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ICRP PUBLICATION 146

Radiological Protection of People and the Environment in the Event of a Large Nuclear Accident

Update of ICRP *Publications 109* and *111*

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ICRP Publication 146

Editorial

BE PREPARED

Accidents happen. Aircraft crash, ships sink, trains derail, chemical factories explode, dams break, and nuclear power plants fail. We also face natural disasters such as floods, droughts, hurricanes and typhoons, earthquakes, heat waves, volcanic eruptions, tornados, meteor strikes, forest fires, ice storms, mud slides, and tsunami. Each of these can shake a city, region, or nation. A few have shaken the world. The consequences can be political, societal, environmental, economic, and, most of all, human.

At the heart of accidents and disasters are personal consequences. The most obvious of these are physical injury and death, sometimes on a massive scale. On 3 December 1984, a leak from a pesticide factory in Bhopal, India killed at least 3000 people and more than 100,000 suffered permanent disability. Compensation for injury was awarded to more than half a million people (Broughton, 2005).

These figures are staggering, but looking more deeply reveals that the consequences of accidents and disasters go far beyond the obvious. A flood can destroy a village, washing away homes that have stood for generations and destroying culturally significant places, breaking a community's connection with its own history. Releases from facilities can taint entire regions whether there are immediate health consequences or not. Even if people can continue to live there, property values drop, populations dwindle, and job opportunities disappear as new people and businesses are reluctant to move in. Looking even more closely, consider the despair of grandparents whose grandchildren will no longer visit them in their homes, or families that break apart because of conflicting priorities.

Learning to deal with accidents and natural disasters is essential to reduce human suffering and environmental impacts.

Everyone hopes that there will never be another nuclear accident on the scale of what occurred in 2011 at the Fukushima Daiichi nuclear power plant in Japan, or, even worse, in 1986 at the Chernobyl nuclear power plant in the USSR (now Ukraine). Today, there are approximately 440 nuclear power reactors supplying electricity globally, and approximately 15 more are under construction (WNA, 2020).

ICRP has no position on nuclear power beyond the ethical principles and fundamental recommendations that apply universally. Ethically, this means that good must be preferred over harm, actions must be well informed and carefully considered, and people must be treated fairly and with dignity. We call these the four core ethical values of beneficence/non-maleficence, prudence, justice, and dignity (ICRP, 2018). To enact these, we use the three principles of radiological protection: justification, optimisation of protection, and individual dose limitation. Respectively, these ensure that good outweighs harm, that protection is the best for the circumstances, and that an unfair dose is not imposed on any individual. In short, ICRP's aim in all circumstances is to ensure that, where ionising radiation is involved, people and the environment are protected.

Given this, ICRP applauds all efforts to improve nuclear safety (e.g. NEA, 2016). Our mission is to promote radiological protection. Avoiding and mitigating nuclear accidents, especially those that release radioactive material, are part of protecting people and the environment from detrimental exposures to radiation.

Nonetheless, we must be prepared for another accident. This is an important part of our work, related not only to nuclear power but also, for example, the use of radiation in medicine [see, for example, *Publication 112* 'Preventing Accidental Exposures from New External Beam Radiation Therapy Technologies' (ICRP, 2009a)].

The present publication updates and replaces two previous publications, coincidentally released in the same year as *Publication 112*, and less than 2 years before the Fukushima Daiichi accident:

- *Publication 109* 'Application of the Commission's Recommendations for the Protection of People in Emergency Exposure Situations' (ICRP, 2009b); and
- *Publication 111* 'Application of the Commission's Recommendations to the Protection of People Living in Long-term Contaminated Areas' (ICRP, 2009c).

In theory, the scope of the present publication is narrower than that of *Publications 109* and *111*, as it applies specifically to large nuclear accidents. In practice, these previous publications focused largely on these types of accidents, although the general principles are the same for accidents of almost any scale. Even so, additional recommendations on radiological protection for other types of accidents are being considered.

One of the advantages of combining the two previous publications into one is that the response can be considered more holistically, and more attention can be paid to the transition from the early and intermediate phases to the long-term phase of the accident. The current publication makes it easier to follow the thread through the emergency response to the recovery process, and importantly includes advice on preparation for the long-term phase.

As one might expect, the present publication draws heavily on nearly 10 years of experience following the Fukushima Daiichi accident. However, even after nearly 35 years, there are new insights from the Chernobyl accident too. For example, it is now clearer to see the social impacts of the Chernobyl accident in light of the Fukushima Daiichi accident, and the Fukushima Daiichi accident has taught us that there can be enormous impacts even without immediate and widespread catastrophic health impacts. Reporting on the Fukushima Daiichi accident, the United Nations Scientific Committee on the Effects of Atomic Radiation noted that 'no radiation-related deaths or acute diseases have been observed among the workers and general public exposed to radiation from the accident' and 'no discernible increased incidence of radiation-related health effects are expected among exposed members of the public or their descendants'; however 'the most important health effect is on mental and social well-being' (UNSCEAR, 2013).

This publication could not have been developed in a vacuum. Over nearly a decade, ICRP embarked on what was perhaps its most extensive work stream since the development of our last fundamental recommendations (ICRP, 2007). The ICRP Main Commission met with delegates from Japan in April 2011, just weeks after the Fukushima Daiichi accident. Soon thereafter, ICRP established Task Group 84 on Initial Lessons Learned from the NPP Accident in Japan vis-à-vis the ICRP System of Radiological Protection. The next year, a summary of the task group findings (ICRP, 2012) was accepted by the Main Commission at their meeting in Fukushima City, and not long after, members of Task Group 84 published a paper with considerably more detail (González et al., 2013).

This initial assessment would influence ICRP's programme of work for many years. Notably, this included establishing Task Group 93 on Update of ICRP *Publications 109* and *111*: the group that developed the present publication.

In parallel, ICRP had begun a series of dialogue meetings in Fukushima, the first of which was held in November 2011. The purposes were: to create a forum for free and open discussion of challenges in the recovery process; to share experiences among experts and citizens of Japan and countries directly impacted by the Chernobyl accident, such as Belarus and Norway; to learn about the situation directly from those involved to ensure that any new ICRP recommendations would be as relevant and useful as possible; and, of course, to help people who were facing a very difficult situation (Kotoba, 2015). What became known as the 'Dialogue Initiative' proved to be highly successful on all counts. As of 2020, a total of 22 dialogue meetings have been held, initially led by ICRP but now fully in the hands of local people (Lochard et al., 2019).

The Dialogue Initiative was invaluable in developing the current publication. Not only did the close interactions with people on the front lines provide a deeper level of understanding, but several local participants also participated in drafting and review of the present publication.

Throughout the process, ICRP was also in frequent contact with many experts, health professionals, affected residents, and authorities including Japanese government and expert organisations and nuclear power plant operators, to ensure that all aspects of radiological protection after a large nuclear accident were addressed.

A number of international organisations were involved in the development of the publication. This was through many relatively informal interactions during drafting, and through a more formal peer review later in the process.

All ICRP publications now undergo public consultation before they are completed. This crucial step gives anyone the opportunity to comment on our work via a web-based portal, and is important to make sure we have heard and considered all viewpoints. Given the nature of this publication, and the significant interest expressed by many people, for the first time ever, comments were accepted in English and Japanese, and the comment period was extended. Another first was a public meeting held in Japan during the consultation, so people could hear how we were responding to early comments, and have an opportunity to express their views in person. In all, more than 300 sets of comments were received, approximately 10 times more than for most ICRP publications, and second only to the number of comments received on the current set of fundamental recommendations (ICRP, 2007). I am convinced that this level of interest has increased the quality of this publication, and am thankful that so many people took the time to share their views.

Finally, on a more personal note, I would like to acknowledge the kindness of the many people from and in Japan who I have had the pleasure of meeting since 2011, and the European friends and colleagues who have shared their experiences related to the Chernobyl accident. On many occasions, I have been humbled by their perseverance, ingenuity, and generosity of spirit. I am saddened that the accidents happened, and know that people are still suffering, but one silver lining is the friendships that have grown between people that would not otherwise have met. I hope another silver lining is a more robust understanding of the consequences of nuclear accidents and improved preparedness for the future.

CHRISTOPHER H. CLEMENT
EDITOR-IN-CHIEF

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RADIOLOGICAL PROTECTION OF PEOPLE AND THE ENVIRONMENT IN THE EVENT OF A LARGE NUCLEAR ACCIDENT: UPDATE OF ICRP *PUBLICATIONS 109* AND *111*

ICRP PUBLICATION 146

Approved by the Commission in July 2020

Abstract–This publication provides a framework for the protection of people and the environment in a large nuclear accident, drawing on experience of the Chernobyl and Fukushima accidents. In managing accidents, the Commission makes a distinction between the early and intermediate phases, considered emergency exposure situations, and the long-term phase, considered an existing exposure situation. In emergency and existing exposure situations, mitigating the radiological consequences on humans and the environment is achieved using the fundamental principles of justification of decisions and optimisation of protection. The Commission recommends a set of reference levels for the optimisation of protection of the general population and responders, both on-site and off-site, for all accident phases. Implementation of protective actions should not only take account of radiological factors, but also consider societal, environmental, and economic aspects to protect health, ensure sustainable living conditions for the affected people, ensure suitable working conditions for the responders, and maintain the quality of the environment. In the early phase of an accident, urgent protective actions have to be taken, often with little information. Decisions rely on actions identified during preparedness planning that best match the actual situation. During the intermediate phase, protective actions reduce radiation exposures progressively. When the radiological situation is sufficiently characterised, the long-term phase begins, during which further protective actions are implemented to improve living and working conditions. Authorities should invite key representative stakeholders to participate in the preparedness process, and in the management of the successive phases of the accident. It is the role of the authorities to implement radiation monitoring and health surveillance, and to provide the conditions and means for sharing information and expertise to enable individuals to develop a radiological protection culture and to make informed decisions about their own protection.

Keywords: Chernobyl accident; Fukushima accident; Emergency exposure situation; Existing exposure situation; Justification; Optimisation; Reference level; Protective actions; Stakeholder involvement; Co-expertise process; Radiological protection culture

MAIN POINTS

- **A large nuclear accident causes a breakdown in society affecting all aspects of individual and community life. It has large and long-lasting societal, environmental, and economic consequences.**

- **Characterisation of the radiological situation on-site and off-site is essential to guide protective actions, and should be conducted as quickly as possible.**

- **The Commission recommends using reference levels to guide the implementation of protective actions during the early, intermediate, and long-term phases of an accident.**

- **The objective of radiological protection is to mitigate radiological consequences for people and the environment whilst, at the same time, ensuring sustainable living conditions for the affected people, suitable working conditions for the responders, and maintaining the quality of the environment.**

- **Responders, who are likely to be the most exposed individuals, should be provided with appropriate protection, taking into account the requirements of the response on-site and off-site.**

- **Responsible organisations should promote the involvement of local communities in a co-operative process with experts (co-expertise process) to help achieve a better assessment of the local situation, the development of an adequate practical radiological protection culture, and informed decision-making among those affected.**

- **Preparedness planning is essential for mitigating the consequences during phases of a large nuclear accident, and should involve stakeholders.**

EXECUTIVE SUMMARY

(a) Large nuclear accidents result when there are significant releases of radioactive material into the environment, impacting widespread areas and affecting extensive populations. They are unexpected events that profoundly affect individuals, society, and the environment. They generate complex situations and legitimate concerns, particularly regarding health, for all those affected by the presence of undesirable sources of radioactivity. Management of these situations requires the long-term mobilisation of considerable human and financial resources. Radiological protection, although indispensable, only represents one dimension of the contributions that need to be mobilised to cope with the issues facing all affected individuals and organisations.

(b) For managing these events, the Commission makes a distinction between the early and intermediate phases of the accident, considered as emergency exposure situations, and the long-term phase, considered as an existing exposure situation. The Commission also distinguishes between on-site and off-site to differentiate activities at the damaged installation and in the affected areas. The present recommendations may be applicable to other types of radiological emergencies, with due consideration of the differences that inevitably exist between a nuclear accident and these emergencies.

(c) Characterisation of the radiological situation on-site and off-site is essential to guide protective actions, and should be conducted as quickly as possible to address the uncertainties regarding the intensity, duration, and extent of the radioactive contamination.

(d) In emergency and existing exposure situations, the objectives of radiological protection are achieved using the fundamental principles of justification and optimisation. The principle of justification ensures that decisions regarding the implementation of protective actions result in a 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.

(e) Justification and optimisation are applied in the mitigation of radiological consequences to people and the environment during all phases of the accident, and should take careful account of all non-radiological factors in order to preserve or restore the living and working conditions of all those affected, including decent lifestyles and livelihoods.

(f) People involved in the direct management of the consequences of a nuclear accident are diverse in terms of their background, status, degree of preparation, and training on radiological protection. They include emergency teams (firefighters, police officers, medical personnel, etc.), workers (occupationally exposed or not), and other people such as elected representatives or citizens acting as volunteers. All these categories are considered by the Commission as 'responders'.

They deserve to be adequately protected and provided with suitable working conditions.

(g) For the protection of responders on-site, the reference level during the early phase should not generally exceed 100 mSv, while recognising that higher levels, in the range of a few hundred millisieverts, may be permitted to responders in exceptional circumstances to save lives or to prevent further degradation at the facility leading to catastrophic conditions. Lower reference levels may be selected based on the situation, in accordance with the severity of the accident. During the intermediate phase, the reference level should not exceed 100 mSv. For the long-term phase, the reference level should not exceed 20 mSv per year, with possible special arrangements limited in time. The Commission recommends that responsible organisations should take all practical actions to avoid unnecessary accumulation of exposures for responders involved in both the early and intermediate phases.

(h) For the protection of responders off-site, the Commission recommends selection of a reference level not exceeding 100 mSv for the early phase and 20mSv per year for the intermediate phase. For the long-term phase, the reference level should be selected within the lower half of the recommended band of 1–20 mSv per year.

(i) For the protection of people, the reference level should not generally exceed 100 mSv for the entire duration of both the early and intermediate phases. The Commission recommends that responsible organisations should adopt a lower reference level whenever possible. For the long-term phase, the reference level should be selected in the lower half of the recommended band of 1–20 mSv per year for existing exposure situations, taking into account the actual distribution of doses in the population and the societal, environmental, and economic factors influencing the exposure situation. The objective of optimisation of protection is a progressive reduction in exposure to levels towards the lower end of the band, or below if possible.

(j) In some nuclear accident scenarios, release of radioactive iodine can result in high thyroid exposures due to inhalation or ingestion. Specific efforts should be made to avoid, or at least reduce, intakes of radioactive iodine, particularly in children and pregnant women. During the early phase or just after, exposed people should be monitored to detect potential exposure to radioactive iodine.

(k) Management of the protection of people in affected areas in the intermediate and long-term phases is a complex process involving not only radiological factors, but also societal, environmental, and economic considerations. This process includes actions implemented by national and local authorities, and self-help protective actions taken by residents of the affected areas. In these phases, radiation exposures of people living and working in affected areas are largely dependent upon individual lifestyles. The Commission recommends that authorities, experts, and stakeholders should co-operate in the so-called 'co-expertise process' to share experience and information, promote involvement in local communities, and develop a practical radiological protection culture to enable people to make informed decisions. Individual measurements with suitable devices, together with relevant information, are very helpful in the implementation of this process.

(l) For the protection of the environment, the Commission recommends that fauna and flora should be protected using its framework based on Reference Animals and Plants, together with derived consideration reference levels. The impacts of protective actions on pets and livestock, as well as on the environment, in terms of sustainable development, conservation, preservation, and maintenance of biological diversity should also be addressed.

(m) The Commission recommends that plans should be prepared in advance to avoid severe and long-term consequences following a nuclear accident. Such preparedness plans should comprise a set of consistent protective actions, adapted to local conditions at nuclear sites, taking into account the societal, environmental, and economic factors that will affect the impact of the accident and its response.