Key Issues on Radiological Protection from Radioactive Waste Management in Existing Exposure Situation

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Abstract

In environmental remediation after the nuclear accident at the Fukushima Daiichi nuclear power station, radioactive wastes have to be appropriately managed in existing exposure situations with contamination resulting from the emission of radionuclides released from the damaged reactors. In this paper, we propose a framework for radiation protection from radioactive waste management in existing exposure situations for application to practical and reasonable waste management in contaminated areas by discussing the following key issues: the definition of reference levels for existing ambient dose and radioactive waste management in existing exposure situations, how to select gradual intermediate reference levels based on the principle of optimisation and the participation of stakeholders in the decision-making process. In the proposed concept, intermediate reference levels are adopted gradually according to the progress of the reduction in the existing ambient dose in the environment by taking into account the practicability of the management of radioactive waste and remediation including the participation of stakeholders.

Key Words

radiological protection; radioactive waste management; existing exposure situation; stakeholder; optimisation

1. Introduction

Since the accident at the Fukushima Daiichi nuclear power plant hit by the magnitude-9.0 earthquake and the subsequent great tsunami of March 11, 2011, large quantities of radionuclides have been released outside the damaged reactors, contaminating a large area around the plant. In environmental remediation (e.g., decontamination of land) in the contaminated area, the generation of radioactive wastes is inevitable and the radioactive wastes have to be managed under an appropriate radiological protection system.

The currently available radiological protection system for radioactive waste management has been constructed only for planned exposure situations with a normal background radiation dose level (e.g., in ICRP Publication 77 (ICRP, 1997) and Publication 81 (ICRP, 1998)), in which compliance with the dose limit of 1 mSv/y for public exposure is demonstrated. In view of the principle of optimisation taking social and economic factors into account, it will not be entirely practical and reasonable to apply the available system in planned exposure situations to remediation in contaminated areas because the radiation level would be reduced using a reference level selected from a band of more than 1 mSv/y order in existing exposure situations. In some instances, it may even cause difficulties in

executing remediation actions.

In this paper, a framework for radiological protection from radioactive waste management in existing exposure situations is proposed on the basis of discussion on the following key issues by referring to some related ICRP recommendations: the definition of reference levels for existing ambient dose and radioactive waste management in existing exposure situations, how to select gradual intermediate reference levels and the participation of stakeholders in the decision-making process. Details of the proposal and further discussion on the application of the framework to the contaminated area after the accident at the Fukushima Daiichi nuclear power plant will also be given by Sugiyama and Hattori (2012).

2. Discussion on Key Issues

2.1 Definition of Reference Levels for Existing Ambient Dose and Radioactive Waste Management in Existing Exposure Situations

Situations that may cause prolonged radiation exposure resulting from contamination by released radionuclides from nuclear accidents or radiological events are recognized as existing exposure situations (ICRP, 2007). ICRP publication 103 (ICRP, 2007) states the following:

- *Existing exposure situations can be complex in that they may involve several exposure pathways and they generally give rise to wide distributions of annual individual doses ranging from the very low to, in rare cases, several tens of millisieverts.* (paragraph 285)
- *In most existing exposure situations, there is a desire from the exposed individual, as well as from the authorities, to reduce exposures to levels that are close to or similar to situations considered as 'normal'.* (paragraph 288)

The concept of the reference level, which is the source-related restriction to the dose that individuals may incur, is used as a tool in the optimisation of protection to ensure that all exposures are kept as low as reasonably achievable taking into account societal and economic factors (ICRP, 2007).

In areas contaminated by radioactive materials under existing exposure situations, remediation activities should be carried out to reduce the annual individual dose. In decontamination, the production of radioactive wastes is inevitable; in other words, the management of radioactive wastes (i.e., temporary and long-term storage, reprocessing and disposal) must be regarded as an integral part of the strategy to reduce the existing annual dose in remediation under existing exposure situations. The management of radioactive wastes can be justified when the reduction in the existing ambient dose by decontamination is optimised by taking the potential exposure from the accompanying radioactive waste management into account. In view of radiological protection from radioactive waste management, the reference level for the additional dose attributable to radioactive waste management should be selected as a source-related restriction to make such waste management reasonably practical. Since radioactive waste management will be carried out to reduce the existing annual dose, the reference level for radioactive waste management should be selected below the reference level for the existing annual ambient dose in circumstances under existing exposure situations. In the planning and execution of radioactive waste management, it is appropriate to ensure that the estimated dose from

the management does not exceed the selected reference level since it is a potential exposure.

2.2 How to Select Gradual Intermediate Reference Levels

In the remediation activities in existing exposure situations, reference levels should be selected appropriately to reduce the existing dose level. Regarding the selection of the reference level, ICRP has described some recommendations:

- *The second band, greater than 1 mSv but not more than 20 mSv, applies in circumstances where individuals receive direct benefits from an exposure situation. Constraints and reference levels in this band will often be set in circumstances where there is individual surveillance or dose monitoring or assessment, and where individuals benefit from training or information.* (ICRP, 2007, paragraph 240)
- *Exposure situations involving abnormally high levels of natural background radiation, or stages in post-accident rehabilitation may also be in this band.* (ICRP, 2007, paragraph 240)
- *The reference level for the optimisation of protection of people living in contaminated areas should be selected from the lower part of the 1–20 mSv/year band recommended in Publication 103 for the management of this category of exposure situation.* (ICRP, 2009, paragraph 50)

If a single low target value (e.g., 1 mSv/y, discussed below) is applied to all the processes of radioactive waste management, there is some concern that the reduction in the existing ambient dose in environmental remediation will not progress well or will proceed late owing to the limitation of decontamination, and the plan of waste management may be made economically and technically impractical. Therefore, intermediate reference levels should be selected progressively according to the progress of the remediation process. This is suggested in ICRP Publication 111 (ICRP, 2009):

- *National authorities may take into account the prevailing circumstances and also take advantage of the timing of the overall rehabilitation programme to adopt intermediate reference levels to improve the situation progressively.* (paragraph 50)

In most existing exposure situations, there should be a desire to reduce exposure to levels that are close to or similar to situations considered as ‘normal’ (ICRP, 2007). If the existing annual ambient dose is reduced to a certain level corresponding to the normal background level as the remediation proceeds, intervention may be exempted. Regarding such a dose level, ICRP states the following:

- *Past experience has demonstrated that a typical value used for constraining the optimisation process in long-term post-accident situations is 1 mSv/year.* (ICRP, 2009, paragraph 50).
- *A generic intervention exemption level of around 1 mSv is recommended for the individual annual dose expected from a dominant type of commodity amenable to intervention.* (ICRP, 1999, paragraph 126)

Therefore, as part of the integrated strategy to reduce the existing ambient dose in the environment to one that corresponds to the normal dose level, it may be appropriate that the final target reference level of the source-related dose restriction attributable to the radioactive waste disposal is set at an equivalent level to the generic intervention exemption level of the order of 1 mSv/y.

2.3 Participation of Stakeholders in the Decision-Making Process

It is essential to establish environmental remediation plans including waste management together with relevant stakeholders living in existing exposure situations to carry out activities to reduce the individual dose. It is important to substantially understand the concept of optimisation that the averted dose resulting from decontamination should be balanced by the potential exposure from the accompanying radioactive waste management. In these circumstances, it is appropriate to select gradual intermediate reference levels for the existing annual ambient dose and for waste management according to the progress of the reduction in the individual dose in the integrated plan of environmental remediation, with the participation of stakeholders..

3. Framework of Radiological Protection from Radioactive Waste Management in Existing Exposure Situations

On the basis of the above discussion, a framework for radiological protection from radioactive waste management in existing exposure situations is proposed as follows:

- The reference level for radioactive waste management as a source-related restriction is selected below the reference level selected for the existing annual ambient dose in the environment.
- Intermediate reference levels are adopted gradually according to the progress of the reduction in the existing ambient dose in the environment by taking into account the practicability of the management of radioactive waste and remediation including the participation of stakeholders.
- In the planning and execution of radioactive waste management, it is ensured that the estimated dose from waste management does not exceed the selected reference level.
- If the existing annual ambient dose and the reference level for waste management are reduced to a certain level corresponding to the normal background level as the remediation proceeds, intervention can be exempted.

4. Application of the Proposed Framework to Environmental Remediation after Fukushima Nuclear Accident

The dominant radionuclides in the contaminated area after the accident at the Fukushima Daiichi nuclear power plant are caesium-137 (^{137}Cs) and caesium-134 (^{134}Cs) (MEXT, 2012a). The radiation dose rate in air in some areas around the damaged nuclear power station was approximately 100 μSv/h on May 27, 2011 (MEXT, 2012b) and the estimated annual dose was more than several hundred millisieverts.

On the basis of the discussion in section 2, radioactive waste management in existing exposure situations under institutional control (e.g., land use control and the prevention of public access to the site) should be planned and executed to ensure that the estimated doses from waste management do not exceed the reference level which is selected to be below the reference level for the existing annual ambient dose in the environment. The dose from the wastes contaminated by ^{137}Cs and ^{134}Cs will decrease with time, as the existing annual ambient dose in the environment decreases, owing to the decay of those radionuclides. In the case that the dominant exposure pathway is direct exposure

(including skyshine exposure) during radioactive waste management, the wastes could be controlled so that their estimated potential dose would not exceed the selected reference level by the appropriate planning and operation of the facilities including shielding measures.

Figure 1 illustrates the conceptual strategy of remediation and waste management. Under an existing exposure situation with a certain ambient dose, the first reference levels for the existing annual ambient dose and for waste management are selected, as shown in Figure 1. When the existing annual ambient dose is reduced to below the first reference level, the second reference levels for the existing annual ambient dose and for waste management are selected to be lower than the first values. This procedure is repeated until the existing annual ambient dose in the environment is reduced to the normal dose level.

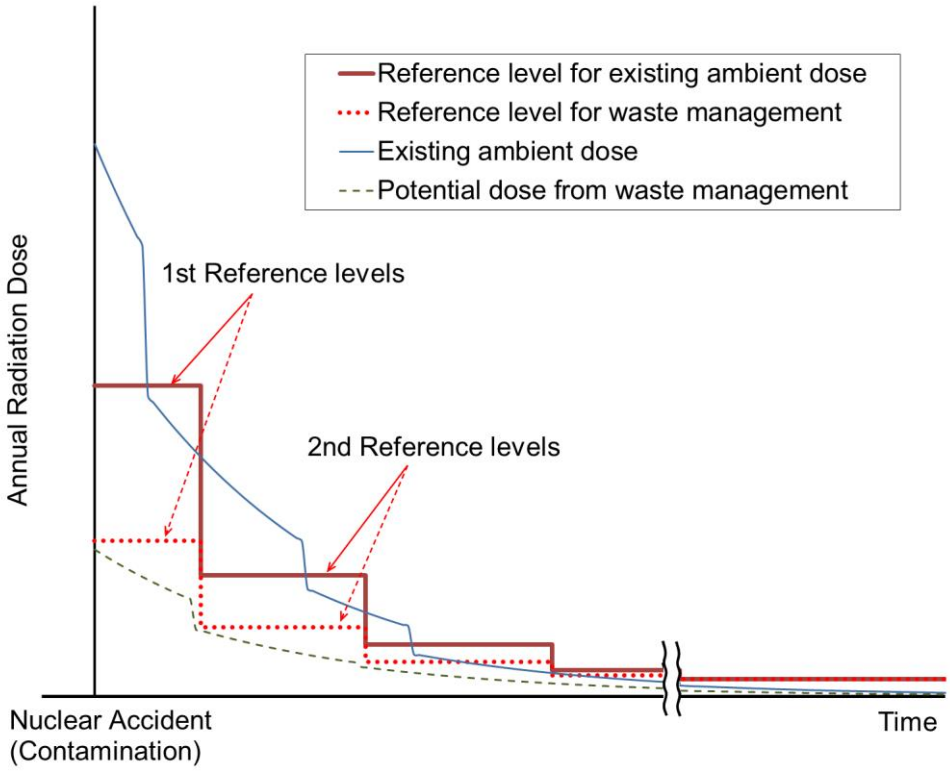

Figure 1 Conceptual strategy of remediation and waste management.

Figure 2 conceptually shows the relationship between the exposure from radioactive waste management and the averted existing ambient dose by remediation that produces wastes for each reduction step of the existing annual ambient dose in Figure 1. By selecting the reference level for waste management below the reference level for the existing ambient dose, the existing ambient dose will be reduced progressively.

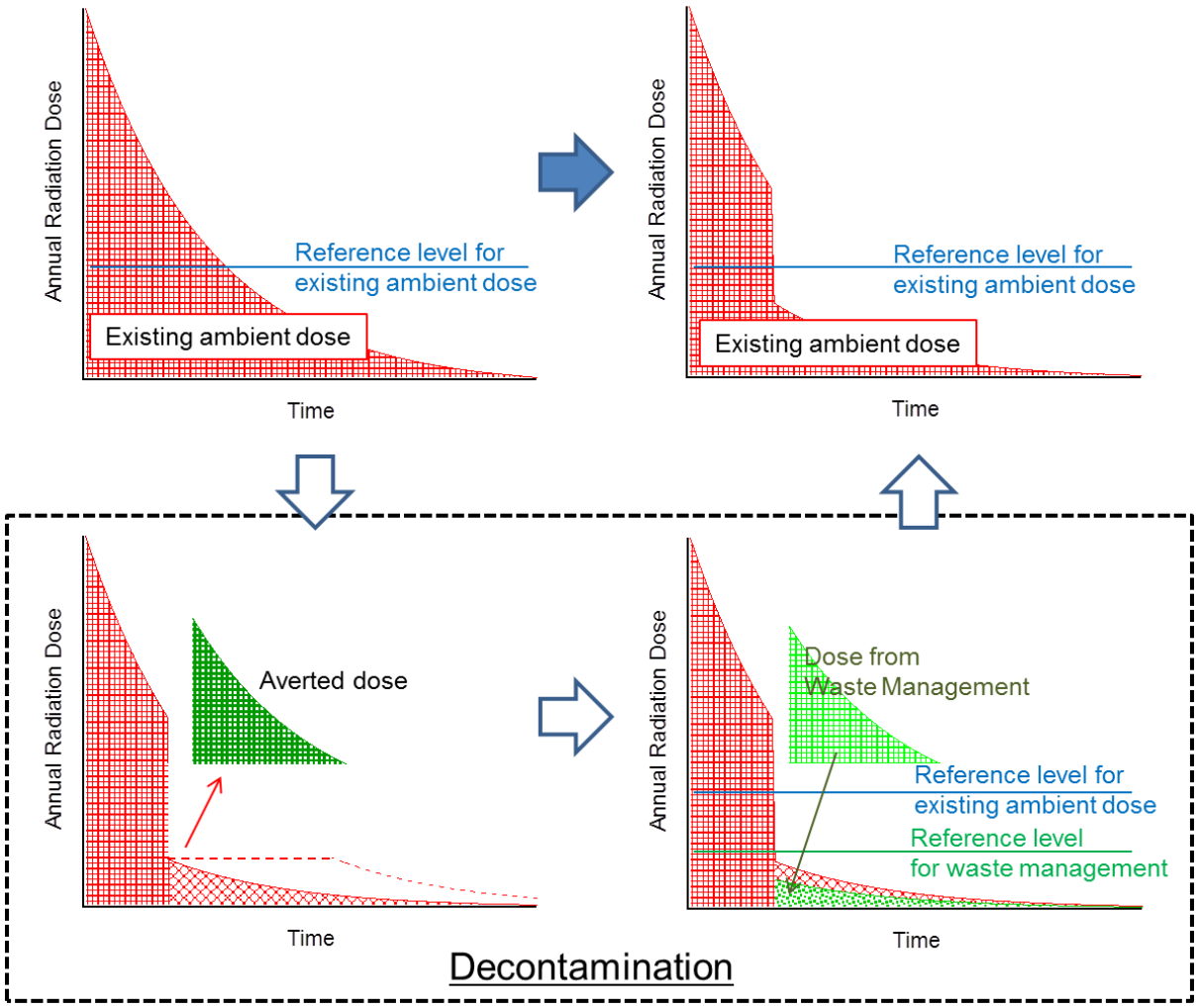

Figure 2 Relationship between potential exposure from radioactive waste management and averted existing ambient dose in remediation using reference levels.

5. Conclusions

A framework for radiation protection from radioactive waste management in existing exposure situations is proposed, in which intermediate reference levels for such waste management are adopted gradually according to the progress of the reduction in the existing ambient dose in the environment. The reference levels should be selected to make the remediation activities reasonably practical on the basis of the principle of justification and optimisation with the reasonable understanding of environmental remediation plans including waste management among relevant stakeholders living in existing exposure situations.

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