VII. Situation of radiation exposure

1. Situation of radiation exposure concerning radiation workers and other related workers

(1) Dose limit for radiation workers

1) Provision of dose limit prior to the accident

Regarding the dose limit, etc., the Radiation Review Council established in the Ministry of Education, Culture, Sports, Science and Technology has studied recommendations made by the International Committee on Radiation Protection (ICRP) and its possible application in Japan, on which it has recommended its views. Under the relevant laws, based on the ICRP 1990 Recommendations (Pub. 60), the dose limit for radiation workers is set at an effective dose of 100 mSv over 5 years and 50 mSv per year. In addition to this limit, the dose limit for women is regulated at 5 mSv over 3 months. (Details about the dose limit can be found in the supplementary materials.)

The dose limit for radiation workers engaged in emergency work is regulated by the relevant laws at 100 mSv for an effective dose, at an equivalent dose of 300 mSv for optic lenses, and at an equivalent dose of 1 Sv to the skin. (See the supplementary materials for detailed regulations.)

2) Revision of dose limit in emergencies based on the accident

In consideration of the situation of this accident, the dose limit for radiation workers in emergencies has been revised due to the need for work in preventing further worsening of the nuclear disaster. In the areas where emergency measures to combat the nuclear emergency were implemented from the day when the Declaration of a Nuclear Emergency was issued according to the Act on Special Measures Concerning Nuclear Emergency Preparedness until the day when the Declaration of Cancellation is issued, the effective dose of 100mSv was raised to 250mSv in the event of an unavoidable emergency, which took effect on March 14. The ICRP 1990 Recommendations (Pub. 60) stipulating a dose of 500 mSv for persons engaged in emergency rescue operations which is aimed at avoiding definitive impact on such persons and others was taken into consideration when determining the basis for the 250 mSv dose limit.

Based on the Act on Technical Standards for the Prevention of Radiation Disasters, in revising the dose limit, the President of the National Personnel Authority, the Minister of the Ministry of Health, Labour and Welfare, and the Minister of the Ministry of Economy, Trade and Industry consulted the Radiation Review Council established in the Ministry of Education, Culture, Sports, Science and Technology on the revision of the dose limit to which the Radiation Review Council's recommended opinion was that such a revision was appropriate.

Furthermore, the Ministry of Health, Labour and Welfare has issued documents for administrative guidance on radiation doses for workers previously engaged in emergency work and have hence been engaged in other work than that of emergency work which nevertheless exposes them to radiation. (See the guidance documents in the supplementary materials for more details.)

(2) Radiation control measures in nuclear power stations

Tokyo Electric Power Co. Inc. (TEPCO) had been performing radiation control measures for the purpose of minimizing radiation doses received by workers by assessing the radiation levels in the "radiation controlled areas" such as the reactor buildings and turbine buildings, and by confirming individual radiation operational plans for each operation. In addition, only personnel confirmed by TEPCO as being designated and registered as radiation workers and granted proper permits were able to work in the controlled area.

Normally, at Fukushima Dai-ichi Nuclear Power Station, a system was established and employed so that each worker was lent and wore an Alarm Pocket Dosimeter (APD) to measure radiation dose at work so that each worker was identified on entering a control area, and the dose of the APD was read after completion of the work which was automatically recorded, so that calculations for a worker's individual daily dose, or by company, or by total individual doses per month, per year, etc. could be obtained.

Furthermore, when entering and leaving a controlled area (in each building), dose readings were taken in the building next to the entrance of each building, as well as when putting on protection equipment and an APD just before entering a controlled area.

1) Radiation control measures by TEPCO after the accident

A. System of radiation control measures

a) System of radiation control measures at Fukushima Dai-ichi Nuclear Power Station

In this accident, tsunamis reached buildings facing the sea coast which provide access to the controlled areas as described in (2), depriving the function of the radiation control system, and rendering many of the APDs and dose reading devices unusable as they became submerged in seawater.

Also, due to the increase of radiation and contamination levels in the power station site, it was decided that workers centralize and conduct all operations in TEPCO's response headquarters established in the quake-proof building, and the lending of APDs and recording of doses were performed in the quake-proof building.

From March 11, shortly after the earthquake, dose management for workers had to be performed manually by recording the names of individuals and their daily dose values on paper to accumulate data. Moreover, such daily individual doses which were manually recorded had to be manually inputted into PCs (using Excel sheets) and saved as a database.

Because many APDs became unusable for reasons described above, not every worker was able to wear an APD and TEPCO has thus been managing radiation doses of all the personnel by making leaders of operational groups wear APDs on behalf of the entire group. As controlling workers' radiation exposure is very important to ensure safety on the site, the Nuclear and Industry Safety Agency (NISA) gave oral instructions to TEPCO to make every effort to manage its workers' radiation exposure and dose. After receiving these instructions, TEPCO had procured the necessary dosimeters by April 1 so that all the workers conducting operations carry portable dosimeters.

Furthermore, the evaluation of external exposure during work in the quake-proof building is based on the length of period of stay because workers couldn't wear APDs when inside the building. Moreover, even though the concentration of radioactive materials within the air of the quake-proof building exceeded the limit of concentration in the air shortly after the earthquake, appropriate protection equipment such as protection masks were not adorned resulting in workers staying in the building inhaling radioactive materials.

On April 14, about one month after the accident occurred, radiation control measures close to that of the previous dose management (the system in which individual names and dose readings are automatically recorded) became available since the system of radiation control measures was nearly completely restored.

b) System of radiation control measures in J Village

Shortly after the accident from March 17, J Village, a soccer training facility located at a point about 20 km south of Fukushima Dai-ichi Nuclear Power Station, was utilized as a place for preparing workers for entry into Fukushima Dai-ichi Nuclear Power Station, where they put on their protection equipment, and performed decontamination tests when leaving, etc.

For radiation workers who don't go through the quake-proof building but nevertheless work at Fukushima Dai-ichi Nuclear Power Station, a system was established for such workers to attach ADPs (there are several kinds of dosimeters due to hasty procurement and assistance received from plural organizations) at J Village before going to work at the site in Fukushima Dai-ichi Nuclear Power Station, and to record doses for the day when returning dosimeters upon leaving. For this reason, dose readings in J Village have been continued to be manually calculated since the beginning of the accident. TEPCO is planning to introduce an individual recognition system using bar codes in J Village from early June.

B. Wearing of radiation protection equipment, work management, etc.

Due to the high concentration of radioactive materials over the entire site of Fukushima Dai-ichi Nuclear Power Station, TEPCO requires workers to wear Tyvek and other protection clothes, gloves, and protection masks. It also requires the wearing of appropriate protection clothes (anoraks, etc.), rubber gloves, and other protective clothes according to weather conditions and contamination levels of the work sites.

As for the quake-proof building, it was difficult to prevent the inflow of radioactive materials because the entrance door was not a airtight structure, and the door was slightly distorted to leave a gap by the hydrogen explosions of Units 1 and 3, and as there were no particular protection equipment installed in the building against such an eventuality, the inhalation of radioactive materials by workers occurred. Since countermeasures to

decrease the concentration of radioactive materials in the air of the building such as connecting a unit house installed with an ambient air filtration system with charcoal filters, to the entrance of the quake-proof building were implemented, the concentration of radioactive materials has been kept at low levels to the extent that it has been unnecessary to implement protection measures.

In addition, a prior survey was conducted and workers were informed of developing a work plan in high radiation areas, etc.

(3) Status of radiation exposure

The status of exposure doses for the workers engaged in emergency work at Fukushima Dai-ichi Nuclear Power Station as of May 23 is that there were approximately 7,800 people who entered the site and were exposed to approximately 7.7 mSv on average. There were thirty people were recorded as receiving doses over 100 mSv. The compiled results of exposure doses are as shown in the supplementary materials.

Cases of violations of laws occurred in this accident, and the outlines are as follows. On March 24, it was confirmed that two out of three workers involved in work for laying electric cables on the 1st and basement floors of the turbine building of Unit No. 3 were wearing low-cut shoes and attached radioactive material to the skin of their feet when stepping into puddles of radioactive water. Although TEPCO decontaminated their exposed skin, it was decided that there was a possibility of beta ray burns and the two workers were transported to Fukushima Medical University Hospital. After examination on the next day of March 25, all three workers including the two that were exposed to the puddle were further transported to an independent administrative institution, the National Institute of Radiological Sciences (NIRS). Immediately after their arrival NIRS performed checkups, etc. after which the workers were also re-examined on April 11 for follow-ups and it has been confirmed that these three workers are not were suffering any health issues. From the results of the evaluations of the exposure doses of their skin, it is estimated that they were exposed to less than 2 to 3 Sv.

Moreover, on April 27, in the course of confirming radiation exposures over a period of three months, TEPCO confirmed that a female employee had been exposed to more than 5 mSv over a period of 3 months, which is above the legally stipulated dose limit (see the supplementary materials for more details.). As some of the people engaged in work were not designated as radiation workers, their exposure dose must not exceed the 1 mSv dose limit set for the public.

For this reason, NISA gave a strict warning to TEPCO, and instructed it to investigate the cause of the exposure, to develop measures to prevent any reoccurrence, to verify the system of radiation control measures in Fukushima Dai-ichi Nuclear Power Station, and to develop appropriate counter-measures based on them. Following the instruction on May 2, TEPCO submitted a report. NISA received the report, and with a view to implement appropriate radiation control measures for radiation workers to ensure their occupational safety and health management, it responded by issuing an instruction to TEPCO on May 25 ordering it to strive to further improve its measures so that it will perform appropriate radiation control measures for radiation workers, and observe safety regulations at Fukushima- Dai-ichi Nuclear Power Station and Fukushima Dai-ni Nuclear Power Station.(See the supplementary materials for a detailed background.)

Also, the government has issued instructions to TEPCO regarding (i) exposure dose management for workers including internal exposure, thorough implementation of temporary health examinations, etc. as decided in the "Policy for Immediate Actions for the Assistance of Nuclear Sufferers" by the Nuclear Emergency Response Headquarters on May 17, and has made it a rule to require it to periodically report its implementation status. In addition, (ii) certain emergency works are required to be reported in advance to the Labor Standards Inspection Office to have their exposure control for workers, etc. confirmed.

Moreover, the policy requires (iii) creating a database capable of tracking all the workers engaged in emergency works even after they have their current jobs if their exposure doses, etc. over the long-term, and conducting long-term health management. On May 20 the Ministry of Health, Labour and Welfare established the "Promotion office for the measures for the health management and other things of workers of Fukushima Dai-ichi Nuclear Power Station" to promote the measures from (i) to (iii).

Others

Besides radiation control measures, as it is important to establish and maintain the working environment of workers, TEPCO is working to improve the occupational safety, health management and the living environment for workers at Fukushima Dai-ichi Nuclear Power Station and Fukushima Dai-ni Nuclear Power Station. (See supplementary materials.)

(4) Radiation control measures for employees of local and national government engaged in restoration works, etc.

1) Radiation control measures by the Self-Defense Forces of Japan

Self-Defense Force members working within 30km of Fukushima Dai-ichi Nuclear Power Station estimate their expected exposure dose in advance from the latest monitoring results in the planned activity area or neighborhood and planned time of the activity, and take necessary appropriate measures such as wearing simple protection clothes (Tyvek) and so on.

The SPF members also monitor their exposure using a dose rate meter as necessary and confirm their cumulative dose during their activity.

The upper limit of the cumulative exposure dose for an individual member is 50 mSv (the limit for exposure of radiation workers, but for female members, it is 5 mSv over a 3-month period), and if there is a possibility that exposure doses will exceed 30 mSv (or 3 mSv for female members) during the activity members temporally suspend their activity and return considering a turn back dose (a dose capable of returning within the limit of cumulative exposure dose).

2) Status of radiation exposure

While exposure doses are measured for members of the Self-Defense Forces finishing activities within 30km from Fukushima Dai-ichi Nuclear Power Station, there were no incidences of exposure exceeding 50 mSv as of May 28.

2. Response to radiation exposure of residents in the vicinity and the overall situation

(1) Distribution of stable iodine, etc.

1) Situation of acquiring stable iodine

Fukushima Prefecture distributed necessary iodine (pills: about 1.51 million pills (for about 0.75 million people), powder: about 6,100 g (for about 0.12 to 0.18 million people)) to cities, towns and villages with administrative districts within 50 km of the Fukushima Dai-ichi Nuclear Power Station.

This amount exceeds the need for 0.69 million people, or the population equivalent (of those under 40 years old) to the cities, towns and villages within the 50 km radius of Fukushima Dai-ichi Nuclear Power Station.

2) Policy for distribution to evacuated residents and their administration of stable iodine

The Chief of Nuclear Emergency Response Headquarters will, on receiving advice from the Nuclear Safety Commission, give instructions to the related cities, towns and villages on the dose of stable iodine by evacuated residents, although the designated cities, towns and villages will distribute stable iodine to residents for administration in the presence of medical experts. This is due to concerns for side effects associated with the dose administration such as allergies.

Stable iodine is stored in the offices of cities, towns and villages and it is necessary to decide on the procedure to precisely distribute the stable iodine to residents in the event of a real evacuation. In this case, because the preliminary distribution of stable iodine to residents is not appropriate, the cities, towns and villages are to adopt necessary measures so that they can securely distribute iodine to their residents according to various types of evacuation as described below. It is also required that the local government do not unnecessarily stir anxiety among residents while keeping them fully informed.

(Evacuation patterns)

i. Residents using evacuation buses:
   Distributed and administrated at the evacuation site or in the buses
ii. Hospitalized residents in hospitals, etc.:
   Distributed and administered in a hospital, etc. or a bus
iii. Residents evacuating on their own:
   Distributed and administered at a doctor's discretion (age and evacuation time, etc. are considered) in an evacuation site or at a screening point

3) Situation responses to directions on the administrate of stable iodine

On March 12, instructions were given by the Chief of the Nuclear Emergency Response Local Headquarters to the Governor of Fukushima Prefecture and 43 surrounding towns to evacuate residents from within 20 km. In the process of evacuation, the possibility of radiation dose increase among the people being evacuated became undeniable due to the hydrogen explosion at Unit No. 3 (March 14), etc. For this reason, on March 16 the Chief of the Nuclear Emergency Response Local Headquarters instructed the Governor of Fukushima Prefecture and others to have residents take stable iodine when evacuating from within the 20 km radius of the nuclear power plant taking into account the technical

advice from the Nuclear Safety Commission recommending that stable iodine be administered to residents remaining in the area (within 20 km) upon evacuation. Although the completion of evacuation was acknowledged, this instruction was given as cautionary measure assuming there might be cases in which residents who couldn't evacuate were left behind. But as a matter of fact no residents took stable iodine based on this instruction because the evacuation had already been completed at the time the instruction was issued. Also, on March 21, the Chief instructed the Governor on precautions necessary in administering stable iodine.

(2) Standards and methods for screening and decontamination

On March 13, Fukushima Prefecture determined the screening level in the case of decontaminating the whole body at 100,000 cpm and that partial decontamination by wiping would be performed in case of detection numerical values greater than 13,000 cpm but less than 100,000 cpm, based on the opinions of experts in radiation medicine dispatched from the Ministry of Education, Culture, Sports, Science and Technology, and doctors and others from the National Institute of Radiological Sciences, and the handling by Fukushima Medical University.

Meanwhile, on March 19, the Nuclear Safety Commission determined the screening level for decontamination at 100,000 cpm. This revised to the screening level to 1 μSv/h (dose rate at a distance of 10 cm), which is a standard of decontamination for contamination on the surface of the body for general residents as stipulated by the International Atomic Energy Agency (IAEA) in the *Manual for First Responders to a Radiological Emergency* (VII 2-1).

Note: Measured values are those measured using Type TGS-136 GM Survey Meter (5cm bore).

(3) Status of radiation exposure for residents in the vicinity

With regard to the contamination of residents, Fukushima Prefecture has been implementing screening surveys for residents in the prefecture including people evacuated from within the 20 km radius of the power plant in cooperation with the Nuclear Emergency Response Local Headquarters. Most of the 191,988 people checked as of May 23 were under the 100,000 cpm limit. Decontamination was performed for 102 people exceeding 100,000 cpm but their contamination levels fell to levels of no concern after such decontamination.

Also, from March 26 through March 30 the Nuclear Emergency Response Local Headquarters implemented a survey on thyroid exposure for infants in Iwaki City, Kawamata Town and Iidate Village in cooperation with Fukushima Prefecture in order to understand more precisely the current exposure dose, particularly the health effects to infants who are highly-sensitive. In its implementation, exposure of infants was measured in areas where residents were instructed to stay in-house or in areas whose equivalent dose in thyroid glands was rated as high by the estimation derived by SPEEDI (announced on March 23), and technical advice was received from the Nuclear Safety Commission on the measuring method. From the results among the 1,080 children from 0 to 15 years old that were surveyed for thyroid exposure, there were no children exceeding the screening level of 0.2 μSv/h (equivalent to 100 mSv as thyroid gland equivalent dose for a 1-year old baby).

3. Evaluation of the status of radiation exposure

The purpose of radiation protection is to prevent the occurrence of a deterministic effect on an individual, and unfailingly take all reasonable measures to limit the occurrence of stochastic effects.

(1) Evaluation of the status of radiation exposure by operators, local and national governments

Operators are responsible for the appropriate performance of radiation control measures for radiation workers based on a predetermined plan. In this accident, tsunamis rendered APDs unusable and the functionality of system of radiation control measures was lost. Moreover, the radiation and contamination levels not only within the nuclear power station facilities but also on the site increased along with the progress of the accident.

Performing precise control of dosages is the basis of performing appropriate radiation control measures for radiation workers. However, because of the insufficient number of dosimeters for the above reasons, such actions as only equipping work unit leaders dealing with work that involved relatively low environmental doses were taken. TEPCO should have acted promptly to make it possible to equip every person with a dosimeter.

Also, because the evaluations for individual doses rely upon manual recording, and evaluations are based on behavior record and because measuring the doses of each individual was impossible, it took considerable time to establish a system for radiation control measures as the same level as before.

Moreover, the delay in management for preventing radioactive materials from entering the quake-proof buildings and that of measuring of the concentration of radioactive materials in the air within the building resulted in increasing the risk of internal exposure.

At Fukushima Dai-ichi Nuclear Power Station, whole body counters (WBC) became unusable due to the increase of the background level. Therefore, one WBC mounted on a vehicle has been borrowed and used for measurement while WBC measurement is also being performed at another power station, upon which internal exposure is evaluated, but there are too many people to be measured. Thus, a sufficient measurement system has not been established despite parallel efforts to measure WBC at different plants and assess internal exposure. After July, TEPCO will transfer the WBC at Fukushima Dai-ichi Nuclear Power Station and Fukushima Dai-ni Nuclear Power Station to J Village, and plans to coordinate a measurement system at J Village by purchasing a new WBC and others.

At Fukushima Dai-ichi Nuclear Power Station, along with the increase of the radiation dose, the situation required controlling the non-controlled area in addition to the controlled areas. Against this background, workers who were not designated as radiation workers performed work in places that should be controlled at the same level as controlled area and resulted in the exposure exceeding 1 mSv per year, or the yearly dose limit for the public. This is because, in the beginning, individual dose controls were not changed in line with the enlargement of target area for radiation control measures.

(2) Evaluation of the situation of radiation exposure of residents in the vicinity

Regarding the evaluation of radiation doses received by residents, Fukushima Prefecture will hereafter lead the conduction of surveys in target areas in cooperation with related government offices and the National Institute of Radiological Sciences and others and will estimate and evaluate the radiation dose received by each resident by comparing it to the results of the situation for the release of radioactive materials separately surveyed, etc.

The people to be surveyed are estimated to be about 2 million residents of Fukushima Prefecture. Since the evacuated people have been dispersed by the earthquake and accident, the survey plans to start with people who have a high probability to be surveyed such as current residents, and in principle, evacuated people whose residence after their evacuation is easily obtained.

(3) Evaluation of emergency medical system for exposures

As a precaution, there were some cases, in which some people engaged in emergency work for this accident at Fukushima Dai-ichi Nuclear Power Station, etc. were transported to an independent administrative institution, the National Institute of Radiological Sciences, which is a tertiary emergency medical institution for exposure but there were no case serious enough to be treated as tertiary exposure.

Because this nuclear disaster caused by the Great East Japan Earthquake was a disaster which required responses beyond the assumptions of conventional nuclear disaster countermeasures, and required responses to earthquakes and tsunamis at the same time, the local governments first strengthened their systems by coordinating with medical institutions such as university hospitals nationwide on such issues as how to cope with the high numbers of injured or sick patients.

As such, Fukushima Medical University, an institution for secondary exposure, and other medical institutions in the prefecture were obliged to work under complex emergency conditions such as simultaneously performing disaster medical measures including dispatching on-site disaster medical care. Therefore there is a possibility that these institutions could not sufficiently respond when emergency response against radiological exposure was really needed compared to the anticipated response in the field by the regional disaster prevention plans, which were planned in advance.

However, as the Nuclear Emergency Response Local Headquarters led the immediate restructuring of the medical system for exposure and strengthened the response system in cooperation with related institutions such as university hospitals including tertiary medical institutions for exposure, the medical system for exposure is considered to be performing its necessary functions.