the development of communication strategies (see Chapters 2 and 5 respectively).

One of the major concerns of residents living in areas affected by nuclear and radiological accidents is whether their food and drinking water are safe to consume. Drinking water is a particularly sensitive issue as the consumer cannot choose where their supply originates from (surface water, ground water, etc.) (WHO, 2018). The impact of a radiation emergency on food production systems depends on the presence and bioavailability of the radionuclides for transfer in the food chain, as well as the scale and timing of the release, for example whether livestock are grazing pasture, and crops are ready to harvest.

It is prudent to implement protective actions, including food restrictions, as soon as possible to protect people and the image of the products. Implementing these actions will help guarantee the radiological quality of products and to restore or maintain the confidence of consumers. Nevertheless, the introduction of food controls may give rise to major economic consequences, particularly for agricultural businesses in the contaminated area. Furthermore, there is potential for contaminated waste to be generated following the imposition of food restrictions or where other protective actions fail to reduce the level of radionuclides in food to below statutory levels, e.g. EU maximum permitted levels or Codex Alimentarius guideline levels (Codex Alimentarius Commission, 2006; Council of the European Union, 2016).

Guidance for developing a framework

One factor to consider when developing a framework in this area is the complexity and integration of international food markets, as well as the potential for cross-country impacts of nuclear or radiological accidents. This aspect of the recovery framework should be viewed through an international lens, providing enough flexibility to consider national and regional specificities rather than exclusively national or local level strategies. The three major goals of a food and drinking water management strategy are to ensure the quality of products, maintain consumer confidence, and ensure the economic sustainability of the affected areas.

To address these challenging issues during the preparedness phase, there is a need to:

- develop radiological criteria for maintaining food safety in the days, weeks, months or even years after the radiation emergency;
- produce an outline monitoring strategy for national and local authorities;
- collect and collate information on applicable protective actions; and
- develop a mechanism for engaging with stakeholders and the local community.

These elements would be facilitated through a well-prepared communications strategy to disseminate information about food and drinking water quality, radiological criteria, protective actions, compensation, etc.

Evaluate radiological criteria

In preparedness, it is important to evaluate the various radiological criteria that might be applied at different stages of response and recovery. Maximum permitted levels (MPLs), expressed in terms of Bq/kg or Bq/l, are important criteria used in the emergency phase for identifying food products subject to restrictions. The underlying rationale for MPLs is complex and difficult to understand. The values are generic and are not adapted to the actual situation, so MPLs should not be implemented as absolutes. An activity concentration below a particular level is not necessarily good, as increased levels of artificial radioactivity are still present. Conversely, an activity concentration above an MPL is not always hazardous for consumption, depending on the composition of the diet. Producers request that a graded approach be taken in the management of contaminated foodstuffs, based on a process of continual improvement. Regaining credibility and trust of consumers depends on the proactive and transparent implementation of protective actions during the recovery phase.

Regarding the regulatory regime, any changes in the values of the MPLs during the recovery phase should be properly explained to the population to avoid negative perceptions. Furthermore, an element of flexibility is encouraged during preparedness to allow for a variety of dietary and cultural aspects to be incorporated into regulations, and consideration given to adopting a range of MPLs rather than a unique value for each food group. The fixing of radiological criteria is complex and needs to balance many considerations, including the interests of producers, retailers, and consumers at the local, national and international level. In-depth debate at the national level is needed to maintain a degree of solidarity in the country (ICRP, 2020).

In addition to MPLs, other dose criteria such as reference levels (RLs), expressed in terms of residual effective dose, should be considered during recovery. The value of RLs should be selected considering the appropriate time frame, individual dose distribution of the affected people, and the tolerability of risk in the circumstances (ICRP, 2020). At the planning stage, RLs are values not to be exceeded. After a radiation emergency, and subsequent dose assessment, RLs act as benchmarks for evaluating the effectiveness of protective actions. RLs can be refined according to the prevailing circumstances. RLs were used, for example, in the United Kingdom to lift restrictions on the marketing of sheep meat after the Chernobyl accident and were accepted by farmers, the food sector, and consumers (NEA, 2018). MPLs can be used in the recovery strategy for maintaining consumer confidence, although dose calculations for comparison with the RL will play a key role in defining the exit strategy.

Findings from previous nuclear accidents have shown that there are important considerations other than activity concentrations of radionuclides in foodstuffs, including, the quality and taste, price, and availability of alternative supplies.

Prepare a food monitoring strategy

Many countries have routine programmes for monitoring of foodstuffs as part of normal operations, but these will need considerable expansion and adaptation to cope with a post-accident situation, according to the risk assessment carried out during preparedness. Clearly, it is not practical to monitor each and every food sample. So, the authorities need to prioritise sensitive foodstuffs (e.g. milk, free ranging livestock) when developing plans for well-designed and transparent monitoring and control systems that consider the temporal and spatial heterogeneity in radionuclide uptake by pasture and other crops.

Experience after the Chernobyl and Fukushima Daiichi accidents show that the population in the affected areas might not find the systems established by the authorities satisfactory for their needs (Maître et al, 2020). Potential reasons include priorities and the level of detail in the authorities' systems, as well as trust in the published monitoring results. Members of the public and the local food industry for example, have therefore established independent monitoring capacities for their own needs (Maître et al, 2020). Experience shows that such initiatives can be useful in addition to the authorities' systems, and that they can contribute substantially to increasing local competence, confidence, and trust. The plurality of radiation monitoring networks is important when comparing measurements and to improve the effectiveness of protective actions (Charron et al., 2016).

Small-scale domestic produce (e.g. garden or wild products) are foods typically not covered by the authorities' control systems, but which may be important for the public. These products must be measured before consumption. Self-help actions performed by individuals are a key factor in empowering the public to build their own reference scale and to regain control in their lives. Preparedness must consider how complementary but independent measurements taken by various groups, such as non-governmental organisations, businesses and cooperatives, can be integrated into databases to expand the information available to members of the public. Monitoring and control of foodstuffs is a key aspect of food and drinking water management to both reassure the public and facilitate trade inside and outside the affected area. Based on learning from the fishery sector around Fukushima, it would be useful to identify factors at the preparedness stage which may impact specific markets even when radiological measurements indicate products are safe.

Plan for protective actions

There are a wide range of protective actions to reduce activity concentrations in food products and drinking water that can be implemented in the days, weeks, months, and years following a radiation emergency. Early phase protective actions mainly involve precautionary restrictions on the consumption of agricultural and fishery products and drinking water, as well as the banning of hunting and the gathering of wild foods. Monitoring of the affected areas enables food restrictions to be more accurately defined in terms of location and types of produce. It is in these areas that subsequent protective actions should be implemented to improve the radiological quality of products and to sustain food and drinking water supplies and economic activities. The types of protective actions include removal of topsoil, ploughing, chemical treatment of soils, provision of clean feed or additive for livestock, and industrial scale food processing to remove contamination. The actions selected depend on the physical and chemical properties of the radionuclides released, the season of the year and the types of soil and land use. There are fewer protective actions for drinking water either involving alternative supplies or water treatment.

Preparedness should include:

- Ensuring access to, and familiarisation with, databases and information on protective actions that can be applied by the authorities as well self-help actions, e.g. UK Recovery Handbook for Radiation Incidents v4 (PHE, 2015) and EURANOS handbooks (Nisbet et al., 2009).
- Planning to involve local communities and affected stakeholders in the evaluation of protective actions to identify feasible options and those for which capacity might be limited. For planning purposes, some indication of the volumes of waste that could be generated by a protective action will be an important consideration (see Chapter 5 "Stakeholder involvement and communications").
- Developing experimental approaches for refining/adapting protective actions under local conditions.

- Developing a pre-prepared outline communications plan to present the rationale for protective actions, including timescale, technologies, uncertainties, etc. (see Chapter 5 "Stakeholder involvement and communications").
- Developing an approach to compensate producers for loss of production or adaptation to new practices or procedures (see Chapter 3 "Supporting the economy").
- Agreeing on factors to be included in defining "end-state"/success criteria that allow protective actions to be withdrawn. This will require the availability of measurement devices and provision of up-to-date information.

Chapter 8. Remediation and decontamination

Introduction and definitions

Definitions

Remediation is the process of reducing radiation exposure from contamination through remedial actions to remove the contamination itself (**decontamination**) or to affect the exposure pathways (based on ICRP, n.d.).

A **remedial action** is the removal of a source or the reduction of its magnitude (in terms of activity or amount) for the purposes of preventing or reducing exposures that might otherwise occur in an emergency exposure situation or in an existing exposure situation (ICRP, n.d.).

A remediation strategy should be developed in the preparedness phase to ensure it can be implemented efficiently and effectively during an emergency or post-emergency situation. Past accidents have shown that authorities can be overwhelmed during the emergency phase, resulting in delays in initiating remedial actions. For example, human, technical and financial resources that are required for remediation may not be available on the timescales required, resulting in reduced levels of protection.

Decisions on remedial actions will depend on the agreed endpoints, current and future land use, size of the affected area(s), levels and characterisation of the contamination in terms of the radionuclides involved and hazards posed, exposure pathways, time of year of the release and prevalent soil types, as well as public acceptance and the feasibility of remedial actions at the local level, based on available resources and routes for waste management.

Decisions on remediation are underpinned by the principles of justification and optimisation. The principle of justification ensures that decisions regarding the implementation of remedial actions result in a net benefit for the affected people and the environment as these actions can potentially induce significant disruption. The principle of optimisation of protection applied with reference levels aims to limit inequity in the distribution of individual exposures and to maintain or reduce all exposures to as low as reasonably achievable, taking into account societal, environmental and economic factors (ICRP, 2020).

Guidance for developing a framework

When preparing remediation guidance, it is important to ensure that it is risk-based, proportionate, flexible, scalable, open to lessons from previous events, inclusive, and co-ordinated (DECC, 2015b). There is a wealth of information available to support planning for remediation and signposting the relevant reference documents is recommended. A remediation framework comprises three main aspects: the infrastructure and resource requirements; the remediation process; and the collection and compilation of data and information in advance.

Anticipate infrastructure and resource requirements

Infrastructure requirements encompass: identifying the services that might be needed, the businesses/organisations that can supply them (government, universities, and private suppliers), and the processes that would facilitate procurement. In terms of services, it is important to ensure that a critical level of remediation expertise and decontamination specialists will be available on demand. Furthermore, infrastructure requirements should be able to indicate how this remediation workforce capability could be expanded to support remediation over several weeks, months or years, perhaps bringing in public and private contractors and the appropriate level of radiation protection support. Previous experience suggests that contamination may persist for years or decades, so the remediation strategy must be sustainable at local, regional and national levels. Opportunities for supporting self-help protective actions in the community should be considered to complement those remedial actions provided by the authorities. The remediation infrastructure should also identify community representatives and other stakeholders with local knowledge who could help develop the remediation plans.

Establish a process to accomplish remediation

Decisions on remediation need to be part of a holistic decision-making process that considers a broader perspective of recovery issues (e.g. business continuity, trade, environmental impacts). The NCRP (2014) described a seven-step iterative process that helps to frame the decision-making process on remediation. In the United Kingdom, the Department of Energy and Climate Change (DECC, 2015b) and Public Health England[1] (PHE, 2019) have also adopted this stepwise approach in their guidance. The steps are summarised in Table 3 below in the context of what can be done in preparedness.

Table 3: **Stepwise iterative process to deliver remediation goals**

Step	Aim	What is involved	What can be done in preparedness
1	Define radiological situation	Establish a picture of what and who has been affected, and to what extent (i.e. levels of radioactive contamination; land use in affected areas)	Develop the following: a. An outline environmental monitoring strategy and sampling programme b. A process to validate, collate and share information about the contamination pattern c. A database of relevant designated sites for conservation of habitats and species d. Role for local community in monitoring of food and environment (NEA, forthcoming c)
2	Assess impacts on human and non-human species	Use data and models to assess projected doses to people and non-human species living in the affected area taking account of exposure scenarios, habits and prevailing circumstances	Ensure the following are available: a. Habit data for human and non-human species (consumption rates; occupancy etc.) b. Dose assessment models for human and non-human species (e.g. RODOS, ERICA) c. Information on how to apply Reference Levels and other derived radiological criteria d. Local knowledge and plans to assess non-radiological health impacts in the community from remediation

1 In 2021, Public Health England was replaced by the UK Health Security Agency and the Office for Health Improvement and Disparities.

Table 3: **Stepwise iterative process to deliver remediation goals** *(cont'd)*

Step	Aim	What is involved	What can be done in preparedness
3	Identify remediation goals and remedial actions	Engage communities in establishing remediation goals and endpoints, including dose criteria, and targets for environmental protection. Identify options for remediation and decontamination	a. Ensure access to, and familiarisation with databases and information on remedial protective actions that can be applied by the authorities as well as self-help actions (e.g. SSK, 2010; NCRP, 2014; PHE, 2015; MoE, 2018a) b. Agree how radiological risk will be equated with measurable radioactivity in the environment (taking into account the background exposure and natural decay)
4	Evaluate remedial actions	Involve local communities and affected stakeholders in the evaluation of remedial actions to assist in the development of an optimised strategy. Decision support tools can be used to complement discussions with stakeholders (IAEA, 2012)	a. Enable comparisons of remedial actions to identify feasible options and those for which capacity might be limited. For planning purposes, some indication of the volumes of waste that could be generated will be one of the most important factors to be considered b. Ensure access to decision support tools and other software/tools to estimate consequences of remedial actions (e.g. RODOS, CONDO, ERMIN, WEST – more information is provided in Chapter 9) c. Ensure access to up-to-date information on waste management plans as this can influence selection of remedial actions (IAEA, 2015b)
5	Decision-making	Establish a decision-making process for remediation that is open, transparent and involves representatives of the local authority and affected community. Consider local needs, cultural and ethnic sensitivities, liabilities, economics, environmentally protected areas, and applicability of policies and legislation	a. Identify community representatives and stakeholders. Consider the setting up of subgroups to address different issues b. Consider how to present information on remedial actions, their effectiveness, risks, and benefits to a diverse audience c. Identify protected habitats and species d. Develop an outline communications strategy (NEA, forthcoming c) e. Agree factors to be included in defining "endpoints"/success criteria, when remediation is complete and remedial protective actions can be withdrawn (IAEA, 2007)
6	Implement decisions	Put the agreed remediation strategy into practice	a. Break the strategy down into manageable tasks with defined outcomes and ownership, by identifying the 'who, what, where, when and how' to achieve the remediation goals b. Develop a pre-prepared outline communications plan to present the rationale for remediation to stakeholders. This should include timescales, technologies, success criteria, strategy for withdrawing remedial actions
7	Monitor and evaluate	Establish a long-term monitoring programme (food, environment, and public health) to evaluate the success of the remediation strategy and to provide accountability to the affected communities. This will underpin the exit strategy for stopping remedial actions	a. Agree appropriate measurable milestones for remediation, which may include short- to medium-term projected radiation dose targets for both human and non-human species b. Establish mechanisms for adapting/amending the remediation strategy, if it is not effective or causes harm

Adapted from NCRP (2014), DECC (2015b) and PHE (2019)

Collect important data and information

Preparedness should involve the collection and compilation of relevant data and information that will support decision-making on remediation protective actions. For nuclear countries, this may be achieved through the production of templates for compiling information about the area around nuclear facilities to assist in prioritising remediation needs (e.g. infrastructure, schools, nurseries, sites of special scientific interest, historic monuments, listed buildings). Some of this information can be gathered in advance to identify who/what may be impacted, and who may be able to support remediation (PHE, 2015). Examples include:

- Population: distribution, size, demography; sensitive and vulnerable groups based on age, health social/ethical considerations; institutionalised people.
- Business: industrial, commercial, retail, food, farming, and other activities.
- Types of buildings: multi-storey, detached, terrace; and building materials.
- Critical infrastructure: water and sewage treatment plants, roads, railways, schools, medical practices, and hospitals.
- Waste storage and disposal sites.
- Sensitive habitats such as Sites of Special Scientific Interest, areas protected by the Convention on Wetlands of International Importance especially as Waterfowl Habitat (UNESCO, 1994), areas protected by European Union's Birds Directive (European Union, 2009) and Habitats Directive (Council of the European Union, 1992).
- Food production: location of milk and meat producers, supply chains; location of gardens and allotments and areas for gathering of wild plants and animals.
- Drinking water: sources, abstraction points, monitoring points, and alternative supplies.

Chapter 9. Radioactive waste management

Introduction and definitions

Definitions

The guidance provided in this chapter is primarily aimed at large volumes of off-site low-level and very low-level radioactive waste, where:

Radioactive means materials that are contaminated with radionuclides;

Waste means any substance or object which the holder discards or intends to discard or is required to discard;[1] (European Union, 2008); and

Nuclear and radiological accidents have the potential to generate large volumes of radioactive waste. Waste that has been contaminated with radioactivity in emergencies is likely to be far more heterogeneous, voluminous, and complex than waste arising from routine operations. These large volumes of waste could quickly exceed or overwhelm the existing capacity for management of radioactive waste from routine operations (IAEA, 2017). Therefore, specific arrangements need to be put in place to deal with the increased volume and types of waste. One of the key preparedness steps that can be taken at the national level is to make the distinction between waste management during routine operations and emergency scenarios and to consider whether there is a need for modified or additional legal frameworks for the management of radioactive waste arising from emergencies. Countries that make this distinction and prepare for the potentially larger volumes of complex wastes that could be generated in nuclear and radiological accidents will be able to respond and recover more effectively.

Contamination entering conventional waste streams also needs to be considered as part of recovery preparedness plans, along with other hazardous substances that could be present following some incidents and decontamination techniques. Where possible, uncontaminated or lightly contaminated waste (i.e. waste contaminated below certain threshold values) should be segregated and dealt with using appropriate waste routes to avoid all waste being treated as radioactive (IAEA, 2018).

Large amounts of waste may be generated from applying remedial protective actions and from the creation of secondary wastes through treatment and reprocessing. Activity concentration may be low, moderate, or high, depending on the initial level of contamination and treatment method, although large volumes of lower activity waste are likely to be more prevalent.

Guidance for developing a framework

Evaluate national policy, strategy, and legislation

The volume and complexity of waste generated in radiological and nuclear emergencies could overwhelm national capabilities and resources. It is therefore important that national policy, strategy, and legislation for radioactive waste management is prepared in a way that adequately

1 Definition of "waste" based on EU Waste Framework Directive (2008/98/EC) (European Union, 2008).

covers the surge in capacity that is likely to be required in the aftermath of large emergencies. (IAEA, 2018). Recovery preparedness plans and regulatory approaches should allow for flexibility in dealing with wastes from a range of emergency scenarios, while at all times prioritising the safety of people and the environment according to the requirements set out in IAEA GSR Part 5 (IAEA, 2009).

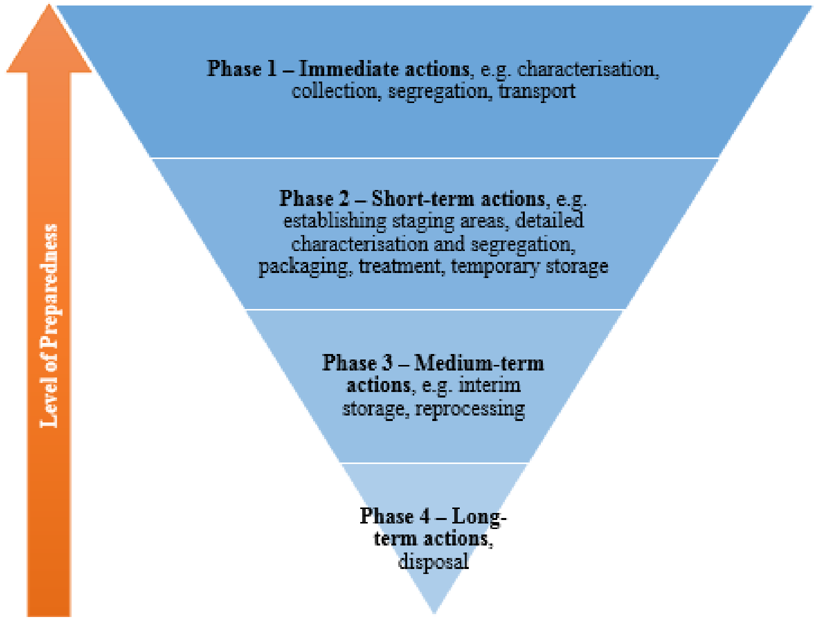
It should also be evaluated if and to what extent the waste hierarchy, which is encouraged by the IAEA for radioactive waste from routine operations, should be applied in recovery and embedded into national policies or strategies. Consideration should be given as to whether certain exemptions or modifications may be adequate when applying the waste hierarchy. Applying the waste hierarchy will help to reduce the amount of waste requiring treatment and disposal and is recognised as good practice internationally.

Existing NEA guidance should be considered where applicable to build national arrangements on best practices and harmonised approaches. This guidance includes "Characterisation Methodology for Unconventional and Legacy Waste" (NEA, 2021c) and *Challenges in Nuclear and Radiological Legacy Site Management* (NEA, 2019a). It supports the management and characterisation of wastes arising at post-accident and legacy sites, as well as the regulation around legacy sites.

Adopt a proportionate approach to waste management preparedness

It is important to take a proportionate approach to preparedness by concentrating on the issues where preparedness has the greatest potential to reduce the impacts on society, the environment, and the economy. To help with this, preparedness for waste management during recovery should be broken down into phases, with the greatest emphasis placed on preparing for the early phases where the maximum benefits can be achieved. This primarily covers how to prepare for the pre-disposal of waste, including characterisation, staging, transport, and temporary/interim storage. Advice on disposal will be limited as it is expected that disposal options for large volumes of waste will need careful consideration at the time of an incident. Developing plans for staging, treatment and temporary storage will help to fill the void until permanent disposal routes are established. Figure 6 below summarises this approach with preparedness targeted at the earlier waste management activities.

Figure 6: **Waste management preparedness: suggested breakdown into phases**



Use modelling

Modelling the potential types, activity levels, and volumes of waste that could be generated in a nuclear or radiological accident will help to illustrate the scale of the task at hand and inform decisions. When assessing the types of waste that could be generated, it is important to develop an understanding of various factors, such as the potential radionuclide activity and mix (nuclide vector), concentration, chemical composition, and physical properties.

Several modelling tools (such as CONDO [Charnock et al., 2003; Charnock, 2004], ERMIN [Charnock at al., 2016] WEST [USEPA, 2014] and RODOS [Forschungszentrum Karlsruhe, 2005]) have been developed to help users estimate the types and volumes of waste that could be generated in urban and rural environments as a result of implementing various remedial protective actions. The potential limitations and accuracy of the modelling software should be factored into the decision-making process. Specific IT expertise (e.g. Geographic Information System expertise) which may be required to effectively use these models should also be considered as part of preparedness.

Prepare plans for characterisation

Waste characterisation is essential in order to provide information about the radionuclides and the activity levels[2] in the waste as well as assurance that wastes or waste packages can meet the acceptance criteria for certain treatment or disposal routes (e.g. for processing, storage, transport and disposal). It is also essential for the design and development of new waste management facilities or the adaptation of existing facilities that may be required during recovery. Ensuring robust plans are in place for characterising wastes as quickly as possible following an emergency should be a priority during preparedness.

Prepare for staging

During the early response and recovery, it is crucial to consolidate waste in collection locations where it does not hinder emergency response or recovery activities. Such collection or lay-down areas can be referred to as "staging sites" and will allow responders to conduct essential waste management activities. Detailed information on the attributes of staging areas is provided in IAEA TecDoc 1826 (2017), together with information on the experience in Fukushima provided in the Ministry of the Environment reports on the decontamination projects (2018a). CODIRPA (2012) recommends that staging sites should be located close to the incident scene to avoid having to transport waste long distances.

Evaluate radiological criteria for waste management

Radiological criteria for specification or classification of waste, mainly in the form of limit values for the activity mass concentration (Bq/kg), is highly important to support an adequate and efficient management of waste arising from emergencies. Such limit values may function similarly to clearance and exemption levels for normal operations as proposed in IAEA GSR-3 (schedule 1) (IAEA, 2014). In this respect, the IAEA GSG-11 (2018) also proposes to apply the same exemption and clearance levels in emergencies as those established for normal operations. However, in addition to these lower threshold values it may also be sensible to set further (i.e. higher) threshold levels to support graded treatment and disposal schemes for contaminated waste. Classification and specification through contamination threshold values will be especially important when it comes to managing large volumes of waste arising from radiological and nuclear emergencies and should be considered in the preparedness phase. See Annex B for national examples of how radiological criteria are applied in emergencies.

2 Some wastes may contain other hazardous contaminants, such as biological or chemotoxic substances. Detailed guidance on the characterisation and categorisation methodologies can be found in the NEA report "Characterisation Methodology for Unconventional and Legacy Waste" (NEA, 2021c).

Establish treatment plans

Treatment or processing of waste will be required for both risk reduction and volume reduction. Existing infrastructure and equipment should be used to treat the waste wherever possible. However, where this is not possible, non-radiological waste facilities may need to be requisitioned and adapted to treat radiological waste, such as sewage treatment works for aqueous waste, or new facilities may need to be constructed at the time. Experience from the Fukushima Daiichi accident has shown that incinerators can play an important role in the processing of organic waste.

Design storage plans

Storage of waste will be required following a radiological or nuclear emergency. This will be for the purposes of either storing the waste prior to onward treatment, reuse, recycling or disposal, or for decay purposes. Storage of waste following radiological accidents can be short-term, i.e. temporary storage within a staging area that lasts weeks to months, or long-term (e.g. up to decades) to allow for decay storage or for permanent disposal solutions to be constructed. These longer-term storage solutions are of particular relevance for the time frames applicable for recovery and must conform to national regulations for the safe management of radioactive waste or other applicable regulations.

Due to the uncertainties associated with the volumes and types of waste that could be generated in an emergency, the IAEA (2017) promotes the use of "modular and scalable" storage designs. The modular concept means that storage facilities can be increased in size according to the needs for recovery. It is recommended that such designs be considered and ideally approved by the waste regulators in the preparedness phase so that they can deployed quickly at the time of an incident.

Define endpoints

Endpoints set out what the final state of the affected area will be after recovery has taken place. Defining endpoints in the recovery strategy is a key tool in determining the remediation and waste management arrangements that will be required. For example, if an area needs to be restored for public use, it is likely that an area will need to undergo extensive remediation to ensure exposures are within publicly accepted and legally defined limits. This endpoint will generate greater volumes of waste than if an area will be restricted from use or only limited use is permitted, i.e. to allow for in situ decay of radionuclides. How quickly an area needs to be restored will have a bearing on the amount of waste generated, along with the selected reference level. The lower the reference level the greater the amount of waste to manage. Waste management considerations need to be factored into endpoint decisions and included within communications with the affected community.

Waste management considerations also need to feature within the recovery framework's exit strategy. For waste management purposes this will be primarily when the waste has been transferred to long-term (interim) storage or disposal facilities and can be managed and regulated according to routine waste management arrangements or other applicable arrangements. Staging areas and temporary reprocessing and short-term storage facilities will need to be closed and restored.

Chapter 10. Environmental monitoring, human dose assessment

Introduction and definitions

Definitions

Environmental monitoring refers broadly to the measurement of radionuclide concentrations in the environment (IAEA, 2010; ICRP, 2020; ICRU, 2015; IMIS, 2006).

Human dose assessment is the process by which estimated doses or doses calculated from measurement results are applied at individual or population levels (IAEA, 2005; ICRP, 2019).

Environmental monitoring[1]

Following a nuclear accident, a comprehensive environmental monitoring programme will confirm details about the radioactive contamination, its spatial distribution, its nuclide composition, physical and chemical properties, heterogeneity, and mobility of contamination. Environmental monitoring includes the measurement of ambient dose rates and radionuclide activity concentrations in different media (e.g. air, water, soil, vegetation, food, and feedstuffs). A well-considered environmental monitoring programme, with clearly defined objectives, is a key part of reducing the risk of chronic exposure, identifying areas that are free from contamination, and building trust and maintaining trade (NEA, 2021a).

Enhanced non-routine environmental monitoring will commence in the response phase and continue long into the recovery phase. The monitoring programme in the recovery phase will evolve as the radiological situation and the needs of stakeholders change. It will also be continued after all decontamination and remediation measures have been completed for clearance and reassurance purposes. Nevertheless, the scope of the monitoring requirements will generally decrease over time and an exit strategy to end monitoring needs to be prepared (NCRP, 2014).

Dose assessment of the affected population must begin early in the emergency response phase. In the recovery phase, dose assessment is a continuously refined process influenced by the increased availability of data and the re-evaluation of the radiological situation, which informs the justification and optimisation of ongoing protective actions. The dose to affected individuals will vary based on lifestyle factors (e.g. food sources, work habits, outdoor activity), even among members of a particular population.

1 Note: The monitoring of foodstuffs is discussed in Chapter 7 “Food and drinking water management”.

Human dose assessment

Human dose assessments show the distribution of doses arising from exposure pathways leading to internal and external exposures. Dose can be estimated at an individual level using dosimeters (external dose) and whole-body counting (internal dose). For chronic internal exposure, such as those that might occur in an existing exposure situation, the suitability of whole-body counting and subsequent dose calculations will depend on factors such as the isotopes of concern (being best suited to gamma emitters) and the mechanisms of exposure. Modelled or estimated doses can be computed for populations based on environmental monitoring data (e.g. ambient air monitoring, transfer parameters) (ICRP, 2020; ICRP, 2019). The balance of estimated vs direct assessments will depend on economic and population specific factors.

Guidance for developing a framework

Set out a monitoring programme

The aspects of a recovery monitoring programme that should be planned for during the preparedness phase have been informed by experience gained through past events (NEA, 2021a; CODIRPA, 2012; Health Canada, 2020). An important aspect of preparedness is understanding how the monitoring programme will change as there is a transition into an existing exposure situation and how it differs from routine environmental monitoring. It is important to set clear objectives, which guide why, how, and where monitoring should be conducted. There should also be a clear plan for how measurements will be used, who is responsible for collecting and interrogating the data, how comparability and consistency will be maintained, and the mechanisms for presenting and sharing data.

Ensuring there is access to monitoring resources (e.g. people and equipment) is another key part of preparedness, including how existing resources will be re-deployed or where new resources will be procured from at the time of an emergency. It is also important to consider in advance how environmental monitoring regulatory requirements will be met during the recovery phase.

Scope of monitoring programme

While details of the recovery monitoring programme will need to be adapted to the accident-specific situation, a generic monitoring strategy can be developed during preparedness. This generic monitoring strategy may include the following points:

- Definition of measurement objectives, rationale, and priorities, including higher priority areas (e.g. critical infrastructure, places where the population spends a lot of time, like homes, schools, worksites, agriculture areas) and lower priority (e.g. restricted areas, forests).
- Continuous representative mapping of the whole area.
- Monitoring of the aquatic environment (particularly sources of drinking water).
- Detailed, higher-resolution characterisation of the contamination in priority areas.
- Identification of small-scale inhomogeneity (hot spots).
- Area-wide nuclide-specific ground contamination measurements.
- Regular air activity measurements.
- Sampling of lands outside the contaminated area (for reassurance purposes).
- Monitoring the need for and effectiveness of decontamination and other remedial protective actions at specified control measuring stations.
- Individual dose monitoring of particular populations or representative persons.

Data sharing and responsibilities

There is a need in preparedness to develop methods for sharing collected data between various authorities, institutions, organisations, stakeholders and the public. The transparent accessibility of monitoring data will build trust among community stakeholders, foster scientific research, and reduce duplicity of efforts. Organisations that might benefit from access to data include scientists, various levels of government, health services, community members, etc.

Self-help actions

Self-help actions are actions undertaken by individuals to manage their own radiological exposure (e.g. monitoring food and ambient dose rates in living and work areas). Direct involvement of individuals, communities, and local professionals in the management of a recovery situation empowers those impacted and can contribute to increased resilience. Self-help actions require co-ordination, technical support, equipment, and the availability of experts to help the public interpret and understand radiological measurements. This should be planned for in the preparedness phase to allow for the quick establishment of programmes.

Equipment used for civilian self-help actions should be simple and intuitively operable (NEA, 2021a; Health Canada, 2020; NCRP, 2014). Existing instruments should be evaluated and validated in advance, with literature prepared for dissemination such that the public can consult a trusted source for advice immediately.

Ongoing re-evaluation and exit strategy

A monitoring programme needs to remain flexible and adapt to the changing realities of a post-accident situation. Over time, the areas of priority, where a population is living or working, and the radiological situation will change. The ongoing re-evaluation of the situation will inform decisions on lifting or modifying restrictions (e.g. travel restrictions, work restrictions, trade restrictions), changing monitoring methodologies, or modifying reference levels. How monitoring programmes will be terminated also needs careful consideration during preparedness and built into the overarching exit strategy.

Plan for a dose assessment programme

Dose assessment is closely linked to the monitoring programme, as well as to health and well-being monitoring (ICRP, 2020; Health Canada, 2020; UNSCEAR, 2014). The available dose assessment methodologies will in many cases depend on, or be influenced by, the established monitoring programme (i.e. population dose assessment models require detailed environmental monitoring). Therefore, the dose assessment cannot be considered in isolation from monitoring.

- *Importance of data collection in the early emergency phase:* Monitoring data collected in the emergency phase are crucial for a comprehensive characterisation of the radiological situation and therefore for an adequate dose assessment. Measurements of radionuclides from the emergency phase can greatly reduce uncertainties in dose estimation, especially because of short-lived radionuclides (e.g. iodine isotopes). While not specific to recovery, these measurements are essential for the analysis that may continue to be refined and examined well into the recovery phase.
- *Heterogeneous dose distribution in the affected population:* In most existing exposure situations the level of exposure is mainly determined by individual behaviour. This usually leads to a very heterogeneous distribution of radiation exposures. It is therefore important to assess individual doses, especially for vulnerable persons (e.g. children).

Reference levels

A reference level is an annual dose value (e.g. the effective dose) "above which it is generally judged to be inappropriate to allow exposures to occur". Reference levels are provided as a range by the ICRP (ICRP, 2020) and should be set between 1 and 20 mSv in the recovery phase (existing exposure situation). During the recovery phase, if protection is optimised so that doses are below the specified reference level, it is generally safe to live in the contaminated area. However, protection needs to be continually optimised and justified, even if doses fall below the reference level (i.e. as low as reasonably achievable). Reference levels should be defined during preparedness, noting that some flexibility will be needed at the time of an emergency to meet recovery objectives.

Preparedness must also include the development of information materials to explain the purpose of a reference level to the population. This includes building the understanding of what the reference level represents, how it is used, and what exceeding the reference level does and does not mean on an individual level.

Exposure pathways (community specific considerations)

Collecting information about communities is an important aspect of preparedness for dose assessment. This allows for the evaluation of relevant exposure pathways and how lifestyle factors affect potential internal and external exposures. Some information that may be collected in advance includes population density, local food supplies, drinking water sources, businesses, indoor and outdoor activities, and general demographics, such as age. Dose assessment models will rely on these lifestyle factors to estimate dose to the population for assessment and for the planning of restrictions.

Dose assessment based on modelling using environmental monitoring data

Dose assessment based on modelling can be used to estimate doses at the population or individual level (NEA, 2021a; ICRU, 2015). Data required to run dose assessment models should be considered in preparedness and should be linked to the monitoring strategy. It is also necessary to consider what aspects of dose assessment will be modelled in recovery and for what purpose. Modelling should take into account:

- All available radiological measurements such as ambient dose rate, nuclide-specific ground contamination, and air concentration (nuclide vector), activity concentrations in foodstuffs and water supplies.
- All exposure pathways.
- Living habits and behaviour of the affected population.
- Type of buildings (to determine realistic reduction factors for indoors).
- Radioactive decay, weathering processes, etc.
- Demographics.

Dose assessment of individuals living or working in an existing exposure situation is also an important activity during later stages of recovery and can in some cases be usefully modelled. Similar techniques, when applied in general to a population, allow for determining the suitability of lifting restrictions on an area.

Other considerations

During preparedness it is necessary to consider how other dose assessment tools will be used and how these fit in with the wider recovery effort, such as the use of personal dosimeters, as experienced after the Fukushima Daiichi accident (e.g. D-shuttle) (NEA, 2021a). It is also necessary to consider how and when individual dose assessments will be conducted using in-vivo and in-vitro monitoring.

Chapter 11. Conclusion

Experience from past nuclear and radiological accidents shows that preparedness plans and arrangements for the immediate response to such accidents are generally well established. The recovery phase, which is a long, complex, and resource-intensive process, has not been considered to the same extent by many countries and there is a lack of international and national guidance (NEA, 2018a; NEA, 2021a).

This report provides guidance on the development of a national framework for post-accident recovery preparedness that all nuclear and non-nuclear countries should consider in the context of their national situation when developing recovery preparedness arrangements. As nuclear or radiological accidents can have widespread and transboundary impacts, recovery arrangements should be part of preparedness plans and where possible form part of a holistic, all-hazards approach to post-disaster recovery management.

The recovery preparedness framework proposed in this report follows a cyclical approach, starting with the creation of a national framework for recovery preparedness and includes the definition of recovery objectives. This is followed by the evaluation of cross-cutting and topical approaches to achieve and assess the recovery objectives. The cyclical loop is created by incorporating improvements through feedback from exercises or lessons from real situations. The guidance provided in this report addresses a multitude of issues at stake in the areas of concern, which if ignored could cause significant adverse long-term consequences for recovery. Conversely, adoption of a recovery preparedness framework could significantly contribute to the implementation of the recovery objectives of ensuring health and well-being, supporting the economy, and protecting the environment in case of a nuclear or radiological accident.

The strategies to achieve and assess the recovery objectives can be divided into topical and cross-cutting strategies. The former include food and drinking water management, remediation and decontamination, waste management, and monitoring and dose assessment. Cross-cutting strategies, principally stakeholder engagement and communication and building resilience, should be considered throughout the framework as they apply to all stages. Countries should carefully assess the different actions introduced in the respective chapters in order to adapt them to their own needs and requirements for a national recovery preparedness framework.

The integration of long-term recovery management after nuclear or radiological accidents into international and national preparedness requirements is not yet well established. The goal should be to engage and maintain an active exchange of experience, information, and best practices among international actors on the subject over the coming years while national recovery preparedness arrangements are implemented. In this regard, the NEA could play an important role as a forum for exchange.

Further research and examination of direct and indirect long-term consequences on the economy and (international) trade could help improve the recovery of affected areas in socio-economic terms as well as maintaining international product supply chains. This would complement ongoing research on the long-term mental health and psychosocial impacts of nuclear or radiological accidents (e.g. WHO, 2020 and references therein).

Methods to optimise decision-making in response to and after nuclear or radiological accidents should also be identified, in particular regarding stakeholder involvement and the balancing of protective actions and their long-term socio-economic, environmental and public health impacts. This should be part of a broader analysis of optimisation in decision-making across the nuclear sector with the objective to reach more sustainable and inclusive decisions through reinforced stakeholder involvement. Workshops organised by the NEA in the past, including the 2020 workshop on “Optimisation: Rethinking the Art of Reasonable”, and related publications, point towards the importance of holistic and inclusive approaches to optimisation while considering prevailing circumstances (NEA 2017b; NEA 2021b, d and e). However, more investigation is needed on how to transparently achieve accepted or tolerated and sustainable policy decisions through a process that is inclusive towards stakeholders and balances various risk components, i.e. considers both benefits and detriments.

A key part of effective national recovery preparedness is the continuous improvement of arrangements through topical exercises to identify and address potential gaps or emerging issues. While emergency response exercises are common and required by international or regional standards, this is not yet the case for recovery exercises (Council of the European Union, 2013; IAEA, 2014; IAEA, 2015a). A small number of countries have recently started to plan and conduct recovery exercises.

Exercising long-term recovery comes with a number of challenges regarding the adopted scenario and the scope of the exercise and stakeholders involved (NEA, 2007; NEA, 2010). In this regard, an innovative international exercise focused on long-term recovery to harness experience and expertise from different NEA member countries could be an ideal platform to test the findings of this report. The NEA is preparing such a recovery exercise in the framework of International Nuclear Emergency Exercise-6 (INEX-6). It is expected to take place in 2023-2024.

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Annex A. Checklist for organising a recovery exercise

This checklist is focused on steps for developing an exercise for recovery issues. It should be considered alongside more general guidance for exercise process management to cover topics such as organisation, logistics etc. (such as that provided by the IAEA[1]).

<table>
<tr><th>Step</th><th colspan="2">Description</th></tr>
<tr><td rowspan="2">A) Identify exercise requirement</td><td colspan="2">a) Decide whether the primary purpose is to provide training or test recovery framework; decide whether it is necessary to test some recent change to a particular aspect of the recovery framework</td></tr>
<tr><td colspan="2">b) Strategic considerations: how it fits into the planned programme of exercises; how it helps to test across the range of scenarios and scales; how arrangements between relevant organisations/stakeholders/nations are tested</td></tr>
<tr><td rowspan="7">B) Develop specifications (identify exercise objectives, scope, structure, constraints)</td><td colspan="2">a) Set clear exercise objectives and share these with participants: decide what (at minimum) the exercise should achieve; if its purpose is performance evaluation, consider setting key performance indicators based on recovery objectives
TIP: Avoid being overambitious in the number of recovery objectives tested in a single exercise. It is preferable to focus on those areas which are key or have been weak in the past</td></tr>
<tr><td rowspan="3">b) Decide the scope:</td><td>i) which participants will be invited and what will be the extent of their involvement; and whether it is possible to involve stakeholders not usually involved; participants required will partially depend on the objectives to be tested</td></tr>
<tr><td>ii) what will be the time and duration of the exercise</td></tr>
<tr><td>iii) if there are recovery subgroups, whether co-ordination between subgroups will be exercised</td></tr>
<tr><td rowspan="2">c) Decide the structure:</td><td>i) Full or Modular? If modular, identify modules to be tested and involvement in modules etc.</td></tr>
<tr><td>ii) Simulated or table-top? Simulated exercises have the advantage of being closer to reality but table-top can be more cost-effective or more practical in some situations</td></tr>
<tr><td colspan="2">d) Identify the constraints: what limitations will affect the exercise design; which factors (such as practical limitations) will be accepted and which will be mitigated</td></tr>
<tr><td rowspan="3">C) Develop scenario</td><td colspan="2">a) What is the spatial and temporal scope of the scenario; what parts of the recovery phase are included; what is the starting situation at the point at which the exercise commences; what are the key events and timeline; at what points will "exercise injects" be provided?</td></tr>
<tr><td colspan="2">b) Map exercise timeline to real-time, consider use of "time jumps" to focus on the time steps of most relevance/interest
TIP: The timelines of recovery are longer than those of the response phase and so exercise design can be more challenging in this respect. The use of 'time jumps', where the participants end one phase of the recovery and immediately move on some time to another phase of interest, is common but introduces additional complexity. To avoid confusion, 'time jumps' should be clearly communicated to participants and the transition from one time step to another made obvious, for example by separating them with a natural break in play</td></tr>
<tr><td colspan="2">c) Consider how individual exercises may be linked (e.g. linked response phase and recovery phase exercises, played sequentially and both based on the same accident scenario)</td></tr>
</table>

1 IAEA (2005), *Preparation, Conduct and Evaluation of Exercises to Test Preparedness for a Nuclear or Radiological Emergency*, EPR-EXERCISE 2005, IAEA, Vienna.

Step	Description
D) Develop data	a) Identify the data necessary to test the exercise objectives. For recovery situations, the range of data that could be required is extensive and will include information not only on the radiological hazard (dose rate measurements, food contamination measurements etc.), but issues such as geography, demographics, meteorology, media and public responses and the resources available to be deployed
	b) Realism: there is a balance to be struck between realism and practicality; participants should ideally receive data in the form they would expect to receive it in a real event
E) Management arrangements	a) Consider how instructions, data and exercise injects will be provided; where possible, provision of data should simulate reality TIP: Bear in mind that information control is an important function that exercises can be used to test
	b) Give adequate consideration to exercise logistics
F) Undertake exercise	
G) Perform evaluation and hold debrief	a) Evaluate the performance in terms of recovery decisions, co-ordination, outcomes and other issues; where possible, evaluation of a given topic/objective should be carried out by someone with relevant expertise
	b) Evaluate the exercise and consider what can be done better or differently for future exercises; include the players' experiences in identifying what went well and what could be improved
H) Produce exercise report	a) Record observations made during the exercise, including performance against the relevant objectives and any lessons learnt
	b) Set recommendations or follow-up actions to improve recovery framework and address any weaknesses or issues identified
I) Share, refine and improve exercise design	a) Share best practice and lessons learnt to feed back into future exercise design; where possible, also share these internationally
	b) Identify existing international best practice and feed into future exercise design

Annex B. National examples for the application of radiological criteria in emergencies

Example 1 – Waste management in Japan after the Fukushima Daiichi accident:

In Japan, different waste management programmes apply for waste arising from decontamination measures and municipal waste.

Decontamination waste (e.g. soil removal, removed plants, undergrowth) is disposed of separately and in special facilities, regardless of the degree of contamination. After short-term temporary storage in staging areas the waste is moved to long-term (30 years) interim storage facilities and treated (e.g. incineration of combustibles or other methods for volume reduction) until disposal in a final repository. However, the largest part (approximately 80%) of the soil removed is only slightly contaminated (i.e. below 8 kBq/kg for Cs-134 and Cs-137) (MoE, 2019a and 2019b). This soil is meant to be reused under certain conditions and protective measures, e.g. as structure material for coastal levees or for road construction. Depending on the type of use, limit values for the mass-specific contamination between 4 and 8 kBq/kg apply. These values are based on dose criteria of 1 mSv/a for the workers involved and 10 µSv/a for the population after completion of the work (MoE, 2018a and 2018b).

For other waste from outside the former evacuation zone, such as municipal waste or waste from clean-up works following the tsunami, a limit for the mass-specific contamination of 8 kBq/kg applies. This is based on a dose criterion of 1 mSv/a. Waste exceeding 8 kBq/kg and any waste from inside the former evacuation zone (regardless of the degree of contamination) is managed separately under special protective measures. Waste from outside the former evacuation zone not exceeding 8 kBq/kg is managed as conventional waste in accordance with the stipulations of the Waste Management and Public Cleansing Act (i.e. regulatory framework for conventional waste management).

The additional effective dose to workers involved in managing contaminated waste is restricted to 1 mSv/a. Incinerators, storage facilities or other installations have to be laid out and operated such that the additional effective dose to the public in the vicinity of these installations does not exceed 10 µSv/a (MoE, n.d.).

Example 2 – Guidelines of the Nordic countries for waste management in nuclear or radiological emergencies:

The Nordic Flag Book (STUK et al., 2014) was developed by the Nordic radiation protection and nuclear safety authorities to provide generic guidelines and recommendations for protective measures in early and intermediate phases of nuclear or radiological emergencies. Besides various other areas of emergency preparedness and response (EPR), the document covers general options and principles of waste management. With respect to large amounts of contaminated waste, it defines four waste categories by means of the degree of contamination (for small amounts stricter limit values may apply) (see Table 4).

For each of these categories the document discusses amounts and types of waste to be expected as well as graded protective measures and requirements during waste management. Under certain conditions category III waste arising from decontamination measures "can be used for constructing roads, streets and similar and also for landscaping when otherwise suited for this kind of use". With respect to category IV waste no radiation protection requirements limit the conventional waste management routes.

Table 4: **Contaminated waste categories defined by the Nordic Flag Book**

Category	Activity concentration (kBq/kg)		
	Alpha emitters	Strong gamma and beta emitters	Weak gamma and beta emitters
I	over 100	over 1 000	over 10 000
II	1 – 100	10 - 1 000	100 - 10 000
III	0.1 – 1	1 - 10	10 - 100
IV	below 0.1	below 1	below 10

Source: STUK et al., 2014.

Example 3 – Legal provisions in Germany for off-site waste management in nuclear and radiological emergencies:

The German Radiation Protection Act differentiates between radioactive materials that are used or arise in the context of planned exposure situations and radioactive contamination occurring in connection with existing exposure situations or emergency exposure situations (Government of Germany, 2017). The latter legal category includes waste that has been contaminated as a result of an emergency.

According to the so-called sector interlinking approach[1], the Circular Economy Act and the other Federal legislation applicable to conventional waste are generally applicable to radioactively contaminated off-site waste, but the competent authorities have to act in accordance with any additional statutory ordinances on the basis of the Radiation Protection Act and in accordance with the relevant emergency response plans.

The Radiation Protection Act requires contamination limit values (specific activity, Bq/kg) for the management of waste contaminated due to an emergency to be specified at the sub-statutory level [in a statutory ordinance] (Government of Germany, 2017). These limit values function in a similar way to the exemption and clearance levels for radioactive materials from planned exposure situations. In case the actual contamination levels fall below these limit values, it shall be assumed that the requisite protection against the harmful effects of ionising radiation is in place without additional special protective measures as far as this waste is managed in accordance with the general Federal waste legislation and the permits of the facilities in which this waste is managed. This applies for any kind of off-site waste including waste from decontamination or from other protective or remedial actions.

According to the Radiation Protection Act, the Federal Government shall further issue a statutory ordinance for potential emergencies or for an emergency that has already occurred introducing supplementary safety requirements and exception rules for the management of waste exceeding these limit values (Government of Germany, 2017). This may include further limit values for contamination or other radiological criteria such as ambient dose rates to support adequate graded protective measures for workers and the public with regards to waste management.

Any of the above-mentioned limit values will be set taking into account radiation protection requirements, modelling results on the waste amounts to be expected for certain reference scenarios, as well as disposal and treatment capacities. However, as with any predefined radiological criterion, in case of an emergency the Radiation Protection Act allows these limit values to be changed via fast-track legislation in order to adapt to the contamination situation if necessary.

1 The Radiation Protection Act prescribes for the German emergency management system a clear delimitation of the areas of responsibility of the radiation protection regulators and regulators in other legal or economic sectors by implementing a so-called sector interlinking approach. This means that the federal and regional departments and specialist authorities that undertake hazard prevention tasks in day-to-day business for the enforcement of federal laws in a certain sector of life or the economy retain this responsibility and competence in the case of a nuclear or radiological emergency. This ensures that proven, established and tested organisational principles, administrative structures, installations and precautions for disaster control and hazard prevention can be also be used in the response to nuclear and radiological emergency situations and in emergency preparedness and planning.

Annex C. Observations and lessons learnt from the Fukushima Daiichi Nuclear Power Plant accident for remediation activities and food safety management in terms of legal systems and roles and responsibilities

Legal framework of disaster management in Japan prior to the Fukushima Daiichi Nuclear Power Plant accident

In Japan, many lives and properties are lost due to natural disasters every year. Until the early 1950s, large-scale typhoons and earthquakes often caused extensive damage and thousands of casualties. In response to the Ise-wan Typhoon of 1959, which caused enormous damage, the Basic Act on Disaster Control Measures (Basic Act) was enacted in 1961 to develop a comprehensive and strategic disaster management system (NLA, 1961). Thereafter, the disaster management system has been constantly reviewed and revised following lessons learnt from large-scale disasters.

The Basic Plan for Emergency Preparedness (Basic Plan), which was prepared by the Central Disaster Management Council[1] in 1963 and based on the Basic Act, is the foundation of Japan's disaster countermeasures. It provides basic policies on matters that should be emphasised in the establishment of a disaster management system, promotion of disaster management projects, rapid and appropriate disaster recovery, promotion of science and technology and research on disaster management, and disaster management operational plans and regional disaster management plans.

Based on the experience of the Great Hanshin-Awaji Earthquake in January 1995, the Basic Plan was fully revised to clearly define the responsibilities of the national government, local governments, and public organisations, and to introduce the concept of an all-hazards approach. This approach described the measures to be taken by related entities in the public and private sectors in co-operation with each other, according to the type of disaster and at each phase of a disaster, including prevention, preparedness, emergency response as well as recovery and reconstruction. A chapter on measures common to all disasters was also included, and the basic policy for appropriate and prompt disaster recovery and reconstruction was set out as follows:

- Prompt determination of the basic direction of recovery and reconstruction of the affected areas and systematic promotion of the projects.
- Prompt restoration of damaged facilities and wide-area support for that purpose.
- Disaster prevention city planning to prevent recurrent disasters and create a more comfortable urban environment.
- Prompt and appropriate disposal of disaster waste.
- Support for the reconstruction of independent livelihoods by providing financial assistance, securing housing, and securing employment for disaster victims.
- Support for economic reconstruction for self-sustaining development of the region, including reconstruction of affected small- and medium-sized enterprises.

1 The Central Disaster Management Council is one of the councils that deal with crucial policies of the Cabinet, and is established in the Cabinet Office based on the Basic Act on Disaster Control Measures. The Council consists of the Prime Minister as the chairperson, all members of the Cabinet, heads of major public corporations and experts.

A chapter on nuclear disaster management was added to Volume 10 of the Basic Plan, which further clarified the responsibilities and roles of each organisation related to a nuclear disaster. However, in the section on disaster recovery, only the following roles were specified:

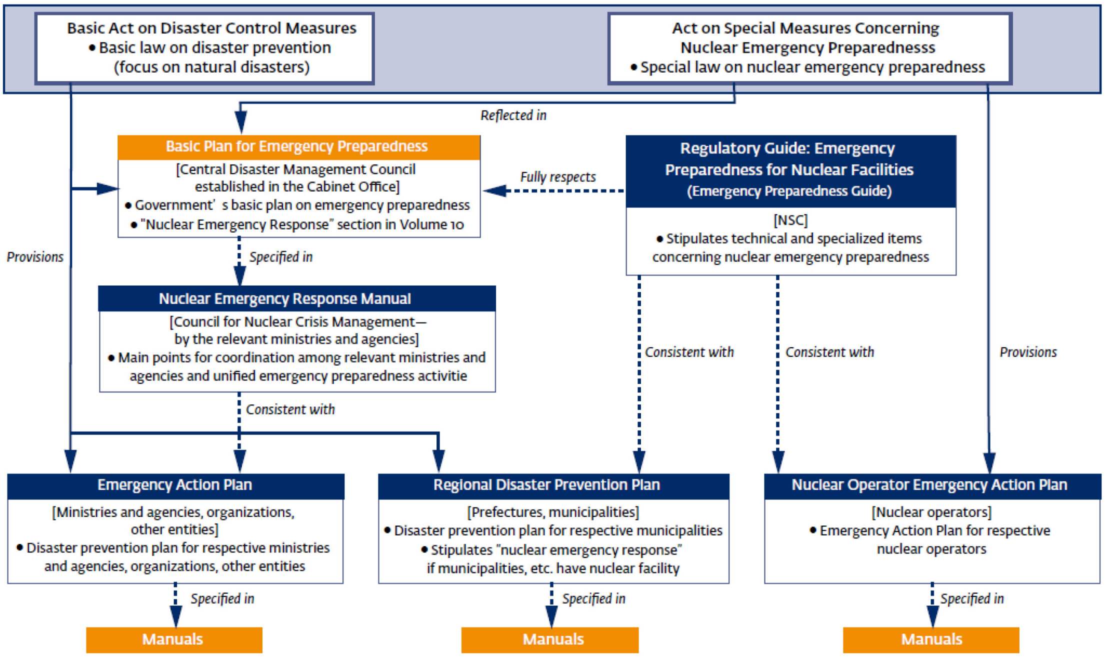
- Environmental monitoring (by local governments).
- Disaster recovery activities and response to claims for damages by victims (by nuclear operators).
- Development of a consultation system for residents' physical and mental health (by the Ministry of Education, Culture, Sports, Science and Technology, the Ministry of Economy, Trade and Industry, and local governments).
- Public relations activities to advise on the effects of damaged reputations (by the national and local governments).
- Public relations and consultation services to provide support and subsidies to small- and medium-sized businesses (by the Ministry of Economy, Trade and Industry and local governments).

After the Tokaimura criticality accident at the JCO nuclear fuel fabrication facilities in October 1999, the Act on Special Measures Concerning Nuclear Emergency (Special Measures Act) was enacted (GOJ, 1999). The purpose of this Act was to strengthen measures against a nuclear emergency and thereby protect the lives, bodies and properties of the people from a nuclear emergency, in co-operation with the Act on Regulation of Nuclear Source Materials, Nuclear Fuel Materials and Reactors (Reactor Regulation Act), the Basic Act and other Acts concerning nuclear emergencies. The Special Measures Act provided special measures for the responsibilities of nuclear operators, the issuance of a declaration of a nuclear emergency situation and the establishment of a Nuclear Emergency Response Headquarters (NERHQ) for the implementation of emergency response measures. Chapter 5 of this Act included provisions on measures for recovery, but since the experience of the criticality accident was mainly reflected in the emergency response phase, the provisions did not go beyond the recovery section of the Basic Plan mentioned above.

On the other hand, the Basic Plan specified that the Regulatory Guide on Emergency Preparedness for Nuclear Facilities (Nuclear Emergency Preparedness Guide) should be fully followed regarding technical and specialised items pertaining to emergency preparedness. The Nuclear Emergency Preparedness Guide was established by the Nuclear Safety Commission (NSC) in 1980 in light of the Three Mile Island nuclear accident to assist stakeholders, including the national and local governments and nuclear operators, in establishing emergency preparedness plans and implementing protective actions during an emergency. Revisions have since been made in the wake of the Tokaimura criticality accident and in line with international trends. Nonetheless, a drastic review of the Nuclear Emergency Preparedness Guide was not carried out because of the belief that a Chernobyl-type nuclear accident could not occur in Japan. Therefore, there were no guidelines for the recovery process, including even no criteria for long-term protective action such as temporary relocation.

Figure 7 (NAIIC, 2012) shows key documents defining the national emergency preparedness and response system for a nuclear emergency in Japan at the time of the accident. The Special Measures Act and the Nuclear Emergency Preparedness Guide were the central pillars of the measures to protect residents during a nuclear emergency.

Figure 7: **Key documents defining the national emergency preparedness and response system for a nuclear emergency in Japan (NAIIC, 2012)**



Source: The National Diet of Japan, 2012.

Roadmap as a good practice to characterise the situation and prepare the recovery process

As described above, prior to the Fukushima Daiichi Nuclear Power Plant accident, the national disaster management framework in Japan included some arrangements for disaster recovery and restoration but had not fully taken into account situations requiring long-term recovery operations over wide areas after a nuclear emergency. The specific policies, guidelines and criteria, as well as overall arrangements for the transition from the emergency response to the recovery process, were developed after the accident.

The process for transition from the emergency response to the recovery process included adjusting the protective actions and arrangements made early in the emergency phase and taking account of the information available on the circumstances in the affected areas. It also included consideration of the necessary long-term recovery operations.

The establishment of a "Roadmap" on 17 May 2011 by the NERHQ was a process used to characterise the situation in order to take control of the exposures. It facilitated the transition to long-term recovery operations, enabling a phased return to normality. The application of this graded approach proved to be effective in the preparation for long-term recovery operations. The overall responsibility of managing the process for returning to normality rested with the NERHQ.

The Roadmap listed nine groups of actions to be taken that were scheduled to be implemented over different target time periods[2]. The Actions were either for on-site at the nuclear power plant – restoration of the accident (Action 1), or for off-site – provision of assistance for those from the affected areas (Actions 2–9). Each Action listed in the Roadmap had associated steps for completion, which then guided the development of more detailed plans to complete the actions listed.

2 Defined by TEPCO's roadmap on 17 April 2011 [Ref. Tokyo Electric Power Company, Roadmap towards Restoration from the Accident at Fukushima Daiichi Nuclear Power Station, 17 April 2011, www.tepco.co.jp/en/press/corp-com/release/betu11_e/images/110417e12.pdf, (2011)].

The nine groups of actions were:

1. Actions for the recovery from the accident at TEPCO's Fukushima Daiichi Nuclear Power Plant.
2. Actions related to the area evacuated up to 20 km based on plant conditions (Evacuation Area).
3. Actions related to the area whose population was to be relocated (Deliberate Evacuation Area).
4. Actions related to the area whose population was advised to shelter (Evacuation Prepared Area in Case of Emergency).
5. Actions to ensure the safety and reassurance of those affected.
6. Actions to secure employment and provide support to farms and industries.
7. Actions to support the local municipalities in the affected areas.
8. Actions related to compensation of sufferers, affected businesses, etc.
9. Actions to assist those returning to areas that were evacuated.

During the transition process, several key issues were addressed to characterise the exposure situation in order to attain adequate knowledge of where, when and how people are exposed (and will be exposed in the future) in the affected areas. This was undertaken by the Japanese authorities gathering relevant information via monitoring, sampling and analysis. The characterisation progressively enabled informed planning and implementation of longer-term actions, including the establishment of detailed environmental monitoring plans (June and August 2011), long-term health surveillance (June 2011), formalisation of the long-term management of radioactive waste (August 2011), and the establishment of long-term plans for decontamination (August 2011).

The Roadmap subsequently enabled a review of the areas where protective actions were being implemented, which resulted in the implementation of adjustments to the protective actions, such as lifting the recommendation to shelter on 30 September 2011.

The Roadmap was revised in July 2011. Status updates on the progress in implementing the roadmap were issued each month until December 2011. On 16 December 2011, a cold shutdown state was reached at the nuclear power plant, but no termination of the emergency was officially declared at that time. The basic concept underlying the arrangement of the areas where evacuation orders had been in effect was issued on 26 December 2011. The Act on Special Measures Concerning the Handling of Environmental Pollution came into force on 1 January 2012. Among other things, the Act created the necessary institutional arrangements for the implementation of a co-ordinated work programme involving different organisations at the national level. Issues addressed by the Act also included the prioritisation of sites to be remediated and the allocation of funds to carry out the remediation works. The Act recognised the need to involve different stakeholders in the overall remediation process.

In early 2012 the recovery phase started. From this period onwards, the situation could be considered as an existing exposure situation. In January 2012, a decontamination programme was launched (Action 9 of the Roadmap). In April 2012, new regulations on contaminated foodstuff were established and rearrangement of the restricted areas was started. The first lifting of an evacuation order was announced for Tamura city in April 2014.

Legal framework and responsibilities for recovery process

Remediation activities

Prior to the Fukushima Daiichi Nuclear Power Plant accident, there were no laws and regulations in Japan to deal with environmental contamination. Therefore, the NERHQ and the Ministry of the Environment (MOE) took the lead in dealing with environmental contamination by presenting policies and guidelines.

In response to the need to properly manage waste contaminated by radioactive material until disposal standards and treatment methods are established, the MOE compiled the Immediate Handling of Disaster Waste in Fukushima Prefecture on 2 May 2011 and then presented the Disposal Guideline for Disaster Waste in Fukushima Prefecture in June 2011. On the other hand, the issue of sewage sludge became apparent before disaster waste. On 30 April 2011, a high concentration of radioactive caesium was detected in sewage sludge in Fukushima Prefecture. On 12 May 2011, the NERHQ compiled the Policy on the Immediate Handling of Sewage Treatment By-products in Fukushima Prefecture. Subsequently, similar cases were reported from outside Fukushima Prefecture, and on 16 June 2011, the relevant ministries were notified of the Policy on the Immediate Handling of By-products of Water and Sewage Treatment in Which Radioactive Substances Have Been Detected (Investigation Committee, 2012).

In the meantime, the NSC issued on 3 June 2011 the Near-term Policy to Ensure the Safety in Treating and Disposing Contaminated Waste around the Site of Fukushima Daiichi Nuclear Power Plants. This document provided dosimetric criteria for recycled materials, the protection of workers treating the materials, and the protection of members of the public in the vicinity of treatment facilities and disposal sites.

The Act on Special Measures Concerning the Handling of Environmental Pollution by Radioactive Materials Discharged by the Nuclear Power Station Accident Associated with the Tohoku District – Off the Pacific Ocean Earthquake that Occurred on 11 March 2011 (Remediation Act) was enacted in August 2011 after the issuance of governmental and ministerial ordinances by the Ministry of the Environment, to provide a comprehensive framework for off-site recovery operations following the Fukushima Daiichi Nuclear Power Plant accident.

This Remediation Act specifies the responsibilities of the national government, local governments, relevant nuclear power operators (TEPCO), and other operators in order to promptly reduce the impact on people and the environment caused by the environmental contamination from the radioactive material released by the accident.

In terms of the legal system, the Basic Environment Act excluded radioactive material from the scope of measures to prevent pollution under the law, stating that measures to prevent air pollution, water pollution, and soil contamination by radioactive material shall be as provided for in the Atomic Energy Basic Act and related laws. The Waste Disposal and Public Cleansing Act also excluded radioactive material and objects contaminated by radioactive material from waste subject to this law.

On the other hand, Japan's nuclear legal system has been based on the policy that "The nuclear emergency preparedness response is an administrative measure prepared independently of safety regulations based on the Reactor Regulation Act and is outside of safety measures at nuclear facilities."[3] The Reactor Regulation Act had no provisions on radioactive material released off-site due to a nuclear reactor accident, and the Special Measures Act had no provisions to deal with environmental remediation. Although there were matters related to preventing the spread of a nuclear disaster or recovering from it, specific plans and procedures of such measures were not clearly defined.

3 In the NSC there had been discussions several times on the relationship between the siting of facilities and accident management or emergency preparedness, when the Regulatory Guide for Reactor Siting had been reviewed. The document "Reviewing the structure of the NSC Regulatory Guides" (2003), stated that the "Nuclear emergency response plans are established … based on the Basic Act on Disaster Control Measures, to ensure that the national and local governments can take the most effective and appropriate actions to prevent a disaster, or to reduce the radiological consequences as low as practicable. The protective actions are established beyond the framework of technical aspects of defence in depth and isolating facilities from the public ("No impediments to the prevention of disasters" had been secured in the previous provisions), which are taken to ensure the safety of nuclear reactor facilities, and it should be considered part of defence in depth in a broad sense. Therefore, emergency response planning is a kind of administrative measure prepared independently from the safety regulations under the Nuclear Reactor Regulation Act, and should not be considered as requirements for site evaluation for the construction permit of nuclear facilities."

The arrangements for managing radioactive waste established in Japan before the accident covered waste generated within facilities, such as nuclear power plants, but did not include radioactive waste that had been generated in public areas. Therefore, the fact that a large amount of radioactive material was dispersed in the environment beyond the control of the nuclear operator overturned the assumptions of the conventional nuclear legal system for waste management.

Food safety management

Prior to the Fukushima Daiichi Nuclear Power Plant accident, the Ministry of Health, Labour and Welfare (MHLW) which is in charge of the Food Sanitation Act, had set provisional limits for radioactive material (370 Bq/kg total for Cs-134 and 137) for imported food following the Chernobyl accident, but had never considered criteria for dealing with cases where food, milk and drinking water distributed in Japan were contaminated by radioactive material.

After the accident, in order to prevent the distribution of food, milk and drinking water contaminated with radioactive material, the MHLW decided that "the index for restriction on the intake of food, milk and drinking water" in the NSC's Nuclear Emergency Preparedness Guide should be adopted as provisional regulation values for radioactive material under the Food Sanitation Act on 17 March 2011 and issued a notice stating that food exceeding these values should not be provided for human consumption.

This index by the NSC was intended to provide a guide to start considering whether or not it was appropriate to take measures to restrict food, milk, and drinking water, but was not intended as criteria for taking measures to restrict shipments. This is because the NSC was a technical advisory body and did not have the legal authority to enforce restrictions on food, milk and drinking water intake. This regulation value by the MHLW was called "provisional" regulation values because it was not subject to consultation with the Food Safety Commission (Investigation Committee, 2012).

The Basic Plan prescribed that, as a response to food, milk and drinking water contamination by radioactive material, the national government will investigate the contamination situation and, if necessary, request relevant organisations to restrict the shipment and intake, while local governments will implement restrictions on the shipment and intake. The regulations under the Food Sanitation Act take the basic approach of establishing regulatory limits and requiring businesses, including farmers and retailers, to make voluntary measurements before selling their products as a first priority. If tests of food sold on the market show radiation levels exceeding the limits, the sale of food by individual businesses should be prohibited. No prior restrictions on shipments are planned as a general rule. However, due to the widespread release of radioactive material in the accident, it was necessary to establish a legal framework for placing widespread shipping restrictions on food, milk and drinking water. Therefore, under the Special Measures Act, the NERHQ responded to the situation by issuing instructions to restrict shipments by the head of the local government for a certain area, including that area where food contamination exceeding the provisional regulation values was found through inspections conducted by the local government (NAIIC, 2012).

Food safety governance in Japan, which now involves the Consumer Affairs Agency, the MHLW, and the Ministry of Agriculture, Forestry and Fisheries, was restructured in the wake of the BSE (Bovine Spongiform Encephalopathy) problem in 2003. The concept of risk analysis, consisting of risk assessment, risk management and risk communication, was introduced into the Japanese food safety administration at that time. Based on the Food Safety Basic Act, a risk assessment body, the Food Safety Commission (FSC), was established. With the establishment of the FSC, the procedure for food safety management was structured as follows: the MHLW as the risk manager asks the FSC for the risk assessment, and the MHLW, based on the scientific advice of the FSC, consults the MHLW Council and takes risk management measures.

On the other hand, a different governance structure existed for radioactive material, where the Radiation Council, established by the Ministry of Education, Culture, Sports, Science and Technology (MEXT) based on the "Act on Technical Standards for Prevention of Radiation Hazards", provided advice, including the introduction of the recommendations of the International Commission on Radiological Protection (ICRP).

Subsequently, the establishment of new safety standards for radioactive material in food was considered within this existing framework[4]. The new regulation limits were established on 1 April 2012, following the existing procedure where the MHLW requests that the FSC evaluate the risk, the FSC submits its evaluation report, the MHLW's Pharmaceutical Affairs and Food Sanitation Council consults the MHLW, and the MEXT holds its Radiation Council.

Some observations and lessons learnt

- Japan, through repeated experiences of natural disasters, had developed an EPR system and formally adopted the concept of an all-hazards approach. In addition, a legal framework and high-level documents included arrangements that took into account the phases of emergency response.
- Prior to the Fukushima Daiichi Nuclear Power Plant accident, the roles and responsibilities of organisations in response to a nuclear emergency had been clarified to some extent through the Basic Act, the Basic Plan and the Special Measures Act. In the case of remediation activities and food safety management, the scope was not clarified based on the legal framework and the organisations involved were not sufficiently co-ordinated.
- The problem of the interface with the governance of environmental contamination and food contamination, which was not a problem in normal times, was revealed by the large-scale release of radioactive material into the environment.
- This can be attributed to the lack of hazard assessment in the preparation stage. The experience of the Chernobyl accident had not been fully reflected in Japan's nuclear safety and EPR arrangements. Therefore, after the accident, there were a series of unexpected problems that had to be dealt with on an ad hoc basis.
- Since there was a certain amount of time available to deal with the recovery process, the response during the transition phase may have yielded certain results in preparing for the long-term recovery process that followed. However, although not addressed in this note, a number of failures have been exposed in terms of the consistency of responses to environmental contamination and food contamination that should be addressed on the basis of the optimisation of protection using reference levels.
- Weaknesses in arrangements are a consequence of responding to emergencies that are beyond the scope of the assumptions made prior to the accident, when these arrangements are developed. Therefore, it is important to consider how to ensure reasonable preparedness for foreseeable events depending on the assessment of the hazard and also ensuring the flexibility to respond to an emergency beyond what had originally been assumed.
- Different governance structures exist between radiation protection and the management of environmental safety and food safety. In order to ensure that differences in governance do not bring problems to the surface, it is essential to understand all aspects of risk, including what risks are covered from a legal and sociological perspective, and whether there are any risks that are being overlooked.

4 On 20 March 2011, the MHLW asked the FSC for an optional food impact assessment based on the Food Sanitation Act. In response to this, the FSC issued the "Emergency Report on Radioactive Materials" on 29 March 2011. The commission held nine further discussions in working groups and on 27 October 2011 notified the MHLW of its Risk Assessment Report on Radioactive Nuclides in Food. The report summarised the views of the commission, including their judgment that "within the scope of the assessment of the impact of food on health performed by the FSC, the impact due to radioactivity detected was about over 100 mSv as the cumulative lifetime effective dose, after excluding the amount of radiation people receive in the course of their normal lives. In that process the commission considered the fact that susceptibility (to thyroid cancer and leukaemia) is higher in childhood than in adulthood. It is difficult to verify an impact on health due to less than 100 mSv of radiation, based on the findings the commission have currently obtained." (NAIIC, 2012).

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Building a Framework for Post-Nuclear Accident Recovery Preparedness: National-Level Guidance

Ten years after the Fukushima Daiichi Nuclear Power Plant accident, many lessons have been learnt that have helped improve preparedness for nuclear emergencies and awareness of the global risks that such accidents can entail. This includes a number of long-lasting, multidimensional impacts on health (including mental health and psychosocial support), the economy, and the environment. Recovery from a nuclear or radiological accident is a long, complex and resource-intensive process. To facilitate efficient recovery, it is important to establish processes and procedures during the preparedness phase to activate the resources required and to involve the relevant stakeholders at all levels. This report addresses the need for a harmonised approach towards efficient recovery management from nuclear or radiological accidents, which aims to assist countries to develop their own national plans and procedures for post-accident recovery preparedness in a harmonised manner, through the introduction of a cyclical approach.

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