Annex II of Technical Volume 5
INTERNATIONAL BEST PRACTICE BASIS FOR ASSESSING RECOVERY OPERATIONS

II–1. DEFINITION OF INTERNATIONAL BEST PRACTICE

This volume seeks to identify lessons learned related to post-accident recovery that may further improve preparedness worldwide. This objective assessment of the recovery programme is made according to ***international best practice***.

In the practice and assessment of radiation and nuclear safety, international best practice is a process or technique that is likely to consistently produce superior results. An important principle is that a 'best' practice can evolve to become better as improvements are discovered and lessons are learned from past experience. The lessons to be learned from the recovery programme as it unfolds in Japan will feed back into improving international best practice in post-accident recovery worldwide.

Best practice is used to maintain quality and is a component of quality management systems and standards, such as ISO 9000. It is generally regarded as being the most efficient and effective way to accomplish desired outcomes. The body of best practice is used as a benchmark and for self-assessment.

The IAEA's technical cooperation (TC) programme describes best practice as follows [II–1]:

> "For the IAEA's TC programme, a 'best practice' is an example of a standing policy, strategy, procedure, process, tool, technique or method that supports enhanced compliance with relevant performance indicators in the effective and efficient delivery of the objectives of a TC task".

There is no one source for international best practice. It is necessary to look in different places for the various aspects of the relevant situation to find international best practice for those different elements. In many areas, the IAEA safety standards provide guidance on meeting essential safety requirements based on international best practice. By reference to these documents, and also comparing different national systems and national facilities, it is possible to identify what is international best practice. In addition, a particular university or other organizations, such as the OECD Nuclear Energy Agency (OECD/NEA) also provide information on best practice, for example in relation to safety assessment or stakeholder engagement. For the latter, for example, there is the Forum on Stakeholder Confidence [II–2].

For the purposes of this volume, international best practice is derived in the main from relevant international safety standards, past experience and peer review.

II–2. SOURCES OF INTERNATIONAL BEST PRACTICE

An overview of some of the relevant sources of international best practice is presented here. Other sources include expert reports by organizations, such as United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) and the OECD/NEA.

II–2.1. The IAEA safety standards

The IAEA has led the development of an international framework on nuclear and radiation safety. This involves three key elements: legally binding international treaties, globally agreed international safety standards, and provisions for facilitating the application of those standards.

The hierarchy of the IAEA safety standards involves three levels, with the IAEA Safety Fundamentals [II–3] set out the fundamental safety objective and ten associated safety principles.

Beneath the Safety Fundamentals are the Safety Requirements, comprising seven General Safety Requirements (GSRs) and six Specific Safety Requirements (SSRs). This integrated set of Safety Requirements, when complete, will establish the international consensus of standards that is required to be met to ensure the protection of people and the environment, both now and in the future, governed by the objective and principles of the Safety Fundamentals.

Supporting the Safety Requirements is a suite of Safety Guides which are based on an international consensus and provide assistance on how to comply with the Safety Requirements.

Currently, under the terms of the IAEA Action Plan on Nuclear Safety[1], a review of all IAEA Safety Requirements has been conducted and revision is under way where changes are warranted as a result of initial lessons learned from the Fukushima Daiichi nuclear power plant (NPP) accident. The lessons related to those safety standards that deal with the various aspects involved in post-accident recovery are presented in Technical Volume 5 and will form part of this ongoing revision process.

International experience of remediation

There are a number of recovery exercises that have been conducted around the world that provide useful experience for aspects of Japanese recovery efforts. Some of this wealth of experience and information is presented here.

Three Mile Island

In 1979, at the Three Mile Island (TMI) NPP in the United States of America, a cooling malfunction caused part of the core to melt in the No. 2 reactor, leading to its destruction. The cleanup of the damaged nuclear reactor took nearly 12 years and cost approximately US $973 million. The cleanup was uniquely challenging, technically and radiologically. Plant surfaces had to be decontaminated. Water used and stored during the cleanup had to be processed. And about 100 t of damaged uranium fuel had to be removed from the reactor vessel. Defuelling the TMI-2 reactor vessel was at the heart of the cleanup efforts.

Chernobyl

From 1996 the issue of rehabilitation of living conditions in a territory affected by long lasting radioactive contamination as a consequence of a nuclear accident has been identified and explored through different European projects. These have been carried out in the context of the post-accident situation involving the areas contaminated by the deposition from the accident at the Chernobyl NPP in the former Soviet Union.

For example, the FARMING and STRATEGY European projects (2001–2004) had the aim of selecting and evaluating methodologies for the rehabilitation of living environments after a nuclear accident based on a multi-criteria approach for decision making. The European Approach to Nuclear and Radiological Emergency Management and Rehabilitation Strategies (EURANOS) programme (2004-2009) aimed to establish various handbooks for the management of post-accident situations and recovery after a nuclear accident [II–4 to II–6], to enhance decision support systems, and to develop preparedness and management strategies and guidance for rehabilitation of living conditions in territories affected by long lasting radioactive contamination as a result of a nuclear event.

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[1] See Technical Volume 1, Section 1. 6 for more information.

The European projects ETHOS 1 and 2 (1996–2001), developed in Belarus and demonstrated the feasibility of post-accident strategies that rely on the active engagement of local authorities and professionals in the response to radioactive contamination. These strategies involve practical evaluation of the local contamination situation by local stakeholders, and the development of concrete actions aimed at the protection of the inhabitants and the improvement of their living conditions.

Palomares

An accident in 1966 involving the mid-air collision of two US military aircraft near Palomares in Spain resulted in four nuclear weapons being dropped. Two of these were damaged, resulting in the dispersal of plutonium in the local environment by conventional explosions.

At the time, Spain had no established criteria for the cleanup of plutonium contamination from residential and farming lands. Negotiations between US and Spanish authorities on levels and methods of decontamination were difficult, due to varied opinions on what was acceptable and the need for speedy action. Significantly, in 1966, there were also no criteria in the USA for permissible levels of plutonium in accident situations. The importance of being prepared with agreed and publicly accepted cleanup criteria is highlighted by the Palomares experience.

The US Defense Nuclear Agency issued a Palomares Summary Report [II–7] in 1975 that stated that there were, however, broad guidelines for plutonium contamination levels established from the Nevada nuclear weapons tests, and that for Palomares "A sense of urgency prevailed, primarily from a political standpoint, to arrive at criteria and begin the clean-up".

The stated policy of the US Government was "to decontaminate to levels which were more than adequate by US safety standards". However, the Spanish Government "desired levels far beyond safety requirements in the interest of combating psychological consequences of the accident". The USA also expressed the concern that whatever decontamination levels were agreed to at Palomares could in the future be pointed to as 'safety standards' in any subsequent contamination incidents.

Goiânia

In 1987, an abandoned teletherapy machine complete with its ^{137}Cs source was taken and subsequently broken up and dispersed in Goiânia, in Brazil [II–8]. Various remedial actions were undertaken, such as decontamination of property, collection of contaminated clothing, removal of contaminated soil, and restrictions on some home grown produce. The dose criterion adopted was that the dose to the critical group in the first year should not exceed 5 mSv. Action levels were derived from this criterion. The area over which remediation was carried out was relatively small (1 km^2).

Criteria were employed to guide the evacuation of some houses, although as the IAEA report states,

> "The approach adopted was heavily influenced by political and social pressures and an unwillingness for the accident to be considered as an emergency in any way comparable with a possible nuclear power accident" (see p. 69 [II–8]).

The contaminated waste from the Goiânia remediation was stored temporarily until a permanent repository for disposal could be developed.

Maralinga

An area of South Australia remained contaminated following British atomic tests at Maralinga between 1955 and 1963. Of importance was long lived ^{239}Pu, of which some 24 kg was explosively dispersed in several 'minor trials'. The inhalation of plutonium dust presented the most significant health hazard arising from residual contamination of the Maralinga area, due to the very low solubility of the plutonium oxide and the dusty, dry conditions.

The dilemma faced by the Maralinga Indigenous Australian community was what form of cleanup could adequately deal with the contamination, without causing the massive environmental damage that top soil removal from large areas would cause (involving the removal of trees and grass from an area of verdant bush land, with potential for subsequent erosion problems).

The programme of remediation that was agreed with all stakeholders involved a standard, for any scenario involving permanent occupancy, that the risk of fatal cancer following uptake of contamination should not exceed 1 in 10 000 by the 50th year, from which was derived an annual committed dose of less than 5 mSv. Criteria were also established and agreed for the removal of hot particles and contaminated fragments [II–9].

In fact, following the cleanup, annual doses were estimated to not exceed 1 mSv for all realistic scenarios. This outcome was due to a number of reasons, some of which are relevant to the situation following the Fukushima Daiichi accident. These include the inherent conservatism in calculating the 5 mSv/y cleanup boundaries and the practicalities in setting cleanup boundaries, which meant that a greater degree of cleanup was undertaken than was strictly required by the agreed reference levels. The environmental processes such as migration and erosion, that have the effect of lowering the availability of contamination over time, were also a common factor.

The contaminated soil and debris resulting from the successful remediation of the Maralinga lands were buried on-site in near surface disposal trenches.

Hanford

Much of the radioactive waste from the remediation of the partially decommissioned Hanford nuclear production site in Washington State, in the USA, is being disposed of in a near surface disposal facility following immobilization of the waste by vitrification. Immobilizing the waste in this manner, together with envisioned long term institutional controls on access, means that waste containing higher concentrations of long lived radionuclides such as ^{99}Tc can be safely disposed of in a near surface facility, rather than requiring deep geological disposal to meet the safety objectives, as indicated in the safety case [II–10].

International Experts Meeting on Decommissioning and Remediation after a Nuclear Accident

An important source of international best practice for benchmarking the Japanese recovery programme was the IAEA’s International Experts Meeting on Decommissioning and Remediation after a Nuclear Accident (IEM 4), held in January 2013. At this meeting, the international nuclear and radiation safety community recognized that, based on lessons from the Fukushima Daiichi accident, and past major nuclear accidents, that it is too late to begin planning for accident recovery after an accident has occurred.

The IAEA’s report on IEM 4 [II–11], summarizes many lessons which are relevant in the context of the Fukushima Daiichi accident. While these will not be repeated in detail here, there are three broad categories of lessons that are highlighted in the IEM 4 report that are crucial for post-accident recovery and that are emphasized in the lessons that are drawn from the assessments reported here.

II–2.2. The role of planning in post-accident recovery

The Chairperson’s Summary of IEM 4 states:

> “There is no reason to believe that accidents will not happen in the future, leading to future actions related to recovery activities such as decommissioning and remediation. Before an accident, planning should identify and establish appropriate procedures to handle acute consequences and bring the situations under control in a manner that reduces, to the extent practicable and possible, the long term consequences that will turn into legacy. If such a legacy occurs, or already exists, a system to deal with it, which includes decommissioning and remediation, must be available.” [II–11]

In essence, the lesson is that it is too late to start planning the essential and urgently required elements of post-accident recovery in the aftermath of a radiation or nuclear accident. These elements include:

- Reference levels for remediation strategy and action levels for specific remedial actions.
- End states and strategies for decommissioning of accident-damaged facilities.
- Waste management and disposal strategies (e.g. availability of a generic safety case).

The narrative presented below and in more detail in Annex I underlines the crucial IEM 4 recommendation that forward planning for recovery is essential.

Stakeholder engagement and an understanding of ‘what is safe’

Again, quoting from the Chairperson’s Summary of IEM 4:

> “The importance of trust for a constructive stakeholder interaction cannot be overestimated. Trust will not be achieved if potential events (such as accidents) have not been identified and clearly communicated in the planning phase — and it subsequently turns out that such an event takes place.” [II–11]

The Chairperson’s Summary also concludes:

> *“The accident at the Fukushima Daiichi nuclear power plant has highlighted the concern of people to be assured of their safety. The international community should strive to develop a practical definition of ‘safe’ as an aid for communicating with the public.”* [II–11]

Management of damaged fuel and radioactive waste

The Chairperson’s Summary of IEM 4 has two recommendations in this area, both relevant to specific lessons identified in Sections 5.3 and 5.4:

> “With regard to waste management strategies, a recommendation can be suggested as follows: *The IAEA should assist Member States with the development of end states and decommissioning strategies for decommissioning of accident-damaged facilities.*
>
> With particular reference to the large volumes of — often — low activity waste from existing exposure situations, a recommendation can be suggested as follows: *Large volumes of radioactive waste and materials with residual amounts of radionuclides are present in many countries. The IAEA should review its guidance on the management of these wastes and materials, with the view to ensuring their practical application after a nuclear accident.*” [II–11]

The experts at the IEM 4 called for strengthened international programmes, assistance and guidance on forward planning for post-accident recovery. The IEM 4 report concludes that information collected from the Fukushima Daiichi accident should be periodically evaluated for incorporation into the IAEA’s safety standards and technical reports.

International Experts Meeting on Radiation Protection after the Fukushima Daiichi Accident: Promoting Confidence and Understanding

Another important source of international best practice for benchmarking radiation protection aspects of the Japanese recovery programme is the IAEA International Experts Meeting on Radiation Protection after the Fukushima Daiichi Accident: Promoting Confidence and Understanding (IEM 6), held in February 2014 [II–12]. An issue of considerable interest at IEM 6 was the use of social media as a communications tool, particularly among young people. The fact that there is no limit on who can convey very different and even contradictory messages to large groups of people over a very short time period brings new challenges to national authorities in communicating with the public. But practices such as crowdsourcing, for example in the collection and dissemination of radiation data, were observed to also help to improve confidence in information from official sources.

The meeting noted that the complexity of the System of Radiological Protection can be an impediment to its effective implementation. Furthermore, decisions must be made by use of sound judgement based on strong ethical considerations and accepted societal values.

The Chairperson’s Summary of IEM 6 states that the purpose of the meeting was to provide an opportunity for experts to discuss the various radiation protection issues that have been highlighted by the Fukushima Daiichi accident, and to consider how these should be addressed at both the national and international levels. The recommendations and conclusions of the Chairperson’s Summary were as follows [II–13]:

Release of radionuclides to the environment:

> *“(Conclusion) Early real-time sampling and personnel monitoring is important to improve the source term estimation and reduce the uncertainty in estimated values.”* [II–12]

Foods and drinking water:

> *“(Conclusion) The relevant international organizations need to prioritize work to develop a harmonized approach to the control of foodstuffs and drinking water contaminated as a result of a nuclear or radiological accident. This needs to be simple to implement and take fully into account the issues that apply in the accident State, other affected States and States that are not affected Similarly, guidance needs to be developed on the international trade in and the control of contaminated non-food commodities.”* [II–12]

Remediation:

> *“(Conclusion) The ultimate success of remediation programmes depends on the combined efforts of actions by the local authorities, affected communities, and individual citizens.”* [II–12]

Social media:

> *“(Conclusion) The development of social media brings challenges in terms of the increase in the sources and the amount of information, even contradictory information, that is available and the difficulty in identifying credible sources. This is a challenge for national authorities, but can also be used to their benefit as social media provide a much more efficient outlet for dissemination.”* [II–12]

Risk communication:

> *"(Conclusion) The need for better communication falls on the radiation protection community as a whole. We need to dedicate resources to ensure we adequately inform decision makers and the general public about radiation, radiation risks and the underlying philosophy and ethics of the International System of Radiation Protection. If people don't understand our advice, it is unreasonable to expect them to implement it."* [II–12]

System of radiation protection:

> *"(Recommendation) While the International System of Radiation Protection is, generally, fit for purpose, it should be modified and improved in line with the lessons learned from the Fukushima accident." "(Recommendation) While the International System of Radiation Protection is, generally, fit for purpose, it should be modified and improved in line with the lessons learned from the Fukushima accident."* [II–12]

Capacity building:

> *"(Recommendation) All States should develop and implement a national strategy in relation to building and maintaining competence in radiation protection."* [II–12]

The Joint Convention — peer review

The Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management [II–14] (the Joint Convention) represents a commitment by Contracting Parties (participating countries) to achieve and maintain a consistently high level of safety in the management of spent fuel and radioactive waste as part of the global safety regime for ensuring the protection of people and the environment.

The Joint Convention requires Contracting Parties to report and to promote open and transparent discussions on the safety of spent fuel and radioactive waste management. One mechanism for achieving these objectives is peer review of national programmes for spent fuel and radioactive waste management. The articles of the Joint Convention call for review meetings to be held at periods not exceeding three years.

The National Report of Japan to the Fourth Review Meeting of the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management, held in May 2012, reported on the Fukushima Daiichi accident and its early implications for management and safety of spent fuel and accident waste [II–15]. The National Report of Japan for the Fifth Review Meeting of the Joint Convention, to be held in May 2015, contains updated information on these issues and peer review process provides valuable feedback for both Japan and the rest of the world.

It was agreed by the Contracting Parties [II–16] that national reports to the 2015 Review Meeting of the Joint Convention should address: (i) safety implications of very long storage periods and delayed disposal of spent fuel and radioactive waste; and (ii) progress on lessons learned from the Fukushima Daiichi accident, in particular regarding strategies for spent fuel management.

II–3. RADIATION PROTECTION PRINCIPLES AND THE REMEDIATION REFERENCE LEVEL

II–3.1. The use of 1 mSv/y in post-accident recovery

There has been considerable confusion on International Commission on Radiological Protection (ICRP) recommendations regarding the use of the value of 1 mSv/y in post-accident recovery. ICRP has recommended 1 mSv/y as a reference level for protection of people living in affected areas in the long term (see para 288 in [II–17] and para 50 in Ref. [II–18]), acknowledging the long term success with remediation and the effects of natural processes two decades after the Chernobyl accident. Long term may mean several years or even decades depending on the situation and the radionuclides involved. It is no coincidence that this is numerically equal to the dose limit for members of the public in planned exposure situations, as the long term objective is to reduce exposures to levels that are similar to situations considered to be normal.

As a long term objective in post-accident recovery, 1 mSv/y is a reference level, not a dose limit, and therefore applies to the dose received from the source (residual radioactivity in the environment in the case of the Fukushima Daiichi accident). It is used as a benchmark when evaluating the distribution of doses to members of the public, a few of whom may exceed the value and the vast majority of whom should be well below it.

In this context, a reference level of 1 mSv/y:

- Is not recommended as a short or medium term objective (although it is the bottom of the band of doses recommended for reference levels for this purpose);
- Is not meant for use during the emergency phase of an accident;
- Is not meant as a criterion for relocation, evacuation, or return to homes;
- Is not meant to be applied to occupational doses incurred during recovery operations;
- Is not a dose limit;
- Is not a boundary between ‘safe’ and ‘unsafe’.

Several examples in various post-accident recovery situations are cited in ICRP Publication 111, Annex A [II–18]. Recent estimates by UNSCEAR [II–19] show that, within two decades, doses from the Fukushima Daiichi accident will be below 1 mSv/y in all but a few small areas, taking into account only natural processes of radioactive decay and weathering.

II–3.2. Optimization

The important principle of optimization of radiation protection involves the process of determining what level of protection makes exposures as low as reasonably achievable, with economic and social factors being taken into account. Optimization ensures that available funds for remediation are used as effectively as possible, while considering all social factors of importance to the affected population as well as the technical feasibility.

The issues relating to optimization and the choice of remediation reference level are complex. They include the following aspects:

- Optimization goes further than weighing doses and financial costs.
- Optimization can involve more than just selecting a different numerical value for the long term objective.
- Radiation dose rate is only one consideration among many for recovery, and as dose rates become relatively low with time, other social issues may progressively dominate decision-making.

— Spending a lot of resources to reduce dose rates that are already relatively low implies that those resources cannot be spent for other, possibly more socially beneficial purposes.

This last point in particular has been the main issue when considering how the application of a reference level of 1 mSv/y for the remediation target. Answers can be found in the application of an overall optimization process. The choice of the value of 1 mSv/y as a reference level in Japan goes beyond purely radiation protection considerations, since it includes also factors of equity.

The chaotic aftermath of an accident presents a far from ideal conditions in which to develop optimized criteria for accident recovery, in particular, following the Fukushima Daiichi accident, due to the societal disruption arising from the combined effects of the earthquake, tsunami and the nuclear accident. Under these circumstances, it is difficult to involve stakeholders in determining recovery criteria and strategies. This is a strong argument for the need for prior preparations involving education and consultation with stakeholders in order to be prepared for optimized recovery solutions.

There is flexibility in how a long term numerical objective could be applied. It has been noted that it is not a dose limit, and that the distribution of doses to members of the public is generally log-normal, i.e. characterized by the vast majority of people receiving doses considerably below the mean, and a long tail with relatively few people receiving higher doses. It may be possible to work with the relatively few individuals that may receive higher doses to help them reduce their doses. It may also be decided that is not necessary for the long term objective to be that everyone receives an additional dose below 1 mSv/y immediately; success could be progressively defined in terms of the percentage of the affected population receiving additional doses below this reference level. From the recent UNSCEAR data and other sources, it is likely that at least 75% (probably more) of members of the public living in non-evacuated districts of Fukushima Prefecture are already receiving less than 1 mSv/y of radiation that can be directly attributed to the nuclear accident.

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