

**Issues Associated with Radiation Protection after
Fukushima Daiichi Nuclear Power Plant Disaster**

*- Responses of and Recommendations from
Japan Health Physics Society -*

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Japan Health Physics Society



1. Introduction

We express our deepest sympathy to all those affected by the Tohoku District - off the Pacific Ocean Earthquake (Great East Japan Earthquake) and tsunami caused by the earthquake, and Fukushima Daiichi nuclear disaster, all of which have had a serious impact on Japan. Soon after the Fukushima Daiichi nuclear disaster, Japan Health Physics Society (JHPS) established a Q&A section on our website and has answered questions from the public in our capacity as a group of radiation protection experts. In addition, we held symposia on measures for dealing with the nuclear disaster and their criteria on 16 June 2011 and on exposure to radiation among the general public on 12 August 2011. We also held a session on the Fukushima Daiichi nuclear disaster at the 44th JHPS Annual Meeting on 18 October 2011 to deepen understanding and promote discussion about various topics related to the disaster. On 17 December 2011, we also held a comprehensive symposium on measures for dealing with the Fukushima nuclear disaster from the viewpoints of radiation exposure assessment and radioactive waste management, focusing on internal exposure, to comprehensively discuss the Society's activities carried out over the year following the earthquake, and we identified the important issues associated with radiation protection to be examined in the future. The purpose of JHPS is to widely contribute to the prosperity of humankind through the promotion of academic and technological advances in health physics and to ensure that human society and industry benefit from these advances. With these aims in mind, we summarize the issues associated with radiation protection on the basis of the findings and lessons learned through the responses to the Fukushima Daiichi nuclear disaster, and report the response of and the recommendations from JHPS.

2. Issues associated with radiation protection and their points of discussion

On the basis of discussions during the past three symposia on Measures for Dealing with the Fukushima Nuclear Disaster and a session on the Fukushima Daiichi nuclear disaster at the 44th JHPS Annual Meeting in 2011, important issues associated with radiation protection can be summarized into the following eleven items in accordance with the exposure situation that changed over time after the accident.

1) Comprehensive issues related to all situations

- (Issue 1) Strategies for reducing anxiety and doubts of the general public regarding radiation risk

- (Issue 2) Methods of measuring ambient dose rate, surface contamination density, and concentration of radioactive materials in foods
- 2) Issues related to emergency exposure situation
 - (Issue 3) Criteria for evacuation and stay in-house
 - (Issue 4) Administration of stable iodide
 - (Issue 5) Principles for regulation of ingestion of foods and drinks
 - (Issue 6) Screening criteria for decontamination
 - (Issue 7) Dose limit for emergency workers
 - (Issue 8) Post disaster investigation of thyroid equivalent dose of radioactive iodine
- 3) Issues related to existing exposure situation
 - (Issue 9) Provisional criteria for judging the safety of using school yards, forage, cropping soil, fertilizers, bathing areas, etc.
 - (Issue 10) Systems for temporary entry into restricted zones
 - (Issue 11) Management of radioactive wastes such as cesium-containing rubble, sludge, and decontaminated soil

The points of discussion mentioned above are described below.

2.1 Comprehensive issues related to all situations

Issue 1: Strategies for reducing anxiety and doubts of the general public regarding radiation risk

[Points of discussion]

- Anxiety of the general public regarding foods and drinks
Foods and drinks are daily necessities. The general public is worried about their radiation risks in the case of daily shopping and needs information on whether people should purchase them. It is important to understand the correct meaning of regulatory values of foods and drinks and to verify how the actual radiation measurements of foods and drinks are carried out and whether measurement results are disseminated to consumers with accuracy.
- Anxiety of the general public regarding contamination hot spots
There are many cases wherein high-level radioactivity is found in sewage sludge and incinerated ash in the Kanto district, and radioactivity relatively higher than that in areas surrounding residential communities is observed, whereas the amount of radiation exposure would be minimal if it is estimated in terms of the radiation effect on the human body. It is important to respond to the needs of local residents and properly inform them of the results of dose

assessments.

- Anxiety of the general public regarding provisional criteria for judging the safety of using school yards, forage, cropping soil, fertilizers, bathing areas, etc.
Although parameters and exposure scenarios for deriving these criteria are assumed conservatively, it is important to comprehensively and correctly disseminate the methods of deriving the criteria and their magnitude of conservativeness.
- Anxiety of the general public regarding pregnant women, fetuses, and children
The radiation sensitivities and risks of pregnant women, fetuses and children are higher than those of adults. This high sensitivity is not considered in the current domestic radiation protection system that is based on international standards, except for the regulation for the thyroid equivalent dose for infants in an emergency exposure situation. A simple explanation on the triviality of radiation exposure leads to the shortage of information. A well-balanced radiation protection system must be reconstructed, taking into consideration the relatively high sensitivity of younger individuals and comprehensive accountability to the general public.

Issue 2: Methods of measuring ambient dose rate, surface contamination density, and concentration of radioactive materials in foods

[Points of discussion]

- Methods of measuring ambient dose rate
Some ambient dose rate meters in local governments are set on the housetops because the measurement target is radioactive plume in the air. It is necessary to take into consideration the measurement height dependence in the case of radiation monitoring on broadly contaminated soil. The method of measuring the ambient dose rate according to the monitoring objective must be standardized, that is, to select a short time constant in the case of an overall survey of contamination hot spots.
- Consideration of high background count rate
In many cases, Geiger-Müller (GM) survey meters for surface contamination are usually used in measurements of surface contamination density for beta emitters. Since this type of survey meter has a low sensitivity for gamma rays that come from outside of the surface of a detection area, the net count rate should be estimated in the case of measuring the surface contamination density by subtracting the background count rate that increases with the ambient dose rate from the measured total count rate. Such a method must be standardized.

- **Methods of measuring the concentration of radioactive materials in foods**
 A highly accurate Ge semiconductor detector is often used to confirm that radioactivity concentration in foods is below the regulatory values, on the other hand, the measurement system is too expensive. Outsourcing to measure them is also expensive. For this reason, screening measurement using a NaI(Tl) scintillation survey meter that is relatively cheaper to purchase may be feasible. In the case of such a simple screening measurement, a gamma ray shield is necessary to reduce the background count rate accordingly. An appropriate measurement method must be standardized, taking into consideration the relationship between the detection limit and regulatory values in foods.
- **Methods of estimating internal dose using whole-body counters and the bioassay method**
 Estimation of internal exposure using whole-body counters and the bioassay method depends on how to calibrate the measurement system in accordance with radioactive nuclides and how to provide a dose coefficient assuming a variety of timings of intake, which is a significant issue that would clearly affect the effective dose assessment. Considering such issues, the method of estimating the internal exposure must be standardized.
- **Methods of measuring a screening level for the thyroid equivalent dose of radioactive iodine**
 A screening level for simplified thyroid measurement that is equivalent to 100 mSv thyroid equivalent dose for one-year-old infants was established just after the Fukushima accident. In the case of such a simplified measurement, it is necessary to maintain a constant distance between the survey meter and thyroid of the target person, and to subtract the background ambient dose rate from the measured dose rate. Considering such issues, the method of measuring a screening level for the thyroid equivalent dose of radioactive iodine must be standardized.

2.2 Issues related to emergency exposure situation

Issue 3: Criteria for evacuation and stay in-house

[Points of discussion]

- **Balance among other emergency criteria (the same as Issues 4 and 5)**
 In the current system, the emergency criteria of evacuation and stay in-house, distribution of stable iodide, and regulation of the ingestion of foods and drinks are independently determined. The emergency measures are closely connected,

that is, it is stated that stable iodide should be distributed at evacuation centers after the evacuation instruction. It is important to determine the emergency criteria by overlooking beyond each emergency criterion.

- Assumption of long-term emergency situation and maintenance of infrastructure including electricity, water, and communications (the same as Issue 5)

The current system assumes a short-term and temporary emergency situation. Emergency measures applicable to a long-term emergency situation must be examined by considering the balance with the maintenance of infrastructure including electricity, water, and communications.

- Use of SPEEDI and simulations on the diffusion of radioactive materials in the ocean

The results of the System for Prediction of Environmental Emergency Dose Information (SPEEDI) and simulations on the diffusion of radioactive materials in the ocean must be disclosed at an early stage so that municipalities and evacuees can actively use the data.

- Communication with residents to designate the deliberate evacuation zones

Since residents in the deliberate evacuation zones have sufficient time to evacuate, the designation of deliberate evacuation zones and the deadline for the completion of evacuation must be determined after sufficient discussions with municipalities.

- Emergency planning zones (EPZs) (the same as Issue 4)

Emergency planning zones (EPZs) that are designated for emergency preparedness within a radius of 8-10 km from nuclear power plants and related anti-disaster measures through full discussions with municipalities must be reviewed by considering the post disaster spread of contamination to a large area.

Issue 4: Administration of stable iodide

[Points of discussion]

- Balance among other emergency criteria (the same as Issues 3 and 5)

In the current system, the emergency criteria of evacuation and stay in-house, the distribution of stable iodide, and regulation of the ingestion of foods and drinks are independently determined. The emergency measures are closely connected, that is, it is stated that stable iodide should be distributed at evacuation centers after the evacuation instruction. It is important to determine the emergency criteria by overlooking beyond each emergency criterion.

- Emergency planning zones (EPZs) (the same as Issue 3)

Emergency planning zones (EPZs) that are designated for emergency preparedness within a radius of 8-10 km from nuclear power plants and related anti-disaster measures through full discussions with municipalities must be reviewed by considering the post disaster spread of contamination to a large area.

Issue 5: Principles for regulation of ingestion of foods and drinks

[Points of discussion]

- Balance among other emergency criteria (the same as Issues 3 and 4)
 In the current system, the emergency criteria of evacuation and stay in-house, distribution of stable iodide, and regulation of the ingestion of foods and drinks are independently determined. Since the emergency measures are closely connected, it is important to determine the dose criteria for the derivation of provisional regulatory values for radioactive materials contained in foods by overlooking beyond each emergency criterion.
- Assumption of emergency situation over a long-term and maintenance of infrastructure including electricity, water, and communications (the same as Issue 3)
 The current system assumes a short-term and temporary emergency situation. Emergency measures applicable to a long-term emergency situation must be examined by considering the balance with the maintenance of infrastructure including electricity, water, and communications.
- Category of foods
 In the provisional regulatory values (by 31 March 2012) for radioactive materials contained in foods before the disaster, the restriction value for radioactive iodine in fish, for example, was not specified. The categories of foods must be reviewed, taking into consideration the annual amounts of ingestion and monitoring results of actual foods.
- Scope of radioactive nuclides except for key nuclides
 Provisional regulatory values (by 31 March 2012) for radioactive materials contained in foods were derived assuming the ratio, Cs-137: Sr-90 = 1:0.1. Since radioactive strontium tends to concentrate in bone in the food chain, the provisional regulatory values must be reviewed by considering the results of radiation monitoring in marine products.

Issue 6: Screening criteria for decontamination

[Points of discussion]

- Validity of screening levels (100 and 13 kcpm) from the viewpoint of radiation protection

The local nuclear emergency response headquarters increased the level of screening contaminated surfaces for decontamination to 100 kcpm (100,000 counts per minute) on 20 March 2011 following the advice from the Nuclear Safety Commission of Japan. The screening level was equal to the criterion for decontamination in the International Atomic Energy Agency (IAEA) publication entitled “Manual for First Responders to a Radiological Emergency”, which is equivalent to 1 μ Sv/h at a distance of 10cm. It was then lowered to 13 kcpm on 16 September 2011 following the advice from the Commission that it is desirable to appropriately decrease the screening level in a stepwise manner by considering the overall situation such as radiation monitoring results and number of people going in and out of the checkpoint. The validity of the screening criteria for decontamination in an emergency must be verified in terms of their effectiveness for radiation protection by considering the relationship between screening levels for radioactive nuclides and effective doses owing to surface contamination remained without decontamination in accordance with the principles of other emergency measures.

- Underestimation of count rate of GM survey meters

In many cases, Geiger-Müller (GM) survey meters have been used to measure the radioactive contamination of surfaces. GM counters underestimate the actual count by at least 20% in the measurement range with a count rate of as high as 100 kcpm because of the occurrence of dead time due to a long resolving time. Such an issue in radiation measurement must be included in the verification of the validity of the criteria from the viewpoint of radiation protection.

Issue 7: Dose limit for emergency workers

[Points of discussion]

- Transition of dose limit for emergency workers to 250 mSv

In the second interim report on the incorporation of the 2007 Recommendations of the International Commission on Radiological Protection (ICRP) into domestic systems, the Basic Committee of the Radiation Council proposed to match the dose limits to internationally recommended values because the current restriction criteria in Japan (dose limit, 100 mSv) interfered with emergency medical care and other essential operations. On the other hand,

the Ministry of Economy, Trade and Industry on 16 March 2011 consulted the Radiation Council to change the upper limit of individual dose for emergency workers from 100 to 250 mSv and obtained an opinion that such a revision was appropriate on 26 March 2011. Taking into consideration that the other various emergency measures are based on internationally approved principles and the recommended value of the 2007 Recommendations of ICRP (emergency medical care, no restriction; other emergency rescue operations, 1,000 or 500 mSv; other rescue operations, 100 mSv), 500 mSv must be adopted as a dose limit for emergency workers.

- Relationship between individual dose received in an emergency situation and dose limit for radiation workers under normal conditions

When the individual dose received in emergency situation is applied to control the exposure of radiation workers under normal conditions (50 mSv per year and 100 mSv over five years), radiation workers who have been exposed to radiation exceeding 100 mSv during emergency work are prevented from engaging in radiation work for a given period. After this disaster, taking into consideration that the dose limit for emergency workers was set to 250 mSv, which is lower than the internationally recommended value, and the current dose limit under normal conditions for radiation workers was determined on the basis of a lifetime individual dose of 1,000 mSv, the individual dose in an emergency should be controlled independently of a compliance of the dose limits for radiation workers under normal conditions (50 mSv per year and 100 mSv over five years) to control radiation exposure.

Issue 8: Post disaster investigation of thyroid equivalent dose of radioactive iodine

[Points of discussion]

- Simulating the atmospheric diffusion of the radioactive plume using SPEEDI and surveys on residents' behavior

Radiation monitoring was not satisfactorily carried out for approximately one week after the nuclear disaster owing to its aftermath. Therefore, the results of simulations of the atmospheric diffusion of the radioactive plume using SPEEDI and surveys on resident's behavior are essential for assessing the thyroid equivalent dose for radioactive iodine among residents after the disaster. The thyroid equivalent dose for radioactive iodine must be estimated and disclosed with its uncertainty on the basis of the results of simulating the atmospheric diffusion of radioactive plume using SPEEDI and surveys on residents' behavior.

2.2 Issues related to existing exposure situation

Issue 9: Provisional criteria for judging the safety of using school yards, forage, cropping soil, fertilizers, bathing areas, etc.

[Points of discussion]

- Balance among provisional criteria

As a temporary policy for judging the safety of using school yards and other outdoor facilities, the Ministry of Education, Culture, Sports, Science and Technology (MEXT) initially announced a provisional criterion of 3.8 $\mu\text{Sv/h}$, which was derived from the reference level of 20 mSv/y, and decided to aim to reduce the level of contamination to 1 mSv/y. The provisional criteria for forage fed to cows, cropping soil, and fertilizers announced by the Ministry of Agriculture, Forestry and Fisheries (MAFF) were derived on the basis of the provisional values for foods, which was determined with consideration of the individual dose for radioactive cesium (5 mSv/y). In addition, the provisional criterion for bathing areas announced by the Ministry of the Environment (MOE) was derived so that the individual dose due to external and internal exposure was within 10% of 1 mSv/y. These provisional criteria must be reconsidered on the basis of the overall policy by considering the radiation sensitivity of children and the balance among reference levels including and, if necessary, adopting stepwise reference levels.

Issue 10: Systems for temporary entry into restricted zones

[Points of discussion]

- Balance among radiation protection measures, inconvenience and heat stroke

During the temporary home visits allowed in summer 2011, the room temperature reached 37 °C at some centers established as relay points through which residents returned to their homes. Therefore, the requirement of wearing Tyvek clothing was loosened to prevent heat stroke, i.e., people wearing long-sleeved clothes and long trousers were allowed to enter the restricted zones, although they were required to wear overshoes, gloves, a mask, and a hat. The maximum time spent at home was limited to 2 h, and the total time taken for the round trip from the relay point to their homes was limited to 5 h. Since the elderly were included in the list of individuals allowed temporary home visits, flexible systems must be proposed by considering their own needs and ages, rather than uniformly imposing the wearing of a protective suit and

limiting the entry time.

Issue 11: Management of radioactive wastes such as cesium-containing rubble, sludge, and decontaminated soil

[Points of discussion]

- Policy for managing radioactive wastes under the existing exposure situation
 The radiation protection policies for the disposal of radioactive wastes in ICRP and the Nuclear Safety Commission in Japan have been established assuming the situation is under normal condition (planned exposure situation) where the dose limit for the public of 1 mSv/y is complied. The application of these policies to the management of radioactive wastes (e.g., temporary placement, treatment, storage, and disposal) under the existing exposure situation, where decontamination (dose reduction) in a large contaminated area is planned by setting reference levels chosen from between 1 and 20 mSv/y, may be unrealistic from the viewpoints of justification and optimization taking into consideration social and economical factors. The radiation protection policy for the management of radioactive wastes under the existing exposure situation must be established to make the environmental restoration reasonably practical.
- Reference level for managing radioactive wastes
 In the existing exposure situation, the management of radioactive wastes is justified when the decrease in the ambient dose due to decontamination is judged to be appropriate despite the potential exposure to radiation due to the management of the radioactive wastes necessary for decontamination. Justification and optimization should be fully discussed in the overall plan of environmental restoration. Considering the reference level for the management of radioactive wastes is used to reduce the ambient dose in a large contaminated area, the reference level for the management of radioactive wastes must be selected below the reference level for the existing ambient dose in a stepwise manner. (When environmental restoration is carried out by lowering the reference level for ambient dose due to a broadly contaminated land in a stepwise manner during the management of radioactive wastes, lowering the reference level for the management of radioactive wastes can be achieved by restricting the entry of the public or imposing additional shielding measures.)
- How to determine the reference level for managing radioactive wastes
 Stepwise approaches to decrease the individual dose should be taken by sharing the plan of environmental restoration, including the management of

radioactive wastes, with stakeholders including local residents under the existing exposure situation. The optimized reference level for radioactive waste management in the existing exposure situation must be selected from the dose band (1 to 20 mSv/y) with the relevant stakeholder involvement.

- Dose criteria for disposal of radioactive waste
When the temporary placement and storage are completed and the radioactive waste management enter the disposal stage, radioactive wastes must be disposed of in a planned manner so that the assessed individual dose becomes a target dose of 1 mSv/y or less, which corresponds to the individual dose under normal conditions, in line with the long-term goal of decreasing the individual dose due to environmental radiation to less than the order of 1 mSv/y.

3. Responses of and Recommendations from JHPS

We were shocked by the Fukushima Daiichi nuclear disaster and the resulting effects of radiation on the neighboring environment and residents. As an academic society associated with the study of radiation protection, JHPS should continue our involvement aiming to alleviate radiation-related problems. Our responses, such as Q&A activities and holding symposia, and recommendations are summarized in the following sections.

3.1 Responses of JHPS

JHPS will take the following measures to address the two issues described below from among the issues outlined in Section 2, because the two issues are considered to be comprehensive issues related to all exposure situations rather than specific issues for each exposure situation.

Issue 1: Strategies for reducing anxiety and doubts of the general public regarding radiation risk

- To reduce the anxiety and doubts of the general public regarding radiation risk and facilitate their understanding of the risk, we established a Q&A section on our website entitled “Questions on Radiation in Everyday Life Answered by Experts” for the general public on 25 March 2011, two weeks after the earthquake. The Radiation in Everyday Life Q&A Activities Committee was established by JHPS on 24 August 2011 to improve our attempts to address the concerns of the general public. We will continue Q&A activities during the

remainder of fiscal 2012 and publish a collection of questions received and answers given in a new booklet in fiscal 2012.

- A course of lectures and explanatory sessions towards the improvement of understanding of radiation effects and the technical support of daily radiation measurements will be introduced with the aim of human resource development, such as spokespersons for radiation protection who can provide easy-to-understand explanations, as part of a long-term strategy, while considering future cooperation with other organizations. The ability of JHPS members to explain the concept of radiation risk, cultivated through the above-mentioned Radiation in Everyday Life Q&A activities, will also be utilized in this project.
- Discussions shall be started in expert committees towards the reestablishment of simple systems for protecting the public from radiation exposure, which will require high accountability to the public, both under normal conditions and in emergencies (including emergency and existing exposure situations), reconsidering the scope of application of the Linear Non-Threshold (LNT) model and the concept of radiation risk.
- We will report the issues and recommendations identified through the activities of JHPS since the Fukushima Daiichi nuclear disaster at the 13th International Congress of the International Radiation Protection Association to be held on 13-18 May 2012 in Glasgow, Scotland, to globally disseminate the findings and lessons learned on radiation protection through the responses to the disaster.

Issue 2: Methods of measuring ambient dose rate, surface contamination density, and concentration of radioactive materials in foods

- JHPS will examine the standardization of radiation-related emergency methods, such as methods of measuring the ambient dose rate, surface contamination density, and the concentration of radioactive materials in foods, methods of evaluating the internal dose using whole-body counters and the bioassay method, and methods of evaluating the thyroid equivalent dose of radioactive iodine by simple measurement, in collaboration with expert committees and associated societies while verifying their technological validity by comparison with previous findings and conventional technologies.

3.2 Recommendations from JHPS

JHPS offers the following recommendations for nine issues related to emergency and

existing exposure situations, which require specific measures on the basis of discussions in governmental organizations or radiation protection experts, among the issues described in Section 2. In the elaboration of these recommendations, it was emphasized how to improve the current system of radiation protection by overlooking the various opinions on radiation protection in an emergency. We also considered the direction towards future goals of the radiation protection system into the recommendations by exploiting the strength of JHPS of having many experts in radiation protection among its members. The contents of the recommendations are described below along with their explanations.

Issue 3: Criteria for evacuation and stay in-house

Radiation protection experts should endeavor to:

- Comprehensively examine the emergency measures of evacuation and stay in-house, distribution of stable iodide, and regulation of the ingestion of foods and drinks to ensure consistency in their principles. (the same as Issues 4 and 5)

(Explanations)

In the current system, it is stated that stable iodide should be distributed at evacuation centers, meaning that the distribution of stable iodide is assumed after evacuation. However, the intervention levels of the thyroid equivalent dose for children were 100 mSv for the distribution of stable iodide and 500 mSv for evacuation, which contradicts the original assumption.

- Examine the adoption of both short-term moderate and long-term criteria in a stepwise manner by considering the balance between emergency measures that may be effective both temporarily and over a long term and the maintenance of the infrastructure required to ensure the secure everyday life of the general public. (the same as Issues 5)

(Explanations)

The current system assumes stay in-house for a maximum of a few days and evacuation to evacuation centers for approximately one week and does not assume a long-term evacuation such as that required in this disaster. This caused problems such as difficulty in maintaining the daily life of evacuees during stay in-house over 10 days, and there is a need to newly improve the principles underlying the deliberate evacuation zone.

- Quickly disclose the calculation results obtained from SPEEDI and the results of simulations on the diffusion of radioactive materials in the ocean together with their uncertainty in a clearly understandable form so that municipalities and evacuees can actively use the data.

(Explanations)

In this disaster, the infrastructure including electricity, water, and communications was seriously damaged by the earthquake and tsunami, and offsite centers were not operational. The instruction of evacuation based on the calculation results obtained from SPEEDI was not given to local residents and municipalities.

- Thoroughly discuss issues of evacuation with municipalities to determine suitable evacuation zones and the period of evacuation. This is necessary because the deliberate evacuation zones, which were proposed after the disaster for the first time, were areas in which evacuation was recommended on the basis of the annual individual dose rather than on the need for emergency evacuation.

(Explanations)

After the disaster, deliberate evacuation zones were designated on 22 April 2011 and local residents were instructed to evacuate by the end of May 2011 by the government without consultation with municipalities.

- Review emergency planning zones (EPZs), which are designated for emergency preparedness within a radius of 8-10 km from nuclear power plants and related anti-disaster measures through full discussions with municipalities by considering the post disaster spread of contamination to a large area as observed in this disaster. (the same as Issues 4)

(Explanations)

During the disaster, radioactive contamination was spread outside the area within 10 km of the nuclear power plants, the area within 20 km of the nuclear power plants designated as an evacuation zone, and some areas outside this zone designated as deliberate evacuation zones.

Issue 4: Administration of stable iodide

Radiation protection experts should endeavor to:

- Comprehensively examine the emergency measures of evacuation and stay in-house, distribution of stable iodide, and regulation of the ingestion of foods and drinks to ensure consistency in their principles. (the same as Issues 3 and 5)

(Explanations)

In the current system, it is stated that stable iodide should be distributed at evacuation centers, meaning that the distribution of stable iodide is assumed after evacuation. However, the intervention levels of the thyroid equivalent dose for children were 100 mSv for the distribution of stable iodide and 500 mSv for evacuation, which contradicts the original assumption.

- Review EPZs, which are designated for emergency preparedness within a radius of 8-10 km from nuclear power plants and related anti-disaster measures through full discussions with municipalities by considering the post disaster spread of contamination to a large area as observed in this disaster. (the same as Issues 3)
(Explanations)

During the disaster, radioactive contamination was spread outside the area within 10 km of the nuclear power plants, the area within 20 km of the nuclear power plants designated as an evacuation zone, and some areas outside this zone designated as deliberate evacuation zones.

Issue 5: Principles for regulation of ingestion of foods and drinks

Radiation protection experts should endeavor to:

- Comprehensively examine the emergency measures of evacuation and stay in-house, distribution of stable iodide, and regulation of the ingestion of foods and drinks to ensure consistency in their principles. (the same as Issues 3 and 4)
(Explanations)

In the current system, the restriction levels for the ingestion of foods and drinks were determined on the basis of a principle independent of the criteria for evacuation and stay in-house.

- Examine the adoption of both short-term moderate and long-term criteria in a stepwise manner by considering the balance between emergency measures that may be effective both temporarily and over a long term and the maintenance of the infrastructure required to ensure the secure everyday life of the general public. (the same as Issues 3)
(Explanations)

The current restriction values for the ingestion of foods and drinks were derived by considering radioactive decay on the assumption that there is only temporary radioactive contamination in foods, meaning that a long-term crisis such as that resulting from this disaster was not considered. Moreover, the absence of stepwise criteria led to confusion among the public as indicated by the empty shelves of bottled water sold out.

- Review various types of foods and their restriction values by considering statistical results on their annual amount of ingestion and by monitoring of radiation in foods and following an optimization principle in which social and economic factors are taken into account.
(Explanations)

In the provisional regulatory value applied to foods before the disaster, for

example, the restriction value of radioactive iodine in fish was not specified. To review the restriction values for representative foods, the actual states of foods for which statistics for the annual amount of ingestion are available should be taken into account as well as contaminated foods in which radioactive materials have been detected by radiation monitoring after the disaster. For the monitoring results on radioactive cesium and strontium in fish, for example, if the amount of radioactive strontium exceeds the assumed level used to derive the restriction value for radioactive cesium, the former restriction value should be reviewed. The individual dose criteria used as references to derive the restriction values of radioactive materials in foods should be determined after full discussion with stakeholders associated with the production, distribution, and consumption of foods.

Issue 6: Screening criteria for decontamination

Radiation protection experts should endeavor to:

- Verify the validity of the screening criteria for decontamination in an emergency in terms of their effectiveness for radiation protection in accordance with the principles of other emergency measures by considering problems that may arise in relation to the radiation measurement.

(Explanations)

The local nuclear emergency response headquarters increased the level of screening contaminated surfaces for decontamination to 100 kcpm (100,000 counts per minute) on 20 March 2011 following the advice from the Nuclear Safety Commission of Japan. It was then lowered to 13 kcpm on 16 September 2011 following the advice from the Commission. In many cases, Geiger-Müller (GM) survey meters have been used to measure the radioactive contamination of surfaces. GM counters underestimate the actual count by at least 20% in the measurement range with a count rate of as high as 100 kcpm because of the occurrence of dead time due to a long resolving time. The count rate must be converted into the radiation surface density to confirm the validity of the criteria from the viewpoint of radiation protection, which requires determination depending on the nuclide composition ratios for radioactive iodine and cesium.

Issue 7: Dose limit for emergency workers

Radiation protection experts should endeavor to:

- Examine new dose limits for emergency workers to take into account emergency

medical care considering the facts that the adopted dose limit for emergency workers is 250 mSv, which is lower than the internationally recommended value, and that the current dose limit for radiation workers under normal situation is determined on the basis of a lifetime individual dose of 1,000 mSv. Also the individual dose in an emergency should be controlled independently of a compliance of the dose limits for radiation workers under normal conditions (50 mSv per year and 100 mSv over five years) to control radiation exposure.

(Explanations)

In the second interim report on the incorporation of the 2007 Recommendations of the International Commission on Radiological Protection (ICRP) into domestic systems, the Basic Committee of the Radiation Council proposed to match the dose limits to internationally recommended values by considering increased opportunities engaging domestic radiation workers in the international activities, because the current restriction criteria in Japan (dose limit, 100 mSv) interfered with emergency medical care and other essential operations. After this disaster, the dose limit for emergency workers was set to 250 mSv, which was lower than the internationally recommended value of the 2007 Recommendations of ICRP (emergency medical care, no restriction; other emergency rescue operations, 1,000 or 500 mSv; other rescue operations, 100 mSv). When the individual dose received in emergency situation is applied to control the exposure for radiation workers under normal conditions (50 mSv per year and 100 mSv over five years), radiation workers who have been exposed to radiation exceeding 100 mSv during emergency work are prevented from engaging in radiation work for a given period. The emergency measures for individual dose exposed to radiation during emergency work should be considered in a comparison with lifetime individual dose of 1,000 mSv.

Issue 8: Post disaster investigation of thyroid equivalent dose of radioactive iodine

Radiation protection experts should endeavor to:

- Calculate the thyroid equivalent dose for the internal exposure to radioactive iodine on the basis of the results of simulating the atmospheric diffusion of radioactive plume using SPEEDI, food inspections, and surveys on residents' behavior. The calculation results along with their uncertainty should be disclosed.

(Explanations)

Radiation monitoring was not satisfactorily carried out for approximately one

week after the nuclear disaster owing to its aftermath. Therefore, the results of simulations of the atmospheric diffusion of radioactive plume using SPEEDI, food inspections and surveys on resident's behavior are essential for assessing the thyroid equivalent dose for radioactive iodine among residents after a disaster. However, these results are considered to have high uncertainty.

Issue 9: Provisional criteria for judging the safety of using school yards, forage, cropping soil, fertilizers, bathing areas, etc.

Radiation protection experts should endeavor to:

- Determine reference levels on the basis of the overall policy by considering the radiation sensitivity of children and the balance among reference levels and, if necessary, adopt stepwise reference levels. Also, obtain the active cooperation and understanding of stakeholders including residents to determine the reference levels, which should not be described as permissible levels because they do not indicate a threshold between safe and hazardous levels.

(Explanations)

As a temporary policy for judging the safety of using school yards and other outdoor facilities, the Ministry of Education, Culture, Sports, Science and Technology (MEXT) initially announced a provisional criterion of 3.8 $\mu\text{Sv/h}$, which was derived from the reference level of 20 mSv/y , and decided to aim to reduce the level of contamination to 1 mSv/y . The provisional criteria for forage fed to cows, cropping soil, and fertilizers announced by the Ministry of Agriculture, Forestry and Fisheries (MAFF) were derived on the basis of the provisional value for foods, which was determined with consideration of the individual dose for radioactive cesium (5 mSv/y). In addition, the provisional criterion for bathing areas announced by the Ministry of the Environment (MOE) was derived so that the individual dose due to external and internal exposure was within 10% of 1 mSv/y .

Issue 10: Systems for temporary entry into restricted zones

Radiation protection experts should endeavor to:

- Propose flexible systems that will allow people of different ages including the elderly to temporarily enter restricted zones for various purposes by considering the balance of radiation protection measures with other risks and inconvenience, rather than uniformly imposing the wearing of a protective suit and limiting the entry time.

(Explanations)

During the temporary home visits allowed in summer 2011, the room temperature reached 37 °C at some centers established as relay points through which residents returned to their homes. Therefore, the requirement of wearing Tyvek clothing was loosened to prevent heat stroke, i.e., people wearing long-sleeved clothes and long trousers were allowed to enter the restricted zones, although they were required to wear overshoes, gloves, a mask, and a hat. The maximum time spent at home was limited to 2 h, and the total time taken for the round trip from the relay point to their homes was limited to 5 h.

Issue 11: Management of radioactive wastes such as cesium-containing rubble, sludge, and decontaminated soil

Radiation protection experts should endeavor to:

- Determine the reference levels for radioactive wastes to be below those set for broad contamination in the overall plan of environmental restoration with the active cooperation and understanding of stakeholders including residents, and manage radioactive wastes so that the assessed individual dose becomes lower than the determined reference levels. Also radioactive wastes should be disposed of in a planned manner so that the assessed individual dose becomes a target dose of 1 mSv/y or lower.

(Explanations)

To practically and rationally carry out environmental restoration, it is necessary to establish the policy for managing radioactive wastes (e.g., temporary placement, treatment, storage, and disposal) under the existing exposure situation. The management of radioactive wastes is justified when the decrease in the individual dose due to decontamination is judged to be appropriate despite the potential exposure to radiation due to the management of the radioactive wastes necessary for decontamination. Justification and optimization should be fully discussed in the overall plan of the environmental restoration. When environmental restoration is carried out by lowering the reference level for broad contamination in a stepwise manner during the management of radioactive wastes, lowering the reference level for the management of radioactive wastes can be achieved by restricting the entry of the public or imposing additional shielding measures. Such stepwise approaches to decrease the individual dose should be taken by sharing the plan of environmental restoration including the management of radioactive

wastes with stakeholders including local residents. Also, radioactive wastes should be disposed of in a planned manner so that the assessed individual dose becomes a target dose of 1 mSv/y or lower, which corresponds to the individual dose under normal conditions, in line with the long-term goal of decreasing the individual dose due to environmental radiation to less than the order of 1 mSv/y.

4. Final Remarks

In this report, the responses of JHPS to the Fukushima Daiichi nuclear disaster such as Q&A activities and the holding of symposia are reviewed, and recommendations are summarized by considering the issues related to radiation protection. We will endeavor to further the study of health physics and radiation protection through future discussion and provide useful references for local residents and administrative organizations. In the near future, we will carefully analyze the actual state of the Fukushima area to propose recommendations in cooperation with overseas associated societies such as the Asian and Oceanic Association for Radiation Protection (AOARP), the International Radiation Protection Association (IRPA), and the Health Physics Society in the US.