Priority Subjects — **Establishment of Optimal Risk Management**

Quantitative Evaluation of Low-Dose Radiation Risk and its Reflection on Radiation Protection

Background and Objective

The environmental contamination by radioactive materials which has arisen from the accident at the Fukushima Daiichi nuclear plant has given rise to public concern regarding radiation exposure, which showed that radiation protection for the general public in such situations have not been adequately developed. An epidemiological research study of residents in high natural radiation areas suggested that there is no increase in radiation risk at a prolonged low-dose-rate, in other words, the existence of a dose rate effect. Properly understanding this effect could contribute to the establishment of rational protection criteria and alleviate public concern regarding radiation exposure.

This project is aiming to construct rational radiation protection systems which achieve accountability to society; specifically to propose for the improvement of protective measures under the situation after accidents, and to elucidate biological mechanisms of dose-rate effect by experimental studies.

Main results

1 Proposal of a radiation protection framework with a graded approach in existing exposure situations resulting from nuclear accidents

The International Commission on Radiological Protection (ICRP) recommends that radiation protection be optimized by the application of reference levels selected according to the situation by taking into account economic and social factors in emergency exposure situations*1 and existing exposure situations*2, whereas dose limits apply to normal planned exposure situations. In this study, a concept of reference level application for optimization of protection in the management of radioactive waste and food safety regulation is proposed in light of the fact that several issues in these sectors were revealed by the accident at the Fukushima Daiichi nuclear power plant.

A radiation protection framework for the management of radioactive waste generated in decontamination is proposed, in which intermediate reference levels for such waste management are adopted gradually according to environmental remediation progress and the reduction in the existing ambient dose, in order to make the waste management activities reasonably practical (Fig. 1). Also graded reference levels are specifically proposed to improve food safety regulations, according to the timeframe and exposure situations after a nuclear accident (Fig. 2).

2 Quantitative analysis of tissue stem cell turnover to elucidate mechanisms for dose rate effects

Cancer is considered to be initiated by an accumulation of lesions in tissue stem cells (TSC*3). We are exerting efforts to clarify mechanisms for dose-rate effects, under the working hypothesis that the effects would attribute to the mechanisms for eliminating damaged TSCs from a living body by cell death and/or turnover.

We established an experimental system to quantitatively analyze TSC turnover after irradiation, focusing on intestinal stem cells, of which the behavior has been well studied (Fig. 3). Using this system, we clarified that the turnover of stem cells in small intestines was stimulated by high dose-rate exposure (Fig. 4). This behavior suggested that cancer risk would increase after high dose-rate irradiation which can make lesions in all cells simultaneous, resulting in a reduction of TSCs and reproliferation of surviving damaged TSCs to maintain tissue function. We will extend the application of this method to clarify the difference in the case of low dose rate exposure, which can induce a small number of damaged cells among healthy TSCs.

*1 Exposure situations that require urgent action to avoid or reduce risks.
*2 Exposure situations that already exist when a decision on control has to be taken. Also include long-term exposure situations following a nuclear or radiological emergency.
*3 Cells in which tissue-forming cells originate. They are also considered as origins of cancer because of their proliferative characters.

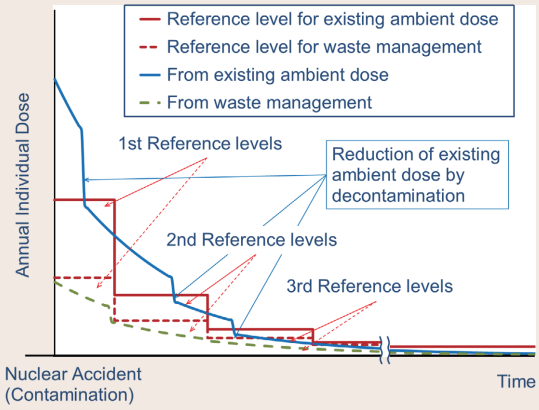

Fig.1: Conceptual diagram of application of intermediate reference levels for waste management in existing exposure situations

Under an existing exposure situation with a certain ambient dose due to contamination resulting from the emission of radionuclides by a nuclear accident, the first 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, taking into account the practicability of the environmental remediation including the waste management. 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 on the basis of the principle of optimization until the existing annual ambient dose in the environment is reduced to the normal dose level.

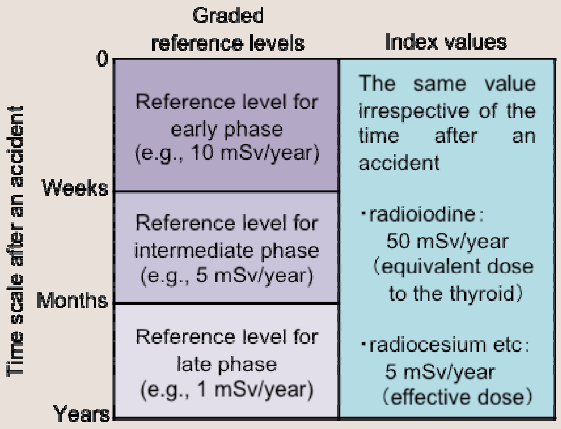

Fig. 2: Comparison of graded reference levels versus index values for food safety regulations

The period of emergency and existing exposure situations are divided into early, intermediate and late phase for which the time scale is in weeks, months and years, respectively, and graded reference level values are assigned for each phase. This approach allows realistic implementation of restrictions on distribution and consumption while the balance between various risks is kept, enabling stepwise reduction of the dose to members of the public. In contrast to index values for which the same values were assigned independent of phases after the accident, implementation of the graded triphasic reference level system permits optimization of the food safety regulation depending on situations of the accident and exposure.

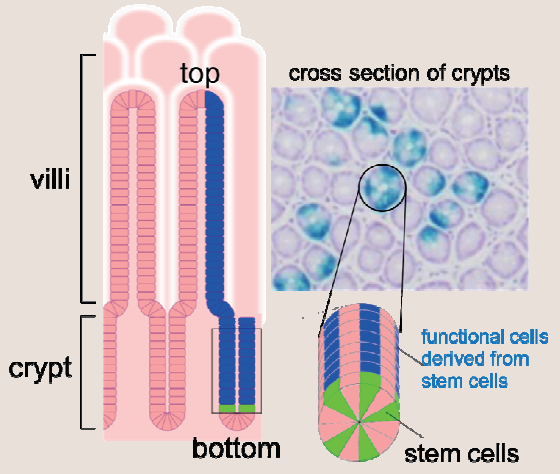

Fig. 3: Experimental system to analyze TSC turnover after irradiation

TSCs and their progenies (functional cells) were visualized as labeled crypts (shown in blue in the figure) from the bottom (crypt) to top (villi) of the intestines of transgenic mice. We found that the percentage of labeled crypts in cross sections could be a useful indicator to understand the frequency of TSC turnover.

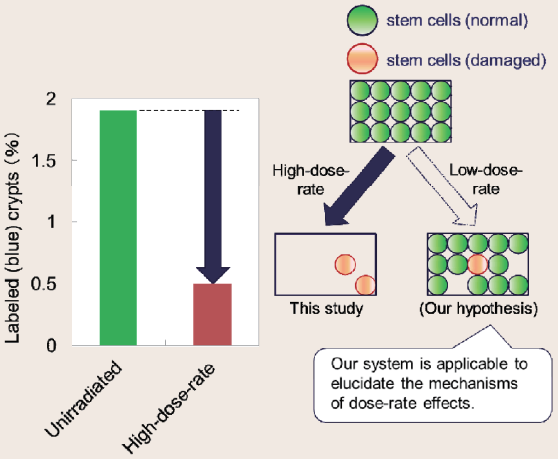

Fig. 4: TSC turnover after high-dose-rate irradiation

The percentage of labeled (blue) crypts in the colon was evaluated after high-dose rate (1.5 Gy/min) X-irradiation (1 Gy). X-irradiation stimulated TSC turnover (loss of TSCs). Since the loss of TSCs has to be reproliferated by surviving (damaged) TSCs, radiation damage induced by high-dose-rate irradiation may accumulate in the tissue cells. On the other hand, we hypothesize that normal TSCs may compensate a loss of TSCs after low dose rate irradiation to prevent the accumulation of radiation damage.