Annals of the ICRP

Experience and current issues with recovery management from the Fukushima accident

M. Kai
Environmental Health Science Division, Department of Health Sciences, Oita University of Nursing and Health Sciences, Oita City, Japan; e-mail: kai@oita-nhs.ac.jp

Abstract–This paper describes the experiences of, and issues with, recovery management following the accident at Fukushima Daiichi nuclear power plant. The Fukushima accident has brought about socio-economic consequences with inevitable changes to daily life, as well as psychological effects. There is heightened concern amongst the population about the risk and effects of radiation at low doses. Experience has shown that the direct involvement of the affected population and local professionals is a decisive factor for management of the recovery phase. The radiological protection system of the International Commission on Radiological Protection (ICRP) seems to be relevant to the recovery requirements of the Fukushima accident, although some problems remain in implementation. Reference levels could play a role in improving the situation by requiring an iterative optimisation process. The Fukushima experience indicated that a routine, top-down approach using radiological criteria alone was unable to deal with the complexity of the problems, and that stakeholder engagement should be explored. The technical knowledge gap between radiation experts and the public caused a lot of confusion. Experts should understand the ethical values attached to recovery, and ICRP should be more active in promoting trustworthy radiological protection advice.

Keywords: Stakeholder involvement; Reference levels; Existing exposure situation; Situation-based approach

1. INTRODUCTION

The accident at Fukushima Daiichi nuclear power plant has had a large impact, not only in the locally affected area but also at a broader national level in Japan. Basic information on the impact mainly originated from measurements of ambient dose rates and radioactivity in soil, water, air, and foodstuffs. The aerial survey

This paper does not necessarily reflect the views of the International Commission on Radiological Protection.

produced a wide range of dose rate maps. In addition, soil sampling was conducted intensively and extensively by the authorities, and researchers provided detailed information on contamination levels in the affected area. These data were collected immediately after the accident to predict the magnitude of the human and environmental impacts. The unprecedented scale of the accident in Japan brought about a nationwide level of social confusion, which can be summarised in three ways. Firstly, socio-economic consequences have caused changes in daily life of affected communities, as well as psychological effects. For example, the evacuation measures taken during the emergency exposure situation have not been lifted in many places since 2011. Secondly, there are many concerns among the population about the risks of low doses, particularly among children and unborn babies. Thirdly, recovery management problems have arisen from slow step-by-step rehabilitation programmes that have moved forwards in a different way from that planned. Lessons learned from the response to the accident should be used to reflect on how radiological protection practices can be improved in the future. The International Commission on Radiological Protection (ICRP) has recommended fundamental principles for application of the radiological protection system (ICRP, 2007), and specific advice for the protection of people living in long-term contaminated areas after a nuclear accident (ICRP, 2009b). This paper focuses specifically on the key issues raised about the ICRP system of radiological protection on recovery management after an accident.

2. UNDERSTANDING RADIOLOGICAL PROTECTION PHILOSOPHY

2.1. Reference levels

ICRP recommends that the level of protection should be the best possible under the prevailing circumstances, maximising the margin of benefit over harm. The ICRP system of radiological protection is based on three exposure situations: existing exposure situations, planned exposure situations, and emergency exposure situations. The experiences and issues that emerged from the situation-based approach in the Fukushima accident have been discussed by Kai (2012) and ICRP TG (ICRP, 2012).

The main protective actions taken in the event of an emergency are sheltering, evacuation, and foodstuff restrictions. Following the Fukushima accident, the evacuation and foodstuff restrictions adopted by the authorities effectively reduced the doses received by people living in the affected area. However, societal concern about the level of protection intensified with transition from the emergency exposure situation to the existing exposure situation.

On 12 March 2011, an emergency evacuation was implemented in a circular zone within 20 km of the accident site. However, on 22 April 2011, the authorities ordered full evacuation of residents from the village of Iitate, located outside the original 20-km zone, as an exceptional case. This was termed 'deliberate evacuation' because it was not a prompt reactive measure in the emergency phase. Iitate became a symbolic village to the population due to this deliberate evacuation. The residents of Iitate faced the dilemma of leaving the village or staying for 2 months following the authority's decision regarding full evacuation. Management of the Iitate situation has led to a lack of understanding regarding the use of radiation protection criteria. It has also had a major effect on the credibility of the authorities.

The Japanese guidelines for nuclear disaster prevention recommended an evacuation criterion of 50 mSv before the Fukushima accident. However, following the accident, the Japanese Government adopted the criterion of 20 mSv year^{-1} based on the lower value of the reference levels proposed in the ICRP system for emergency exposure situations. Protective action was requested to protect people living in a long-term contaminated area with Cs-137 and Cs-134. The new adopted criterion, 20 mSv year^{-1}, created considerable confusion, as the meaning and rationale behind it were not clear for the authorities nor the affected residents.

The concept of intervention levels has long been used in radiological protection in the case of an emergency. In their 2007 Recommendations, ICRP introduced the situation-based approach to replace the process-based approach based on practices and interventions (ICRP, 2007). Reference levels became key drivers in the situation-based approach, and were a key feature of the 2007 Recommendations. They are guides for implementation of the optimisation process, particularly for identifying priorities in management of the situation. However, following the Fukushima accident, 20 mSv year^{-1} was used as an intervention level in the contaminated area (i.e. as a cut-off to identify contaminated areas where protective actions should be taken). The meaning and rationale behind the use of 20 mSv year^{-1} were not understood and explained properly by the authorities, and consequently have been communicated poorly to the public.

A similar problem occurred when the authorities decided to use the same tentative reference level for school playgrounds within the contaminated area. The dose of 20 mSv year^{-1} was understood as the cut-off between safety and danger by most people. Nobody understood why the dose level in these circumstances was much higher than the public dose limit of 1 mSv year^{-1} in the case of a planned exposure situation. Even some radiation experts were unable to understand the difference between contamination from accidental releases and contamination from fully controlled sources, such as in a planned exposure situation. Furthermore, members of the public misunderstood the decision of the authorities, and believed that the annual dose of 20 mSv year^{-1} was to be maintained over a long period of time.

One of the marked differences between reference levels and intervention levels is the inclusion of a time factor for improving the prevailing circumstances. The 2007 Recommendations of ICRP emphasise that a reference level is a key driver to optimise the residual level of dose remaining after implementation of protection strategies (ICRP, 2007). An intervention level is applied to an averted dose for taking a certain protective action, and is also understood as a level above which an action is justified and below which no action is needed (ICRP, 2009a). It is easier for a regulatory body to apply intervention levels for an emergency situation because a single number can be used to distinguish between circumstances where action is required and circumstances where action is not required. On the contrary, reference levels are instruments to identify where protection actions have to be implemented as a priority, and to push improvement in the situation by undertaking an iterative optimisation process. Reference levels are likely to be misunderstood if a single number is used. The dose of 20 mSv year^{-1} may be used as a reference level for an emergency exposure situation, but in this case, a lower reference level should be chosen for managing the recovery phase. After the accident, the authorities did not choose a reference dose between 1 and 20 mSv year^{-1}. An intermediate dose (e.g. 5 mSv year^{-1}) was not chosen because the authorities wanted a single intervention level above which actions were justified and below which no actions were needed.

2.2. Stakeholder involvement

Once an emergency exposure situation begins, it is unlikely that stakeholders will be involved in discussing protective measures. However, ICRP recommends that stakeholders should be involved in the planning for an emergency response, and also as soon as possible in management of the post-accident phase (ICRP, 2009b). When the authorities ordered full evacuation of the residents from Iitate, the residents asked the authorities to keep eight factories open, as well as a nursing home for the elderly. Implementation of the deliberate evacuation was deeply disturbing for the residents of Iitate; nevertheless, the authorities drew a sharp line based on 20mSv year^{-1}. Stakeholder involvement was only possible because the authorities introduced a moratorium for the evacuation. However, the moratorium highlighted an emerging issue on radiological protection, because the preparedness programme did not include the notion of deliberate evacuation.

Stakeholder engagement plays a much more important role once the situation develops into the recovery phase. Previously, radiological protection was expected to be conducted in a top-down fashion. More recently, radiological protection philosophy has evolved through the 2007 Recommendations of ICRP by emphasising the role of relevant stakeholders in the optimisation process (ICRP, 2007). Furthermore, in *Publication 111*, ICRP provided guidance about how to involve stakeholders in radiological protection for recovery management after a nuclear accident (ICRP, 2009b).

After the Fukushima accident, the affected people were drawn to *Publication 111* (ICRP, 2009b) where stakeholder involvement is emphasised for recovery management. Unfortunately, the authorities and some radiation specialists believe that radiological protection should only be considered in terms of applying specific dose criteria to decide on the implementation of protective actions. Currently, ICRP advocates a situation and risk-based approach emphasising the need for an optimisation process and the importance of involving stakeholders. The recovery phase is of sufficient duration to involve stakeholders in the decision-making process. This is quite different from the response during the acute phase of the emergency. To promote stakeholder engagement, ICRP (2009b) recommends that authorities should facilitate setting up local fora involving representatives of the affected populations and relevant experts. Accordingly, a similar forum was set up by local government after the accident at Fukushima, and this played an important role in effective recovery management. One of the difficulties was the selection of representatives from the affected population.

Facilitators may be required to establish effective communication in the forum. Following the Chernobyl accident, a French group appeared to play the role of facilitator. Even then, the uncertainty of future health effects brought about by radioactive contamination can lead residents to lose trust in the authorities. The experience of the ETHOS Project, implemented in Belarus during the 1990s (Lochard, 2013), showed that a key point in the recovery process is to respect the fundamental values of prudence in management of radiological risk, and of dignity of the affected people.

The Fukushima experience indicated that a routine top-down approach based solely on radiological protection criteria was unable to deal with the complexity of the problems resulting from the nuclear accident, and that stakeholder engagement needed to be explored.

2.3. Protective actions for contaminated foodstuffs

Contamination of foodstuffs was of concern not only to the affected population, but also elsewhere in Japan and even worldwide. When the accident occurred, there was no food regulatory law about radioactive materials. Derived intervention levels in the preparedness programme for a nuclear disaster had been developed according to the international standards such as *Publication 63* (ICRP, 1992). These intervention levels had no power of regulatory control. Responding to the accident, the Ministry of Health, Labour, and Welfare (MHLW) immediately gave notification of provisional regulation values, based on intervention levels. Foodstuff regulation started using the provisional regulation values on 17 March 2011.

In July 2011, some contaminated beef exceeding the provisional regulation values were delivered to consumers outside the contaminated area in Fukushima, and trust in the regulatory control was completely lost. Although management of contaminated foodstuffs was reinforced, some consumers were reluctant to buy agricultural products from Fukushima, even though they were controlled below the provisional regulation values. A new foodstuff regulation for the management of recovery was required. The MHLW made a request to the Food Safety Commission under the Cabinet Office. This situation led to a heated debate at national level about what should be considered as a safe level in the future. The media made frequent reports about contaminated foods, and public concern centred on consumer safety, with many consumers considering that the provisional regulatory values were too high.

After public consultation, the Food Safety Commission reported that there was no evidence that lifetime doses below 100 mSv led to detectable incidence of radiation-induced cancer. Finally, the MHLW decided to select 100 Bq kg^{-1} based on 1 mSv $year^{-1}$, and the new foodstuff criteria were introduced in April 2012. The authorities explained that 1 mSv $year^{-1}$ was the intervention exemption level used in the Codex guideline. This argument accelerated the idea that 1 mSv $year^{-1}$ was the threshold for safe annual dose. Most members of the public, other than Fukushima's farmers and their supporters, welcomed the new criteria. However, some voices were raised to draw attention to the need to find a balance between the interests of producers, distributors, and consumers. The Radiation Council, an advisory board to the authorities on radiological protection, emphasised that the new criteria may not contribute to decrease the contamination levels, as most foodstuffs already met the new criteria. There was, however, a strong view that there was no need to protect farmers to the detriment of consumers' safety. After introducing the new foodstuff criteria, there was also concern that the public chose foodstuffs with much lower contamination levels, even below the new criteria. This illustrates the complexities of foodstuff regulation as a protective action.

2.4. Decontamination of the land

The greatest programme for managing recovery in Fukushima is decontamination of the land. The Ministry of the Environment set some criteria for decontamination. Contaminated areas were targeted if ambient dose rates were more than 0.23 μSv h^{-1}, taking into account a background dose rate of 0.04 μSv h^{-1}. It was assumed that people stay indoors for 8 h day^{-1} with a reduction factor of 0.4 applying to the excess dose rate, and that annual doses reach 1 mSv. Originally, it was intended that the criterion was not a designated goal for decontamination but an investigation level. However, before deciding on the criterion, it was recognised that areas with higher dose rates would not be given priority for decontamination. The cost and effectiveness of decontamination strategies in the evacuated areas had been analysed, and these results could help to prioritise the areas suitable for decontamination from the viewpoint of cost and effectiveness of reducing the dose (Yasutaka et al., 2013). Most affected residents considered values of less than 1 mSv $year^{-1}$ to be a safe dose. Decontamination has been performed using an implicit criterion of 1 mSv $year^{-1}$, as no legally binding target dose exists. This situation has brought about various difficulties for returning people to the evacuated areas. In order to resolve these issues, dialogue with the relevant stakeholders needs to be considered, as social and ethical aspects are key factors of the decision-making process.

3. CREDIBILITY OF RADIOLOGICAL PROTECTION

3.1. Inconsistencies between experts and ICRP's message

The credibility of the experts and authorities was lost after the accident, and this was reported frequently by the media. The unprecedented scale of the accident in Japan led to misleading communication between experts and residents. Some radiation experts emphasised that no effects had been shown for radiation doses below 100 mSv. This statement was probably intended to mitigate unnecessary fear among residents about the low dose exposure under the particular circumstances after the accident. However, in the 2007 Recommendations, ICRP states that epidemiological and experimental studies provide evidence of radiation risk, albeit with uncertainties, at doses of approximately 100 mSv or less in the case of cancer, and there is increased likelihood of deterministic effects and a significant risk of cancer at doses above 100 mSv (ICRP, 2007). Most members of the public could not understand how both statements could be true, and they gradually stopped trusting the experts.

There is a gap in understanding of cancer risk at low doses. ICRP recommends that reasonable protection should be used no matter how low the radiation dose. Even before the accident, this message sometimes heightened concerns about medical exposure. When experts faced the problem, they tried to explain that the radiation either had no effect or that a larger benefit was derived compared with the risk. The risk–benefit approach is generally an effective method of communicating with patients. Seemingly, the public believe that the radiation risk after the Fukushima accident should be avoided at much lower doses. In this situation, experts often tried to communicate to the public that there is no significant radiation risk below 100 mSv. In reality, many people felt that this statement would stop the decontamination of contaminated areas. Finally, it seems that the public has gradually understood ICRP's message about the linear, non-threshold model for radiation protection.

The difference between the public and experts regarding the risks at low doses comes not only from scientific knowledge but also from an ethical aspect. People recognised that there is scientific controversy (Yasui, 2013) about cancer risk at low doses. The controversy was, for example, illustrated through media reports on the contradictory statements concerning health effects of radiation on children in Ukraine following the Chernobyl disaster. These scientific health issues on low-dose exposure could not convince the public. Some experts felt that the public did not understand that the risks from low-dose radiation would be quite low. Consequently, the experts tried to emphasise that there were no radiation effects below 100 mSv. This message partly caused the loss of credibility of the experts and authorities after the accident.

After the Fukushima accident, the authorities tried to apply ICRP's recommendations for recovery. However, the public felt that the authorities made a makeshift law because there were no rules about recovery from a nuclear disaster until 2011. Moreover, they felt that the public dose limit of 1 mSv year^{-1} that applies for planned exposure situations was relaxed to adjust to the accident. The loss of trust in the authorities and radiation experts was inevitable.

3.2. Issues to be challenged

Currently, there is a marked gap between the public's and ICRP's positions. Following the Fukushima accident, it has become apparent that differences in perception have brought about much confusion in society. These have caused socio-economic consequences with inevitable changes to daily life, as well as psychological effects. Radiological protection considers the control of health effects using the risk-based approach. Since the accident, most radiation experts have acknowledged the difficulties of the risk-based approach for radiological protection. The experts felt that even a low probability of cancer induction could not convince the public, as they were unable to understand the probability that cancer might occur at low doses. The concept of risk should be used to reduce doses on a prospective basis, but is actually used to calculate the probability of cancer no matter how low the dose and where epidemiological limitations exist.

Contrary to the concept, risk itself cornered the affected people into a dead-end. The experts failed to find a scientific way to discuss tolerability, and compare radiation risk with other risks. When the experts tried to explain that no effects have been observed for exposure levels below 100 mSv, they lost the public's trust.

So, where should we go? Risk quantification is needed to promote radiological protection in a scientific way, but currently lacks what the risk means. Cancer risk should be addressed from the viewpoint of cancer risk management to an individual. Talking about risk comparison, it may be more important to estimate individual risk, rather than average risk among a population. Age and lifestyle behaviours, such as smoking, can be taken into account. Obviously, risk comparison should be used for risk management. To facilitate risk management, it will be necessary for communication between experts and affected individuals to be based on trust.

ICRP, like the United Nations Scientific Committee on the Effects of Atomic Radiation and the World Health Organization, plays a key role in disseminating good science about radiation risk. However, ICRP is in a unique position with respect to maintaining a trustworthy radiological protection system. In the personal opinion of the author, if scientific controversy occurs in relation to an unexpected situation, ICRP should provide timely scientific information and radiation protection advice.

4. CONCLUSIONS

In the case of the Fukushima accident, the ICRP system of radiological protection seems to be relevant, although there have been problems in its implementation. Reference levels could improve the situation by requiring an iterative optimising process. The Fukushima experience indicated that a 'classical' top-down approach relying on radiological criteria was unable to deal with the complexity of the problems, and that stakeholder engagement should be explored. The gap in understanding of radiation risks from low doses between radiation experts and the public has caused much confusion. Experts should recognise that ethical issues, as well as scientific uncertainty, exist in radiological protection. ICRP should aim to be more proactive in order to promote trustworthy radiological protection.

REFERENCES

ICRP, 1992. Principles for intervention for protection of the public in a radiological emergency. ICRP Publication 63. Ann. ICRP 22(4).

ICRP, 2007. The 2007 Recommendations of the International Commission on Radiological Protection. ICRP Publication 103. Ann. ICRP 37(2–4).

ICRP, 2009a. Application of the Commission's Recommendations for the protection of people in emergency exposure situations. ICRP Publication 109. Ann. ICRP 39(1).

ICRP, 2009b. Application of the Commission's Recommendations for the protection of people living in long-term contaminated areas after a nuclear accident or a radiological emergency. ICRP Publication 111. Ann. ICRP 39(3).

ICRP, 2012. Report of ICRP Task Group 84 on Initial Lessons Learned from the Nuclear Power Plant Accident in Japan vis-à-vis the ICRP System of Radiological Protection.

International Commission on Radiological Protection, Ottawa. Available at: http://www.icrp.org/docs/ICRP%20TG84%20Summary%20Report.pdf (last accessed 9 February 2015).
Kai, M., 2012. Some lessons on radiological protection learned from the accident at the Fukushima Daiichi nuclear power plant. J. Radiol. Prot. 32, N101–N105.
Lochard, J., 2013. Stakeholder engagement in regaining decent living conditions after Chernobyl. In: Oughton, D., Hansson, S.O., Baxter, M. (Eds.), Social and Ethical Aspects of Radiation Risk Management. Elsevier Science, Oxford, pp. 311–332.
Yasui, S., 2013. An analysis of the argument over the health effects of low-dose radiation exposure caused by the accident at the Fukushima Daiichi APP in Japan. J. Risk Res. 16, 937–944.
Yasutaka, T., Naito, W., Nakanishi, J., 2013. Cost and effectiveness of decontamination strategies in radiation contaminated areas in Fukushima in regard to external radiation dose. PLOS ONE 8, e75308.