# Responses and Actions Taken by the Ministry of Health, Labour and Welfare of Japan on Radiation Protection at Works Relating to the Accident at TEPCO's Fukushima Daiichi Nuclear Power Plant

3rd Edition (Fiscal Year of 2015)

MHLW

Ministry of Health, Labour and Welfare

31 January 2016
Office for Radiation Protection of Workers
Ministry of Health, Labour and Welfare
1-2-2 Kasumigaseki Chiyoda-ku Tokyo 100-8916, Japan

URL:http://www.mhlw.go.jp/english/topics/2011eq/workers/index.html

# Contents

# List of Figure and Tables

# Introduction

In response to the accident of the Fukushima Daiichi Nuclear Power Plant (NPP) that resulted from the Great East Japan Earthquake on 11 March 2011, the Tokyo Electric Power Company (TEPCO) undertook emergency works to which an emergency dose limit applied. The dose limit for the emergency works, which was originally 100 mSv, was temporarily increased to 250 mSv from 14 March to 16 December 2011, the day on which the Japanese Government declared that the affected plant had been stabilized as explained in Section 1.1.

During the emergency works, the Japanese Government observed various problems with the radiological protection of emergency workers. To regulate the implementation of radiological protection measures, the Ministry of Health, Labour and Welfare (MHLW) issued a series of compulsory directives and administrative guidances to TEPCO.

Based on the experiences and lessons learned, the MHLW recognized that to properly manage radiological exposure should a similar accident occur at another NPP, sufficient measures and systematic preparation for radiological management must be ensured, including the use of an exposure control system; the implementation of an exposure data control system, and worker training and work planning; and the maintenance of stockpiles of dosimeters, personal protective equipment and protective garments.

This document outlines the problems that occurred during the emergency response to the accident and the measures taken by the MHLW and TEPCO in Section 1.2. The recommendations to avoid the recurrence of similar problems are provided in Section 1.5.

Furthermore, the accident at the Fukushima Daiichi NPP released large amounts of radioactive materials. For rehabilitation of the contaminated areas, the Japanese Government decided to carry out decontamination works (e.g., clean-up of buildings and remediation of soils and vegetation) and to manage the wastes resulting from decontamination and unmarketable contaminated goods.

For the radiological protection of the decontamination workers, the Japanese Government needed to establish new regulations because the existing regulations did not fit the "current exposure situations" in which radioactive sources have been scattered in wide areas from the plant. The new regulations aim to set the appropriate protection standards in accordance with the risk of the ambient dose rates, radioactivity concentrations, and types of radionuclides resulting from the NPP accident, which are equivalent to or more than the typical protection standards required in planned situations. This document explains the key issues of the new regulation and guidelines in Section 2, and the established regulations and guidelines are outlined in Section 3.

The third edition is updated with new information in Sections 1.2.4, 1.3, 1.4, 2.3, and 3.1, reflecting the latest numeric data and reports. The exposure dose distribution tables in Section 1.6 were thoroughly updated using the latest information of December 2015. Section 3.8 was newly created for explaining the guidelines on the safety and health management at the Fukushima Daiichi NPP.

Regarding good practices in radiation dose control and exposure dose reduction by TEPCO and several primary contractors at the affected plant, Section 5 was created in the second edition of this document. In this edition, newly obtained information is introduced in Section 5. The information was obtained from the workshop held on 10 December 2015.

# 1. Emergency Exposure Dose Control in the TEPCO Fukushima Daiichi NPP

Emergency works that began in response to the accident of the TEPCO Fukushima Daiichi NPP associated with the Great East Japan Earthquake of 11 March 2011 were undertaken under high radiation levels and extreme conditions for which normal dose control facilities were ill-equipped to deal with, partially due to the station blackout after the tsunami. There were difficulties in recording the cumulative dose, and delays in monitoring of internal exposure due to insufficient exposure control personnel and equipment. Also, in the summer, workers had to work under the blazing sun, while wearing protective clothing, and some suffered heat stroke. From the problems that occurred, MHLW issued a series of compulsory directions and administrative guidance to TEPCO and the primary contractors.

This section explains the lessons learned in exposure dose control at the TEPCO Fukushima Daiichi NPP, and shows necessary preparation for responding to future nuclear accidents that may necessitate emergency works. This section explains:

(a) Problems that occurred after the accident started and the responses by MHLW and TEPCO in Section 1.2;
(b) The status of the long term health care of emergency workers in Section 1.3; and
(c) Future actions based on experiences in Section 1.4.

## 1.1 Temporary raising of emergency dose limits

### 1.1.1 The increase of emergency dose limits by MHLW Ordinance 2011-23 (Exemption Ordinance)

At the time the accident started at the TEPCO Fukushima Daiichi NPP, emergency dose limits of 100mSv were in effect for the workers engaged in emergency works based on the Ordinance on the Prevention of Ionizing Radiation Hazards (hereinafter called Ionizing Radiation Ordinance) under the Industrial Safety and Health Act (Act No.57 -1972) for the prevention of health impairment.

After its start, radiation protection of workers was also implemented in accordance with the Ionizing Radiation Ordinance. However, consideration for the security of the general public and the prevention of expansion of the nuclear disaster, led to the decision to raise the emergency dose limit in the affected plant to 250 mSv from 100 mSv. This was defined in the Exemption Ordinance of Ionizing Radiation Corresponding to the Situation Resulting from the 2011 Tohoku-Pacific Ocean Earthquake (herein after the "Exemption Ordinance", i.e. MHLW Ordinance 2011-23). This Exemption Ordinance was issued on 14 March 2011, and became effective on 15 March 2011.

Concerning the increase of the emergency dose limits, the points below were taken into consideration:

- According to the International Commission of Radiological Protection (ICRP) recommendation, the emergency dose limit for the "emergency exposure situations in the serious accident" should not exceed approximately 500 mSv, with the exception in the case of life saving actions.
- It is recognized that an exposure dose under 250 mSv may not cause acute radiation symptoms.
- The Radiation Council under the Ministry of Education, Culture, Sports, Science and Technology (MEXT) agreed that the dose limit was appropriate.

### 1.1.2 Partial abolishment of increased emergency dose limits for new workers

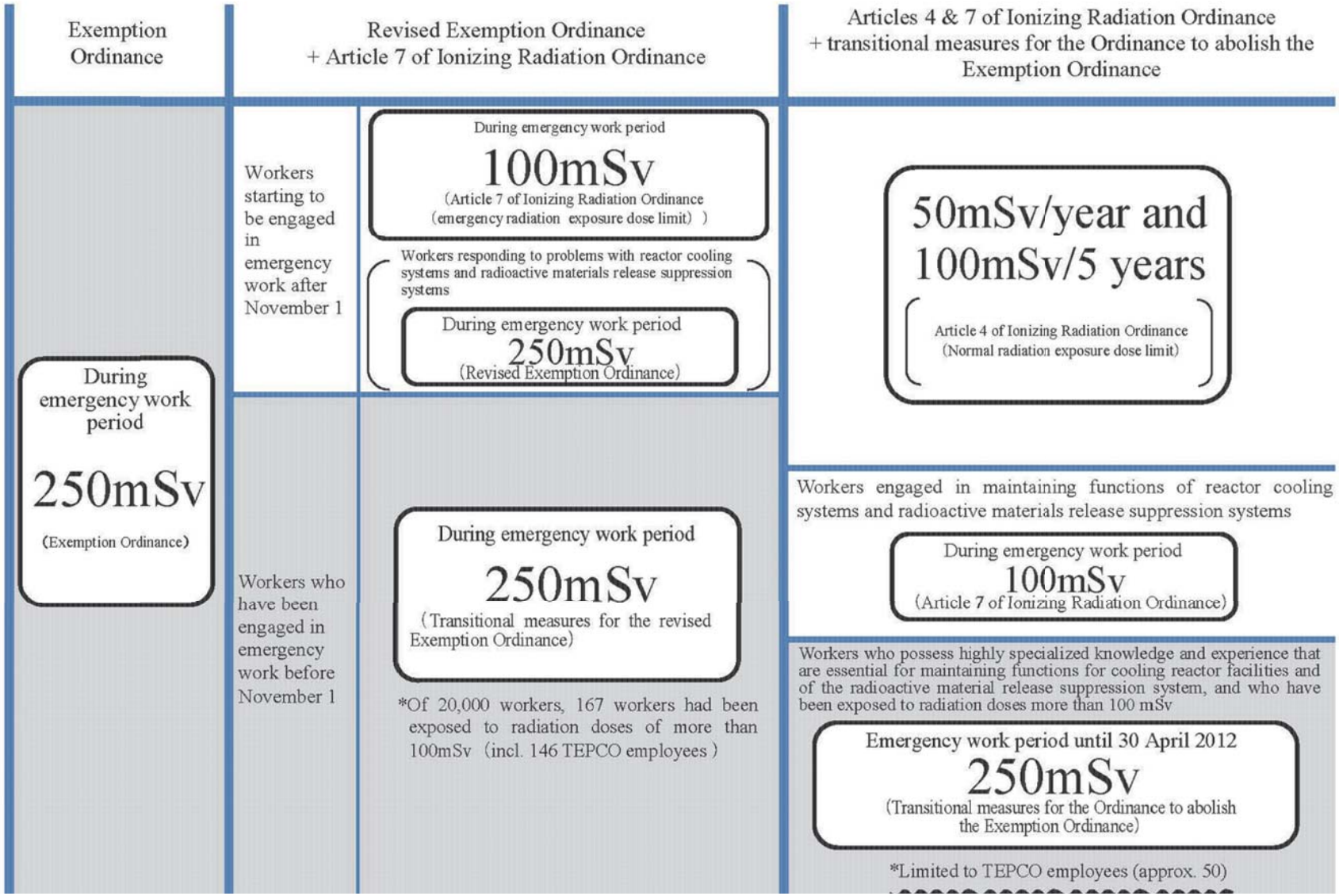
On 1 November 2011, the emergency dose limit for new workers was decreased to the original (100 mSv) with some exceptions designated by the Minister of MHLW. Exempted works were listed as the emergency works related to responses for the prevention of the loss of cooling systems of nuclear reactors and for the loss of the function of the facilities to suppress the release of radioactive materials to offsite areas when engaged in the works in the reactor buildings and the immediate vicinity for a possible dose rate exceeding 0.1 mSv/h. For the exemptions, the dose limit for emergency works was set as 250 mSv.

### 1.1.3 The abolishment of the Exemption Ordinance

The exemption ordinance was abolished when Step 2 of the "Road Map towards the Restoration from TEPCO Fukushima Daiichi NPP Accident", which aimed to achieve long-term stability of the reactors was completed on 16 December 2011.

The dose limit exemption of 250 mSv was applied until 30 April 2012, for those specialists who are highly trained and experienced in operating the reactor cooling systems and in maintaining the facilities for suppressing the emission of radioactive materials (approximately 50 TEPCO employees). For the 20,000 persons who had been engaged in the emergency works, 167 persons had exceeded the100 mSv emergency dose (including 146 TEPCO employees).

# Figure 1 Application of the Radiation Exposure Dose Limit after the Completion of Step 2



## 1.2 Problems that occurred after the accident and the responses by MHLW and TEPCO

The problems that occurred for twenty cases are classified into the five categories shown below.

**1) Personal identification and exposure dose control (6 cases)**
(1) Insufficient exposure dose control system in the exposure dose control department
(2) Insufficient numbers of personal dosimeters
(3) Deficiencies in dosimeter-lending management
(4) Delay of radiation exposure doses notification to workers
(5) Delay of internal exposure monitoring
(6) Unexpected occurrence of workers who could not be contacted

**2) Respiratory protective equipment and protective clothing (4cases)**
(1) Exceeding emergency exposure dose limit
(2) Exceeding exposure dose limit for women
(3) Improper use of respiratory protective equipment
(4) Improper protective garments

**3) Training for new workers (1 case)**
(1) Insufficient training hours for workers

**4) Health and medical care system (5 cases)**
(1) Establishment of the medical care system at the affected plant
(2) Prevention of heat stroke
(3) Instruction to conduct special medical examinations
(4) Establishing patient transport systems from the affected plant
(5) Long-term health care program

**5) Preliminary review of work plans (4 cases)**
(1) Insufficient management systems for developing work plans
(2) Deficiencies of work plans
(3) Insufficient knowledge about contract conditions
(4) Improvement of the lodging and meals

The responses and actions to these twenty cases taken by MHLW and TEPCO are described in the following sections.

### 1.2.1 Personal identification and exposure dose control

**(1) Insufficient exposure dose control system in the exposure dose control department**

As the exposure control systems that were normally used became inoperable due to the tsunami, a significant amount of manual work was required, such as making dosimeter-lending records, inputting dose data and name-based collection and calculation of individual exposure doses. Although the work was eventually taken over by the corporate offices, its progress was delayed due to the many manual records that had to be input. These factors resulted in a substantial delay in the task to accumulate individual exposure dose.

In response to the above, the following actions were taken.

[Actions taken by MHLW]
- MHLW provided guidance for the consolidation of the exposure administration in the corporate offices (23 May).
- MHLW directed the primary contractors with a written notice to submit monthly reports on the status of notifying workers of their exposure doses as well as to consolidate the exposure administration (22 July).
- MHLW directed organization of a dedicated team to survey workers with whom contact had been lost (10 August).

[Actions taken by TEPCO]
- TEPCO increased the number of staff members in the radiation control department of the corporate offices, inputted data regarding the information in the dosimeter lending record managed at the NPP, and collected and calculated the dose data using spreadsheet software, in accordance with directions. TEPCO was able to submit a report on radiation exposure doses at the end of the subsequent month to MHLW, starting with the data from September.
- The primary contractors established a systematic control organization for exposure control in their corporate offices and reported to MHLW on the status of the exposure dose control on a monthly basis.

**(2) Insufficient numbers of personal dosimeters**

Many personal alarm dosimeters (PADs) became inoperable after the tsunami. Due to the shortage of PADs, only one PAD was given per work group during the period of 15–30 March. TEPCO said it had selected the groups working in areas where exposure was expected to be almost constant. However, using the dose of representative workers could have overlooked some extreme exposures of individual workers because highly radioactive contaminated waste was widely dispersed during this period.

In response to the above, the following actions were taken.

[Actions taken by MHLW]
- MHLW instructed TEPCO to provide each worker with a PAD (31 March).

[Actions taken by TEPCO]
- TEPCO obtained PADs from other NPPs and fitted every worker with a PAD (1 April).
- TEPCO obtained 4,100 PADs in total for management of the affected plant and 2,200 PADs were made available at J-Village for lending use (as of 17 November)

**(3) Deficiencies in dosimeter-lending management**

As the normal operating procedures to access controlled areas could not be followed due to the tsunami, TEPCO implemented paper-based dosimeter-lending management, and workers were required to write down their names, affiliations, and radiation exposure doses in the paper-based lending records. However, deficiencies and incorrect information in the records made it difficult to identify individuals and compile name-based consolidated records of doses.

In response to the above, the following actions were taken.

[Actions taken by MHLW]
- MHLW demanded that TEPCO obtain basic information on workers, issue access permits with IDs, and conduct management of entry/exit (23 May).
- MHLW instructed TEPCO to attach a photo to the access permit (7 July).

[Actions taken by TEPCO]

- TEPCO started issuing a "worker identification card" with an ID number at the seismically isolated building (14 April), and at J-Village (8 June); it started writing ID numbers in the dosimeter-lending records.
- TEPCO started identifying individuals based on official documents at J-Village and issuing an access permit with photo ID (29 July).
- TEPCO started using workers' identification cards in combination with the access permit (8 August).

In addition to the above, MHLW issued the instructions stated below on 29 October 2012, as a solution to the issue that the lower exposure dose was falsely recorded by covering the dosimeter with a lead plate:

(a) Check the management system of the exposure dose data.
(b) Use the protective garments (Tyvek coveralls) with a transparent chest pocket.
(c) Increase the accuracy of dose monitoring by limiting the wearing of glass badges solely during working hours.
(d) Record the higher reading of a PAD or a glass badge.
(e) Set the alarm as close as to the reasonable estimated maximum doses as possible.
(f) Notify workers of their radiation exposure doses by providing written documentation.
(g) Exchange workers with a high cumulative radiation exposure in a job to workers with a low cumulative radiation exposure, and ensure close communication between the employers and the workers who had received radiation exposure close to the dose limit

**(4) Delay of radiation exposure dose notification to workers**

The normal dose notification system was inoperable due to the tsunami. It took time to manually input dose data which resulted in TEPCO falling behind notifying primary contractors. In addition, the receipts printing system of radiation exposure doses at the time of returning dosimeters was not functioning. Thus, it became difficult for workers to know their own cumulative exposure.

In response to the above, the following actions were taken.

[Actions taken by MHLW]

- MHLW demanded that TEPCO notify workers of their cumulative exposure doses once a week for external exposure and once a month for internal exposure (23 May).
- MHLW demanded that primary contractors submit a report once a month regarding the situation of notifying workers of their radiation exposure doses (22 July).
- MHLW demanded that workers should be issued receipts when returning their dosimeters, starting on 16 August (10 August).

[Actions taken by TEPCO]

- TEPCO were able to notify the primary contractors once a week (reported on 10 August). The receipt showing radiation exposure doses was issued to each worker when returning their dosimeters, starting on16 August.

**(5) Delay of internal exposure monitoring**

Whole-body counters (WBCs) in the NPP became unavailable, leading to their shortage and that delayed whole body measurements. It also took time to determine an estimation model according to the changes in the target nuclide to be measured as well as to identify the intake date. These factors caused a significant delay in evaluation of the committed dose. In particular, precise measurements were conducted to identify the nuclides at the Japan Atomic Energy Agency (JAEA) and the National Institute of Radiological Sciences (NIRS) for the workers who received high radiation exposure doses, and that took time to determine their committed doses.

In response to the above, the following actions were taken.

[Actions taken by MHLW]

- MHLW demanded that TEPCO measure internal exposure for emergency workers on a monthly basis (23 May).
- MHLW demanded that TEPCO promote internal exposure monitoring and report on the status (22 July).
- MHLW issued warnings of violation of the law to TEPCO and to the employers who had worked in March and had not had their internal exposure measured once within every three months (30 and 31 August).

[Actions taken by TEPCO]

- TEPCO determined the intake dose as that on 12 March in principle. TEPCO opened the WBC center at J-Village (10 July) and increased the number of WBCs by borrowing three "in-vehicle" type WBCs from JAEA, and purchased new ones. TEPCO secured 11 WBCs in total (18 October).
- TEPCO assessed and determined committed dose with the support of JAEA and NIRS. Monthly monitoring became possible from September.

MHLW identified that there were certain discrepancies between the dose evaluated by the primary contractors and the dose by TEPCO.

**(6) Re-evaluation of Internal Dose Assessments**

It was noticed that there were significant discrepancies between internal dose assessments of emergency workers made by TEPCO and those reported by primary contractors, doses which were reported to MHLW in April 2013.

In response to the above, the following actions were taken.

[Actions taken by MHLW]

- MHLW decided to re-evaluate the doses reported since May 2013, and some of the committed doses were re-adjusted based on the re-evaluation.

(a) MHLW readjusted committed doses based on the standardized method;

- Standardization of the estimation methodologies of internal dose assessments (intake date, intake scenario, and estimation of I-131 exposure, etc.) in accordance with TEPCO's methodologies as determined in August 2011.
- Readjustment of committed doses of 450 workers
  1) Increased doses: 431 workers (Max. 48.9mSv, Ave. 5.0mSv)
  2) Decreased doses: 19 workers (Min. 9.2mSv, Ave. 2.1mSv)

(b) MHLW corrected miscalculated committed doses (29 workers)

・Miscalculations and errors were found such as incorrect inputting of coefficients, mixing up of data, transmitting data to the wrong contractor, and omitting input of revised data transmitted from TEPCO, etc. into the database.
・Correction of 29 committed doses of workers among 7 contractors (corrections ranged from 3.5mSv to 18.1mSv)
・MHLW demanded that TEPCO and primary contractors employ the standardized methodologies for internal dose assessments; all parties were strictly instructed to prevent the recurrence of miscalculations and errors related to internal dose assessments (5 July 2013).

Detailed information is available at:
http://www.mhlw.go.jp/english/topics/2011eq/workers/tepco/rp/pr_130705.html

**(7) Additional re-evaluation of internal dose assessments**

In addition to the above, it was found that TEPCO had data on committed effective doses assessed by a method other than the standard methods at the end of January 2014.

[Actions taken by MHLW]

・MHLW examined data on emergency workers' committed effective doses to ascertain whether there were any other similar cases since February 2014. Examined data were for 6,245 emergency workers, excluding those covered by the previous re-evaluation, from a total of 7,529 emergency workers (data for workers engaged in March and April 2011). This examination revealed that the data for 1,536 emergency workers were suspected to have been obtained by methods other than the standard assessment methods.
・MHLW instructed TEPCO and primary contractors to re-evaluate these data. Consequently, the committed effective doses for 142 emergency workers were readjusted.
・MHLW provided TEPCO with guidance on the following matters.
(a) The internal audit sector should inspect the sector in charge of radiation dose control, check the workflow of its operations and data management, etc., and take necessary remedial actions.
(b) Before externally reporting or announcing radiation exposure doses, the data should be checked by a person in a quality assurance sector, in principle.
・MHLW instructed primary contractors that independently assess committed effective doses about thorough preservation of all the records, etc.

Detailed information is available at:
http://www.mhlw.go.jp/english/topics/2011eq/workers/tepco/rp/pr_140325.html

**(8) Unexpected occurrence of workers who could not be contacted**

It was found that a number of workers could not be identified in the name-based consolidated record (174 individuals, a tentative maximum as of 29 July), during the time that the handwritten dosimeter-circulating record was used for management.

In response to the above, the following actions were taken.

[Actions taken by MHLW]

・MHLW demanded that TEPCO ask the primary contractors for cooperation and release the information about missing workers, by name, on TEPCO's website (20 June).
・MHLW demanded that TEPCO correct the problem of the missing individuals, such as by verifying with other primary contractors groups and checking for overlaps of similar names (13 July).
・MHLW demanded the primary contractors consolidate exposure control and add a photo to each worker's identification card (22 and 29 July).
・MHLW directed TEPCO to organize a dedicated team to survey workers who could not be contacted (10 August).

[Actions taken by TEPCO]

・TEPCO, in cooperation with the primary contractors' offices on site, found missing workers one by one by checking the original records, checking for an overlap in similar names, having them confirmed by the primary contractors, making use of professional investigation agencies, and making those missing individuals' names public. However, ten individuals are still missing.

### 1.2.2 Respiratory protective equipment and protective clothing

**(1) Exceeding emergency exposure dose limit**

The assessment of internal exposure revealed that 6 emergency workers exceeded the dose limit of 250 mSv (revealed on 10 June; 678 mSv was the highest). This presumably occurred because the workers did not use the charcoal filter cartridge in the respiratory protective equipment, and ate and drank in the main control room, where the concentration of radioactive materials had increased after the hydrogen explosion (12 March)

In response to the above, the following actions were taken.

[Actions taken by MHLW]

・MHLW instructed TEPCO that the workers who had worked in the main control room right after the hydrogen explosion, and those whose radiation exposure dose had tentatively exceeded 100 mSv should be stopped from undertaking any radiation work until their doses were determined. TEPCO was also instructed to immediately exclude the 12 workers whose tentative doses had exceeded 200 mSv from emergency works (3 June, 7 June, and 13 June).
・MHLW performed on-site inspections (7 June and 11 July) and demanded that TEPCO correct violations, these were making workers continue at their job when having a dose in excess of 250 mSv (10 June), and failing to require that workers use effective respiratory protective equipment and failing to prohibit them from eating and drinking in contaminated areas (14 July).

[Actions taken by TEPCO]

・TEPCO excluded the relevant workers from the work that might cause exposure until their doses were determined, and excluded those whose exposure dose exceeded 200 mSv from any work at Fukushima Daiichi NPP in accordance with instructions (reported on 13 June).

**(2) Exceeding exposure dose limit for women**

The assessment of internal exposure revealed that 2 female workers had exceeded the dose limit of 5 mSv in March (revealed on 27 April; 17 mSv was the highest). While the female workers had been engaged in support tasks in the seismically isolated building since the accident occurred (11-23 March), the flow of radioactive materials into the building could not be avoided due to the distortion of the entrance door caused by the hydrogen explosion. It should be noted that local exhaust ventilation equipment was later installed and the windows were shielded with lead.

In response to the above, the following actions were taken.

[Actions taken by MHLW]

- MHLW performed an on-site inspection (27 May) and demanded that TEPCO correct violations which had caused female workers to be exposed in excess of 5 mSv in March (30 May).
- MHLW also instructed TEPCO to ensure exposure dose control for all workers, monitor their health regularly at the site, and to assess the internal exposure of the 2 female workers after excluding them from the work.

[Actions taken by TEPCO]

- TEPCO decided not to assign women to tasks in the area of the affected plant.

**(3) Improper use of respiratory protective equipment**

TEPCO failed to provide sufficient explanation with the instructions on how to wear respiratory protective equipment in the education of new workers. Thus, there were still workers who received internal exposure, even in June.

(a) Improper fitting of respiratory protective equipment

The survey on fitting respiratory protective equipment conducted on 26 September indicated that the leakage rate of respiratory protective equipment was particularly high for those wearing glasses (56% at the highest, 17% on average).

(b) Neglecting to attach filters

One of the workers of a primary contractor was found working near Unit 2 without a charcoal filter cartridge on his full face mask (13 June). A similar case occurred on 29 June, suggesting that workers had not been well informed about the need to wear respiratory protective equipment.

(c) Contamination inside of respiratory protective equipment

Contamination was found on the inner surface of the mask filters used by 4 workers (14 September). Several similar cases were subsequently found.

In response to the above, the following actions were taken.

[Actions taken by MHLW]

- Instructions were given to inform workers of the procedures for wearing respiratory protective equipment, to ensure that workers follow the rules regarding the correct way of wearing protective equipment, to provide education, and to post instructions on how to wear respiratory protective equipment (22 June).
- Instructions were given to establish work procedures for surveying contamination of respiratory protective equipment filters (5 October).
- TEPCO was instructed to:
  1) Take necessary measures for workers wearing glasses such as giving them sealing pieces to attach to the frames of the eyeglasses to cut leakage;
  2) Provide more masks so workers could choose one that was best suited to their own face;
  3) Show workers how to perform fitting tests;
  4) Introduce respiratory protective equipment with electric powered fans; and
  5) Improve the contents of the training workers received, based on the results of leakage rate tests using a mask fitting tester (26 September).

[Actions taken by TEPCO]

- Respiratory protective equipment were sorted by their product makers and sizes in accordance with the instruction so that workers could choose masks suited to their faces more easily (27 September).
- TEPCO started to provide new workers with training about using fitting testers (17 November).
- Masks with electric powered fans were introduced (25 August).

**(4) Improper protective garments**

(a)The case that a worker soaked his feet in highly contaminated water

A worker who was wearing short mid-calf boots soaked his feet in water (30 cm deep) during work. This caused the skin on both feet to become contaminated (beta ray exposure) (24 March), the radiation dose in the work area had not been monitored before starting work, the worker did not wear high boots, and the worker continued to work although his dosimeter alarm was sounding.

(b)The cases that highly contaminated water was poured over workers

A worker was contaminated when contaminated water was unintentionally poured over his head while he was working to discharge water in the tank of the contaminant removal plant. He was not wearing a hooded, waterproof garment. Another worker, also not wearing a hooded, waterproof garment, was engaged in handling hoses and became contaminated by water (both occurred on 31 August).

In response to the above, the following actions were taken.

[Actions taken by MHLW]

- MHLW instructed TEPCO to establish a safety and health administration system (24 March).
- MHLW issued guidance to TEPCO and the primary contractors to:
  1) Monitor the radiation doses in the work area before starting work in order to understand the contamination level and decide on work procedures;
  2) Ensure that workers evacuate when alarms of dosimeters go off and that workers wear effective protective garments and footwear according to the contamination level of the work area (26 March).
- MHLW instructed TEPCO to make its best effort to determine the causes of the incidents and prevent their recurrence (1 September).
- MHLW performed on-site inspections (27 May and 28 September) and demanded violations be corrected by the

employers who:

1) had not made workers wear suitable footwear (high boots) (in the case of the beta ray exposure on 24 March) (30 May); and
2) had not made workers wear effective protective clothing (hooded, waterproof protective clothing) (the cases on 31 August) (5 October).

[Actions taken by TEPCO]

・TEPCO ensured that workers put on rubber boots, and required workers who might be exposed to contaminated water to wear hooded, waterproof garments. No cases of exposure to contaminated water have occurred since then.

### 1.2.3 Training for new workers

**(1) Insufficient training hours for workers**

In the beginning (until around May), only 30 minutes were spent in worker education on the effects of radiation, how to control radiation dose, and the use of protective equipment; this was done at J-Village with instructional materials developed by TEPCO. In addition, the classroom where the worker education program was given was too small. The classroom accommodated only around 20 people per 30 minute session.

In response to the above, the following actions were taken.

[Actions taken by MHLW]

・MHLW instructed TEPCO and the primary contractors to educate new workers on radiation hazards, the use of protective equipment, and the actions and evacuation methods to take in an emergency (13 May, 23 May and 22 July).

[Actions taken by TEPCO]

・TEPCO started a new worker education program in Tokyo from19 May and the special education program at J-Village from 8 June to both TEPCO staff and contractors. Arrangements were made to secure sufficient classroom space.

### 1.2.4 Health and medical care system

**(1) Establishment of the medical care system at the affected plant**

TEPCO was able to provide physicians only intermittently at the affected plant. In the first month after the accident, 25 workers became sick or were injured, and 31 workers complained of poor health. One case of a worker suffering a heart attack was reported on 14 May, and this incident showed the urgent need for an emergency clinic that provides 24-hour medical services by physicians. However, securing a qualified staff of physicians, nurses, and radiological technologists has posed a great challenge, and establishing the emergency clinic turned out to be extremely difficult.

In response to the above, the following actions were taken.

[Actions taken by MHLW and relevant ministries (MEXT, etc.) and agencies]

・The Fukushima Prefectural Labour Bureau (PLB) demanded that TEPCO ensure workers' mental and physical health.
・The Fukushima PLB contacted and coordinated with the relevant ministers and sent hospitals a request letter for clinic staff under the name of the Director of the Occupational Safety and Health Department.
・The Fukushima PLB was allocated radiological technologists for the clinic, in cooperation with the Association of Radiological Technologists (September 2011).
・MEXT sent the PLB request to a wider range of radiation medicine institutions and was able to secure the dispatch of nurses.
・MHLW also asked the Japan Labour Health and Welfare Organization to steadily supply medical staff from November 2011.
・The University of Occupational and Environmental Health began to dispatch physicians who provide services mainly during the daytime (15 May). A system to ensure the 24-hour on-site presence of physicians was established on 29 May with the arrival of physicians dispatched from Rosai Hospitals (hospitals for labourers) managed by the Japan Labour Health and Welfare Organization. Subsequently, the plant site clinic was relocated to J-Village (September 2011).
・The National Defense Medical College started dispatching teams of critical incident stress specialists (10 July). The teams provide mental health services on a monthly basis.

[Actions taken by TEPCO]

・TEPCO opened the on-site makeshift medical clinic at Units 5 and 6 in July. More physicians were allocated in September 2011 to the clinic in J-Village in order to provide the initial treatment and triage and routine preventative health care.

**(2) Prevention of heat stroke**

It has been a concern since May 2011 that emergency workers might be at risk of occupational hazards derived from heat stroke while working for long hours under the blazing sun while wearing heavy equipment, such as a full-face mask, Tyvek coveralls, and rubber gloves.

In response to the above, the following actions were taken.

[Actions taken by MHLW]

・MHLW demanded that TEPCO undertake the following.
a) Suspend work from 2 p.m. to 5 p.m. in July and August;
b) Shift working hours to early morning, and specify the maximum number of consecutive working hours;
c) Check workers' health prior to work, make available air-conditioned rest places where workers can remove their full face masks;
d) Conduct education for the prevention of heat stroke;
e) Establish a medical care system (10 June 2011).
・MHLW demanded that TEPCO attach checklists for heat stroke prevention measures when they submit work plans to the inspection office.

[Actions taken by TEPCO]

・TEPCO took measures in addition to the instructions by the MHLW, including the following:
a) Distribution of cool vests (vests with refrigerant gel).
b) Provision of the wet bulb globe temperature (WBGT) through the internet.
c) Display the daily warning level for heat stroke at workplaces.

・TEPCO also required workers showing symptoms of mild heat stroke to take a break and a rest. As a result, although 40 patients with heat stroke symptoms were observed, no serious cases were reported.

**(3) Instructions to conduct special medical examinations**

Considering that exposure exceeding the normal exposure dose limit may cause acute radiation syndrome, special medical examinations conducted every six months would be too late to detect acute radiation damage. The more time that was spent on emergency works, the larger the numbers of workers who were subject to medical examinations. This made it difficult to collect information on the multiple-layered contractors, and the percentage of workers who undertook medical examinations was as low as 60% as of June 2011

In response to the above, the following actions were taken.

[Actions taken by MHLW]

・MHLW issued the compulsory instruction to TEPCO, under Item 4, Article 66 of the Industrial Safety and Health Act, to conduct special medical examinations including blood tests, skin test, and weight measurement, and specified the number of days after the completion of emergency works that the examinations must be taken within under the assumption of a short-term emergency works (16 March 2011)

・Additionally, MHLW re-issued instruction to TEPCO to conduct medical examinations for workers who were exposed to more than 100 mSv and who worked for more than 1month (25 April).

・In efforts to raise the implementation rate of medical examinations, MHLW regularly investigated the status of conducting the medical examinations and gave instructions to TEPCO and the primary contractors (May and June 2011).

**(4) Establishing patient transport systems from the affected plant**

In order to transport potentially seriously injured workers from the affected plant, a faster way to transport patients to a hospital was required, because 1-2 hours were needed to transport the patients via J-Village to hospitals. To shorten the transportation time, the MHLW tried to establish efficient patient transportation systems, including direct access of local ambulances to the plant and helicopter airlift to a hospital. The MHLW, however, faced difficulties in making arrangements with the hospitals expected to receive the patients.

In response to the above, the following actions were taken.

[Actions taken by MHLW]

・MHLW staff visited hospitals in Iwaki City and explained decontamination conditions that would allow the hospitals to accept direct patient transportation from the NPP. As a result, in August 2011, non-contaminated patients were allowed to approach hospitals directly from the plant.

・MHLW directed TEPCO to prepare a heliport to be used for an air ambulance, persuaded a helicopter operation company to join the work, and coordinated as a liaison regarding test flights to be conducted by a TEPCO affiliated company.

[Actions taken by TEPCO]

・TEPCO conducted direct transport of non-contaminated patients to hospitals without going through J-Village so that it was not necessary to decontaminate or transfer a patient to another vehicle (August 2011).

・An agreement was reached with the operation company to locate a heliport in the Fukushima Daini NPP, 13km from the affected plant, instead of using the Hirono town playground near J-Village, 20km from the affected plant. (February 2012).

**(5) Long-term health care program**

In addition to the compulsory medical examinations, it became necessary to examine workers who exceeded the normal dose limit of 50 mSv/y and those who exceeded the emergency exposure dose limit of 100 mSv. It also became necessary to conduct health consultations for workers about their long-term mental and physical health.

In response to the above, the following actions were taken.

[Actions taken by MHLW]

・MHLW established the Minister's guidelines pursuant to Item 2, Article 70 of the Industrial Safety and Health Act (11 October 2011). In the guidelines, the employers should basically be required to conduct long-term healthcare. However, the Government should conduct it for the workers who changed their jobs to those that are not related to radiation works, those who are continuously employed by the firms (small to midsize only) but not engaged in radiation work, and persons who are not currently employed.

・As additional medical examinations, MHLW decided to provide cataract eye examinations, for the workers who exceeded 50 mSv, and thyroid examinations and cancer screenings, (stomach, lung, and colon) for those whose dose exceeded 100 mSv, in accordance with the report provided by the experts' meeting.

・The MHLW compiled a report on methods for providing health care and exposure dose control during emergency works in nuclear facilities (1 May 2015). In this report, the items that should be provided to workers were compiled regarding the following items:

1) Long-term health care including the period after termination of employment, such as the medical examination of emergency workers
2) Healthcare during emergency works
3) Ensuring a medical care system in nuclear facilities during emergency works
4) Mid- to long-term exposure dose control to be provided to the workers whose exposure doses exceed the dose limit for regular radiation works
5) Exposure dose control during emergency works
6) Special education to the emergency workers who will be engaged in exceptional emergency works

### 1.2.5 Preliminary review of work plans

**(1) Insufficient management systems for developing work plans**

During the first month from the start of receiving work plans, a large number of plans were summited from TEPCO in which many deficiencies were found. It took a lot of time to revise the work plans in spite of having provided correction instruction afterwards. As there was no other back-up organization to

revise the work plans at that time, the persons in charge at the plant could not respond to reminder notices.

In response to the above, the following actions were taken.

[Actions taken by MHLW]

- The Tomioka Labour Standards Inspection Office developed a review standard and prepared instruction materials to be made available at its office, and continued to give instructions to the persons in charge at the plant.
- MHLW guided the corporate offices to improve the situation by strengthening the organizations involved and increasing the numbers of staff members for the tasks at both the affected plant and corporate offices (30 June). MHLW provided the on-site review service at J-Village on a regular basis.

[Actions taken by TEPCO]

- TEPCO increased the number of staff members to prepare work plans, and defined the roles of the NPP and corporate offices (reported on 13 July).

**(2) Deficiencies of work plans**

MHLW directed the primary contractors conducting work activities associated with doses exceeding 1 mSv per day to submit a radiation work plan to the relevant inspection office (23 May 2011). A lot of deficiencies were found in the submitted requests such as excessive length of the work period, improper personnel in charge, unrealistic estimation of the maximum radiation exposure dose, improper use of dosimeters (glass badges, ring badges, and alarm settings), and lack of identification of the work location and work description.

In response to the above, the following actions were taken.

[Actions taken by MHLW]

- MHLW developed review standards and prepared instruction materials to be made available at the office and continuously gave instructions to the staff in charge.

**(3) Insufficient knowledge about contract conditions**

Information obtained by TEPCO on the relationship among subcontractors, the number of subcontractors and workers, and whether training and medical examinations were provided at the time of employment were not sufficient.

In response to the above, the following actions were taken.

[Actions taken by MHLW]

- MHLW interviewed the primary contractors about the situation of exposure dose control (from late May to mid-June 2011).
- MHLW requested the primary contractors to report the current contract conditions (relationship among subcontractors, the number of subcontractors and workers, and whether education and medical examinations were provided at the time of employment) on a monthly basis (notified on 27 June 2011).

**(4) Improvement of the lodging and meals**

Many workers were unable to go back home or to their usual dormitories because the area within the 20 km radius from the affected plant was designated as the restricted area. Furthermore, many workers had to stay near the plant in preparation for any unexpected events. As a result, many workers were forced to sleep all crowded together on the floor in the seismically isolated building of the affected plant or the gymnasium of Fukushima Daini NPP, 13 km from the affected plant. In addition, the meals served were processed food in retort pouches in order to prevent internal exposure. Because workers were engaged in hard work without sufficient rest nor nutritious meals, there were concerns about worsening workers' health and occurrence of an accident caused by their operational errors.

In response to the above, the following actions were taken.

[Actions taken by MHLW]

- MHLW demanded that TEPCO undertake the following actions (20 April 2011):
  (a) Reserve sleeping areas equipped with bedding and other required supplies.
  (b) Take preventive measures against infectious diseases.

[Actions taken by TEPCO]

(a) TEPCO installed double-deck beds and supplied bedclothes for 240 workers in the gymnasium at Fukushima Daini NPP and installed equipment for 30 showers in the gymnasium and 42 double-deck beds in the seismically isolated building.

(b) TEPCO built a temporary dormitory at J-Village that accommodated 1600 workers.

(c) TEPCO changed meals from ready-made food in retort pouches to fresh boxed lunches in response to the decrease of possible contamination by radioactive materials and reopened the restaurant in J-Village.

(d) TEPCO reopened the restaurants in the main administration building at Fukushima Daini NPP (18 June 2012).

## 1.3 Health control at the TEPCO Fukushima Daiichi NPP

### 1.3.1 The status of long term health control at the TEPCO Fukushima Daiichi NPP

MHLW established "Guidelines on Maintaining and Improving Health of Emergency Workers at the TEPCO Fukushima Daiichi NPP" on 11 October 2011. The Guidelines describe "Actions for long-term health control", "Development of a database for workers who have engaged in emergency works" and "Support provided by the Government".

Based on the guidelines, MHLW and TEPCO are implementing long term health control such as cancer screenings etc. corresponding to the exposure dose values for the workers who had been engaged in the emergency works at the TEPCO Fukushima Daiichi NPP.

The implementation status as of 26 November 2014 is as follows;

**(1) Status of registration card issuance**

Out of 19,675 emergency workers, 19,383 workers (98.3%) were issued cards. For those 337 workers who had not

received the cards, confirmation of addresses was continuing.

**(2) Status of handbook for recording radiation exposure doses (handbook) issuance**

Out of 904 designated emergency workers, 781 workers (86.4%) were issued handbooks. In February 2013, a document that recommended the handbook application was delivered to the employers of the designated workers. Recommendation of application etc. will be continued in the future.

**(3) Status of data base registration of the medical examination results**

The implementation rate of the special medical examinations reached 92.7% (the data registration reached 77.9%), and that of general medical examinations reached 91.9% (the data registration reached 71.2%).

**(4) Status of the data base registration of cancer screening results of designated emergency workers**

(a)Recommendation to implement cancer screenings specified in the guidelines (From June to November 2012 and November 2013)

Several recommendations to implement cancer screenings were delivered to the employers. The survey of current addresses for all designated workers should be conducted once a year. (June 2014)

(b)The results of the implementation status for cancer screenings (From October 2012 to September 2013)

Implementation rate for cataract screening was 67.4%, and that for cancer screenings was 96.78% respectively.

(c)Status of database registration of the cancer screening results (From October 2012 to September 2013)

For current workers, data base registration for cataract screening was 54.7%, and that for cancer screenings was 63.6%.

**(5) Status of health consultation or guidance to emergency workers at the support desk (From April 2013 to March 2014)**

There were 214 consultations cases, of which 91 cases were long term health control, and 53 cases were about radiation exposure and health effects.

### 1.3.2 Certification of occupational disease/injury for workers

On 20 October 2015, the MHLW announced that one worker who had been working at the Fukushima Daiichi NPP had been diagnosed with leukemia. The MHLW admitted that it is difficult to say that the cancer was not related to the work he performed at the plant, and decided to accept the compensation claim the worker had filed.

The impact of low dose exposure at approximately 100 mSv or less on cancer occurrence is much smaller than that of other factors, and it is internationally recognized as being difficult to prove an obvious increase in health risk by low dose exposure. So the MHLW has established criteria for occupational disease/injury approval* related to the occurrence of leukemia caused by radiation exposure from the viewpoint of compensation for workers. And as long as these criteria are met, such occurrences of leukemia shall be approved as an occupational disease/injury unless there is obviously a non-occupational factor, after discussion at a medical review meeting.

*Approval criteria

1) Exposure to ionizing radiation of a certain dose (5 mSv × years of engagement)

2) Development after a period of at least one year following the start of exposure

## 1.4 Implementation status of measures against ionizing radiation hazards associated with decommissioning works

In order to ensure the working conditions as well as the industrial safety and health of workers engaged in decommissioning works at the TEPCO Fukushima Daiichi NPP, the Fukushima Prefectural Labour Bureau provided employers of such workers with focused supervision and instruction. As a result of supervision and instruction provided for 724 employers by 30 September 2015, 409 employers were identified to be violating laws and ordinances related to the labour standards, namely, the Labour Standards Act and the Industrial Safety and Health Act, in some form (violation rate: 56.5%). The total number of violation cases was 656, where violations related to working conditions were found in 406 cases and violations related to industrial safety and health in 250 cases. For the employers discovered to be violating laws and ordinances, the Fukushima Prefectural Labour Bureau provided instruction towards rectification. Additionally, the Bureau has provided instruction on appropriate implementation of measures stipulated in the "Guidelines on occupational safety and health management at the TEPCO Fukushima Daiichi Nuclear Power Plant" formulated on 26 August 2015.

## 1.5 Recommendations

On 10 August 2012, in response to the issues that were shown in previous sections, MHLW demanded the employers who operate nuclear facilities to prepare for nuclear accidents that may necessitate emergency works and also to prepare for the actions that may need to be taken when an accident occurred. This section shows accident preparations, and the actions to be taken at the time of an accident by the employers in response to the directions.

The guidance document is available at;
http://www.mhlw.go.jp/english/topics/2011eq/workers/ri/pr/pr_120810.html

### 1.5.1 Personal identification and exposure dose control

**(1) Insufficient exposure dose control system in the exposure dose control department**

(a)Preparations to be made by the employers

[Actions taken at the nuclear facilities including NPPs (hereinafter referred to as "the nuclear facility")]

- Develop a plan in preparation for emergency works to establish an organization to consolidate the radiation control of all the emergency workers (hereinafter referred to as "systematic control organization") in the nuclear facility (or the corporate offices if it is beyond the ability of the nuclear facility).
- Develop an emergency action plan for the case that the normally used systems become unavailable for exposure dose control, and prepare for increasing staff members to be engaged in temporarily exposure dose control.

[Actions taken by the primary contractors]

- Establish the management system for dose control in emergency situations, as well as educate and train staff members to perform radiation control.

[Actions taken in the corporate offices or at the facilities with the functionality of the nuclear department in the corporate offices, excluding at the nuclear facilities (hereinafter "the corporate offices")]

- If necessary, develop a plan in advance to establish systematic control organization in the corporate offices.
- In preparation for supporting radiation control in the corporate offices and dispatching staff to help at the nuclear facility, make a staff list, provide required preliminary education and training to inexperienced staff members, and establish a system in the corporate offices for being able to increase the number of staff members temporarily.

(b)Post-accident actions to be taken by the employers

[Actions taken at the nuclear facility]

- Establish a system for exposure dose control such as by temporarily increasing the number of staff members in charge of dosimeter-lending for the case that the systems normally used are not available.

[Actions taken by the primary contractors]

- Ensure a system for exposure dose control such as by temporarily increasing the number of staff members carrying out radiation control in each primary contractor, and establishing an organization that can consolidate radiation exposure doses of workers under all the involved subcontractors.

[Actions taken in the corporate offices]

- Check the system for exposure dose control at the nuclear facility, and provide support such as by dispatching staff members from the corporate offices, as appropriate.
- Check the situation in exposure data inputting work at the nuclear facility and, if there are any problems in the system for exposure dose control, obtain the administrative documents from the said facility and perform exposure dose control directly including the exposure data input and name-based dose consolidations in the corporate offices.

**(2) Insufficient numbers of personal dosimeters**

(a)Preparations to be made by the employers

[Actions taken at the nuclear facility]

- Prepare sufficient numbers of extra PADs that can be used during emergency works (including battery chargers and emergency power generators, if non-battery-powered) (hereinafter all PADs and their auxiliary equipment are referred to as "PADs").
- Make agreements with other nuclear facilities in advance to supply sufficient number of PADs for all emergency workers (including those who are not engaged normally in radiation works).

[Actions taken in the corporate offices]

- Support the nuclear facility such as by discussing and making an agreement with other corporate offices for borrowing PADs.

(b)Post-accident actions to be taken by the employers

[Actions taken at the nuclear facility]

- Check whether or not sufficient PADs are available immediately after the occurrence of an accident.
- Once the shortage of PADs is found, borrow them immediately from other nuclear facilities in accordance with the agreement made in advance.

[Actions taken in the corporate offices]

- Check if a sufficient number of PADs are available at the nuclear facility, and if required, provide support to allow the nuclear facility to obtain PADs from other nuclear facilities, as appropriate.

**(3) Deficiencies in dosimeter-lending management**

(a)Preparations to be made by the employers

[Actions taken at the nuclear facility]

- In the case that the normally used system becomes unavailable, issue access permits with both personal identification numbers (hereinafter referred to as "ID number(s)") and photos, and build a backup system in advance that can control exposure dose by the ID number on mobile personal computers or computer systems that can be used in emergency situations (hereinafter referred to as "the backup system").
- In the case that the backup system is not operable, establish in advance an administrative list form to be filled in by hand and the administration method using the central registration number for each worker's radiation passbook and driver's

license number (if it is difficult to use those, a combination of date of birth and name) as a temporary ID number (hereinafter referred to as "the temporary ID number").

・Conduct training on a regular basis so as to implement the management stated in (1) and (2) immediately in emergency situations.

[Actions taken in the corporate offices]

・In the case that the backup system is not operable at the nuclear facility, set up a backup system in the corporate offices as well. Note ,however, that this may not apply to the case that the backup system is installed in the seismically-isolated buildings located at a sufficient isolation distance and consisting of structures and equipment that can maintain internal radiation protective functions (hereinafter referred to as "the seismically isolated building") even if a hydrogen explosion occurs in a nuclear reactor or its vicinity.

(b) Post-accident actions to be taken by the employers

[Actions taken at the nuclear facility]

・Make a backup system available.

・ Use the hand-written administrative list to manage dosimeters using temporary ID numbers until the backup system is running.

・Once the backup system is running, verify individuals based on official documents, issue access permits, lend dosimeters based on the ID number, and record radiation exposure doses.

[Actions taken by the primary contractors]

・Ensure proper management of the access permit to prevent its use by anyone except the registered worker.

[Actions taken in the corporate offices]

・Check the situation of the dosimeter lending administration in the nuclear facility, and provide support such as by making a backup system in the corporate offices operable, as appropriate

**(4) Delay of radiation exposure dose notification to workers**

(a)Preparations to be made by the employers

[Actions taken at the nuclear facility]

・Ensure that the backup system prepared for unavailability of the normally used system provides the function of issuing receipts to workers providing them with a written notice of their daily radiation exposure doses.

・ Specify in advance the procedures for immediately informing the primary contractors of the input data when it is necessary for the corporate offices to undertake inputting of doses.

[Actions taken in the corporate offices]

・Plan in advance the procedures for immediately informing the nuclear facility of the dose data at the corporate offices, if the corporate offices are required to do so after the accident.

・For the case that the backup system is not operable at the nuclear facility, set up a backup system with a function to issue receipts in the corporate offices. Note, however, that this may not apply to the case that the backup system is located in the seismically isolated building. (Repeated notice was given for this action.)

(b)Post-accident actions to be taken by the employers

[Actions taken at the nuclear facility]

・ Make a backup system operable, and issue receipts of radiation exposure doses to workers.

・While the backup system is unavailable, issue a written notice of radiation exposure doses to workers at the time of returning dosimeters (hand-written memos are acceptable).

・Immediately inform the primary contractors of the radiation exposure dose data inputted.

[Actions taken by the primary contractors]

・ Immediately notify all the workers under the involved subcontractors through the said subcontractors of the dose data obtained from the nuclear facility.

[Actions taken in the corporate offices]

・Check the situation in dose data input and notification among employers at the nuclear facility, and perform the tasks such as data input in the corporate offices, as appropriate.

・If the data input task is performed in the corporate offices, provide the input data to the nuclear facility immediately.

**(5) Delay of internal exposure monitoring**

(a)Preparations to be made by the employers

[Actions taken at the nuclear facility]

・In order to measure internal exposure, specify in advance the places to locate mobile WBCs which will be borrowed in case of an accident under the prior agreements made by the relevant corporate offices.

・ Develop in advance the method for evaluating internal exposure in emergency situations, such as identifying the date of ingestion or inhalation through a study of worker behavior.

[Actions taken in the corporate offices]

・For the agreements stated in (1) above, provide support such as by negotiating and concluding agreements with the corporate offices of other utilities and organizations, as appropriate.

・ Develop in advance an assessment model to evaluate exposure to radionuclides of cesium and/or radionuclide of iodine after accidents in cooperation with JAEA and NIRS (hereinafter referred to as "the Advanced Radiation Expert Institutes").

・Develop in advance a plan for responding to an accident including the method for positioning WBCs outside a nuclear facility for the case that they cannot be located inside it. Also, make an agreement with other utilities and the Federation of Electric Power Companies of Japan to make mobile WBCs available for transport in emergency situations.

(b)Post-accident actions to be taken by the employers

[Actions taken at the nuclear facility]

・Ask other nuclear facilities in accordance with the agreement concluded in advance, to obtain mobile WBCs and transport them to a proper location when the normally used WBCs become unavailable.

・ Immediately establish an internal exposure assessment model suitable for the released nuclides, in cooperation with the Advanced Radiation Expert Institutes.

・Immediately determine the nuclides and the date of ingestion or inhalation for the workers who may exceed their normal exposure dose limit, by making use of WBCs in the Advanced Radiation Expert Institute, and determine the committed dose.

・Immediately consolidate the committed doses and external radiation doses by name and calculate the sums to ensure workers do not exceed the exposure limit.

[Actions taken by the primary contractors]

・Check the situation of internal exposure measurement by the involved subcontractors, and guide or support them to provide the measurement to all their workers.

[Actions taken in the corporate offices]

・Check the situation of internal exposure measurement at the nuclear facility, and if the normally used WBCs become unavailable, provide support so that the nuclear facility can obtain transferable WBCs from other nuclear facilities, and can measure internal exposure at other nuclear institutions.

・Provide technical support in cooperation with the Advanced Radiation Expert Institutes to identify the specific nuclides causing internal exposure, develop an exposure model, and identify the date of ingestion or inhalation.

**(6) Unexpected occurrence of workers who could not be contacted**

(a)Preparations to be made by the employers

[Actions taken at the nuclear facility]

・Specify the procedures to successfully identify individuals until the backup system is up and running, such as by recording temporary ID numbers and names on the hand-written dosimeter lending list.

・For the case that contact is lost with any individual workers, specify in advance the investigation methods including checking the original records, checking for overlap of similar names, having them confirmed by other primary contractor groups, asking the employers' office on the site to investigate, making use of professional investigation agencies, and making those individuals' names known in public places.

[Actions taken in the corporate offices]

・Provide support when the nuclear facility develops survey methods, as appropriate.

(b)Post-accident actions to be taken by the employers

[Actions taken at the nuclear facility]

・Conduct the dosimeter-lending administration for emergency situations in the manner specified in advance.

・In the case that contact is lost with any individual workers, immediately check for overlap of similar names and ask the employers' office on the site for reconfirmation, in cooperation with the primary contractors' office on the site.

[Actions taken by the primary contractors]

・In the case that contact is lost with any individual workers, immediately check for overlap of similar names and ask the employers' office on the site for reconfirmation.

[Actions taken in the corporate offices]

・Check the dosimeter lending procedures at the nuclear facility, and if contact is lost with any individual workers, reconfirm the dose records in the corporate offices, as required.

### 1.5.2 Respiratory protective equipment and protective clothing

**(1) Exceeding emergency exposure dose limit**

(a)Preparations to be made by the employers

[Actions taken at the nuclear facility]

・Prepare required measurement instruments and establish measurement procedures so as to measure radiation dose in the air at any time in places inside of the nuclear facilities where workers work or are on standby in emergency situations (hereinafter referred to as "the standby areas") (including places where air is considered to be not contaminated under normal conditions).

・In the case standby areas are contaminated, based on the breakthrough time, prepare a sufficient number of charcoal filters for workers to allow them to stay for several days at the standby areas, and store spare filters in the seismically isolated building.

・Train emergency workers (particularly focusing on such workers as drivers who do not generally wear respiratory protective equipment very often, and those wearing glasses) on how to wear respiratory protective equipment in an appropriate manner, and re-educate them at proper intervals.

・Conclude agreements with other nuclear facilities in advance to lend WBCs that can be transferred in emergency situations so as to measure internal exposure of all the emergency workers. (Repeated notice was given for this action.)

[Actions taken in the corporate offices]

・Provide support to allow the nuclear facility to take the actions, as appropriate.

(b)Post-accident actions to be taken by the employers

[Actions taken at the nuclear facility]

・Make all the workers in the standby areas wear charcoal filter respiratory protective equipment immediately after an accident, until it is verified that the air is not contaminated based on the concentration of radioactive materials in the air.

・Distribute a sufficient number of charcoal filters in every standby area, based on the breakthrough time.

・In the case that workers need to standby in a work area where air contamination is uncertain, give them some rest at a proper interval in a work area where it is verified that the air is not contaminated.

・Measure the concentrations of radioactive materials in the air and ambient dose rates in the standby areas continuously.

・Immediately measure internal exposure for all the workers in the standby areas where air contamination is uncertain.

[Actions taken in the corporate offices]

・Check the situation of radiation measurement in the standby areas of the nuclear facility, and provide support such as by dispatching staff members of the radiation control departments in other nuclear facilities, as appropriate.

**(2) Exceeding exposure dose limit for women**

(a)Preparations to be made by the employers

[Actions taken at the nuclear facility]

・Prepare the required measurement instruments and establish measurement procedures so as to measure radiation dose in the air at any time in the standby areas. (Repeated notice was given for this action.)

・Prepare charcoal filter respiratory protective equipment at

each standby area, and store spare equipment in the seismically isolated building in advance. (Repeated notice was given for this action.)

・Prepare a sufficient number of personal dosimeters such as PADs for all the emergency workers (including those who are not engaged normally in radiation works). (Repeated notice was given for this action.)

[Actions taken in the corporate offices]

・Provide support to allow the nuclear facility to take the necessary actions, as appropriate.

(b)Post-accident actions to be taken by the employers

[Actions taken at the nuclear facility]

・Measure the concentrations of radioactive materials in the air and ambient dose rates in the standby areas continuously, putting a higher priority on those areas where female workers are present. Evacuate female workers immediately if there are any possibilities that the doses may exceed the exposure limit.

・Make all the workers in the standby areas wear charcoal filter respiratory protective equipment and PADs immediately after an accident, until it is verified that air is not contaminated by measuring the concentration of radioactive materials in the air. (Repeated notice was given for this action.)

[Actions taken in the corporate offices]

・Check the situation of measurement in stand-by areas of the nuclear facility, and provide support regarding the management of female workers, as appropriate.

**(3) Improper use of respiratory protective equipment**

(a)Preparations to be made by the employers

[Actions taken at the nuclear facility]

・Group masks by size (or product makers if multiple products are used) in order to have workers easily choose the one best suited to their faces.

・Promote introduction of masks with an electric powered fan.

・Provide new workers with education regarding the performance and usage of masks focusing on the following points, and re-educate them at proper intervals.

1) Verifying proper fitting by using fitting testers.

2) Taking preventive measures against leak-in, especially having workers use sealing pieces on their glasses.

3) Instructing workers how to wear masks, and how to verify operation of fitting filters.

4) Instructing workers how to handle masks properly to prevent contamination inside them.

[Actions taken in the corporate offices]

・Provide support such as by preparing education materials and training instructors to be dispatched in emergency situations, so that the nuclear facilities can take the necessary actions, as appropriate.

(b)Post-accident actions to be taken by the employers

[Actions taken at the nuclear facility]

・Immediately educate new workers regarding the points shown in (3) of the previous section, namely “(a) Preparations to be made by the employers”.

[Actions taken in the corporate offices]

・Check the situation of education for new workers in the nuclear facility, and provide support such as by dispatching instructors to assist in the education sessions and providing education materials, as appropriate.

**(4) Improper protective garments**

(a)Preparations to be made by the employers

[Actions taken at the nuclear facility]

・Prepare a sufficient number of rubber boots, chemical protective suits, and waterproof protective clothing (hereinafter referred to as "the protective clothing") for emergency situations.

・Prepare a sufficient number of dosimeters including PADs for emergency situations (Repeated notice was given for this action.).

[Actions taken in the corporate offices]

・Provide support to allow the nuclear facility to take action in an appropriate manner.

(b)Post-accident actions to be taken by the employers

[Actions taken at the nuclear facility]

・Prepare a sufficient amount of protective clothing and ensure workers wear it in an appropriate manner.

・Develop work instructions for the activities handling contaminated water, and provide appropriate education and training using the instructions.

[Actions taken in the corporate offices]

・Check the status of worker instruction on wearing protective clothing in the nuclear facility, and provide support, as appropriate.

## 1.5.3Training for new workers

**(1) Insufficient training hours for workers**

(a) Preparations to be made by the employers

[Actions taken at nuclear facilities]

・Prepare a large enough classroom and sufficient instructional materials, and train instructors so as to provide sufficient sessions in emergency situations to all of those who need the education as new workers.

・In addition to the special education program conventionally offered in nuclear reactor/nuclear fuel handling, develop instructional materials regarding the evacuation methods, emergency responses and radiation dose control methods at the time of an accident, and provide education and re-education at proper intervals, to workers doing these works.

・Educate workers engaged in radiation works (particularly focusing on those such as drivers who do not generally wear respiratory protective equipment and workers wearing eyeglasses) on how to wear respiratory protective equipment in an appropriate manner, and re-educate them at proper intervals (Repeated notice was given for this action.).

[Actions taken in the corporate offices]

・Support the nuclear facility to develop education and training materials.

・Train a sufficient number of instructors to train workers, in order to dispatch them to the nuclear facility in emergency situations.

(b)Post-accident actions to be taken by the employers

[Actions taken at nuclear facilities]

・Provide education to emergency workers who require education as new workers and according to the curriculum, prepare materials in advance.

・Check if the classroom size, the materials and the number of instructors are sufficient, and ask the corporate offices for support otherwise.

[Actions taken by the primary contractors]

・In cooperation with the nuclear facility, support the education for new workers for all the involved subcontractors.

[Actions taken in the corporate offices]

・Check the situation of educating workers in the nuclear facility, and provide support such as by dispatching instructors to assist in the education sessions and provide education materials, as appropriate.

### 1.5.4 Health and medical care system

**(1) Establishment of the medical care system in the affected plant**

(a)Preparations to be made by the employers

[Actions taken at nuclear facilities]

・Coordinate with the relevant agencies under the support of the District Labour Bureau to establish a council consisting of prefectural health care and medical offices, fire departments, nearby medical centers, nuclear facilities and prefectural labour bureaus, and other relevant agencies (hereinafter referred to as "the council for medical care system") which aims at establishing a proper medical care system for workers in nuclear facilities.

・In the case that the normally used medical center becomes unavailable after an accident has occurred, reserve a place which can accommodate materials and equipment for medical centers in a building of the nuclear facility (or an appropriate building located within several kilometers from the nuclear facility if no such building exists there) with a sufficient distance to ensure safety, even if a hydrogen explosion occurs at a nuclear reactor or its vicinities.

・Consider the health and medical care system required to ensure mental and physical health of workers engaged in emergency works, and make the required preparations.

[Actions taken in the corporate offices]

・Participate in the council for the medical care system to support the nuclear facility in securing a medical care system in emergency situations.

(b)Post-accident actions to be taken by the employers

[Instructions to the nuclear facility]

・Request the dispatch of medical care workers considering the number of emergency workers, based on the medical care system developed in advance.

・Launch operation of an emergency medical center at the location prepared in advance, in the case that the normally used medical center becames unavailable.

・Immediately establish the required medical care system to ensure mental and physical health of workers engaged in emergency works.

[Actions taken in the corporate offices]

・Check the status of the medical care system in the nuclear facility, and provide support, as appropriate

**(2) Prevention of heat stroke**

(a)Preparations to be made by the employers

[Actions taken at nuclear facilities]

・Take preventive measures against heat stroke in advance including determining the suppliers of cooling vests and cooler boxes; building a rest area equipped with the required functions; developing procedures for actions to be taken when heat strokes occurs; forecasting conditions likely to promote heat stroke occurrence using the WBGT; and obtaining educational materials about heat stroke, on the assumption that workers work wearing heavy equipment under the blazing sun.

・Establish in advance a framework to share information among the employers engaged in construction work in the nuclear facility site.

[Actions taken in the corporate offices]

・Provide the nuclear facility with support to take proper preventive measures against heat stroke, as appropriate.

(b)Post-accident actions to be taken by the employers

[Actions taken at nuclear facilities]

・Take the planned preventive measures against heat stroke in a proper manner for workers working in hot and humid places.

・Check physical conditions frequently, making use of medical questionnaires.

・When heat stroke occurs, analyze the causes, and reflect the results in measures to prevent recurrence, and share them through the council consisting of the primary contractors.

[Actions taken by the primary contractors]

・Provide required guidance or support in cooperation with the nuclear facility to ensure that the involved subcontractors can take proper preventive measures against heat stroke.

[Actions taken in the corporate offices]

・Check the status of taking preventive measures against heat stroke in the nuclear facility, and provide support, as appropriate.

**(3) Instructions to conduct special medical examinations**

(a)Preparations to be made by the employers

[Actions taken at nuclear facilities]

・Build a consensus with the relevant parties in the council for the medical care system to immediately conduct special medical examinations in case that emergency works leads to a high-level of exposure.

[Actions taken in the corporate offices]

・In the case that the nuclear facility cannot conduct the special medical examinations during emergency works, consider and make required preparations to directly conduct and manage them.

(b)Post-accident actions to be taken by the employers

[Actions taken at nuclear facilities]

・Conduct special medical examinations in accordance with the inspection items in the examinations as instructed.

・Obtain correct information on the primary contractors, and provide special medical examinations to workers under the involved subcontractors.

・Check the situation of special medical examinations conducted by the primary contractors.

[Actions taken by the primary contractors]
- Obtain the correct number of workers under the involved subcontractors, and provide the required guidance or support to ensure that the workers under the said subcontractors can undertake the special medical examinations.
- Check the situation of the special medical examinations conducted by the involved subcontractors.

[Actions taken in the corporate offices]
- Check the situation of the special medical examinations in the nuclear facility, and provide support such as by dispatching medical care workers to assist, as appropriate.

**(4) Establishing patient transport systems from the affected plant**

(a)Preparations to be made by the employers

[Actions taken at nuclear facilities]
- Build a consensus with the relevant parties in the council for medical care system on the emergency transport systems.
- Prepare a heliport near the nuclear facility to be used by a helicopter ambulance after the occurrence of an accident.

[Actions taken in the corporate offices]
- Participate in the council for the medical care system to support the nuclear facility in providing transport systems.

(b)Post-accident actions to be taken by the employers

[Instructions to the nuclear facility]
- Request emergency transport systems based on the consensus reached in the council for the medical care system.
- Prepare the pre-arranged heliport for an air ambulance according to the severity of the accident, and request the operation of the air ambulance in accordance with the consensus in the council for the medical care system.

[Actions taken in the corporate offices]
- Check the transport systems in the nuclear facility, and provide support such as by consulting with medical care institutions, fire authorities and aviation authorities, as appropriate.

**(5) Long-term health care program**

(a)Preparations to be made by the employers

[Actions taken at nuclear facilities]
- Make advance preparations to take actions for emergency workers, conforming to the Minister's guidelines.

[Actions taken in the corporate offices]
- Support the nuclear facility to make the required preparations for properly conducting long-term health care in emergency situations.

(b)Post-accident actions to be taken by the employers

[Actions taken at nuclear facilities]
- Take actions for emergency workers, in accordance with the Minister's guidelines.

[Actions taken in the corporate offices]
- Check the situation of the long-term health care conducted by the nuclear facility to provide support, as appropriate.

### 1.5.5 Preliminary review of work plans

**(1) Insufficient management system for developing work plans**

(a)Preparations to be made by the employers

[Actions taken at nuclear facilities]
- In the case that emergency works is required, establish an organizational system at both the nuclear facility and the corporate offices to develop and review the emergency work plans.

[Actions taken in the corporate offices]
- Formulate an organizational system in advance that allows the corporate offices to review the emergency work plans directly in the case of an emergency.

(b)Post-accident actions to be taken by the employers

[Actions taken at nuclear facilities]
- Formulate and review details of emergency works under the predetermined organizational system, in order to prepare and submit work plans that include proper actions to mitigate exposure.

[Actions taken in the corporate offices]
- Check the situation of preparing work plans at the nuclear facility, and provide support such as by reviewing the details at the corporate offices and dispatching staff to help, as appropriate.

**(2) Deficiencies of work plans**

(a)Preparations to be made by the employers

[Actions taken at nuclear facilities]
- Reflect the summarized typical findings indicated by the Labour Standard Inspection Office having jurisdiction over the nuclear facility when developing work plans in normal situations in addition to emergency works.

[Actions taken in the corporate offices]
- Plan the organizational system in advance to allow the corporate offices to review the details of works directly, in the case that the nuclear facility cannot do the task properly in the case of an emergency.

(b)Post-accident actions to be taken by the employers

[Actions taken at nuclear facilities]
- Develop and review the details of emergency work plans, and prepare and submit work plans that include proper actions to mitigate exposure, based on the findings indicated in advance.

[Actions taken in the corporate offices]
- Check the situation of the work plans prepared by the nuclear facility, and provides support such as by directly reviewing them at the corporate offices, as appropriate.

**(3) Insufficient knowledge about contract conditions**

(a)Preparations to be made by the employers

[Actions taken at nuclear facilities]
- Arrange in advance the system for collecting information on workers under the involved subcontractors through the primary contractors in the case of an emergency.

[Actions taken by the primary contractors]
- Establish in advance the system for obtaining correct information on workers engaged in emergency works under the involved subcontractors.

[Actions taken in the corporate offices]

・Provide support to allow the nuclear facility to take the necessary actions in an appropriate manner.

(b)Post-accident actions to be taken by the employers

[Actions taken at nuclear facilities]

・Collect information on subcontractors through the primary contractors, and check if education and medical examinations are provided in an appropriate manner.

[Actions taken by the primary contractors]

・Be sure to obtain information on workers under the involved subcontractors who are engaged in emergency works, and provide guidance or support appropriately to ensure that education and medical examinations are provided in a proper manner.

[Actions taken in the corporate offices]

・Check the situation of collecting the information on contract conditions at the nuclear facility, and provide support appropriately.

**(4) Improvement of the lodging and meals**

(a)Preparations to be made by the employers

[Actions taken at nuclear facilities]

・Prepare temporary sleeping equipment with bedclothes, and plan in advance where to locate them for an emergency.

・Prepare a sufficient volume of emergency meals with good nutritional balance for an emergency.

[Actions taken in the corporate offices]

・Provide support to allow for the nuclear facilities to take the necessary actions in an appropriate manner.

(b)Post-accident actions to be taken by the employers

[Actions taken at nuclear facilities]

・Make temporary sleeping areas available and provide meals based on the pre-determined plan.

[Actions taken in the corporate offices]

・Check the conditions of temporary sleeping areas and meals in the nuclear facility, and provide support, as appropriate.

## 1.6 Exposure dose distribution of workers at the TEPCO Fukushima Daiichi NPP

The status of the radiation exposure dose is shown on the URL of the MHLW (English)
http://www.mhlw.go.jp/english/topics/2011eq/workers/irpw/index.html

### Exposure dose distribution of the workers at Fukushima Daiichi NPP (provided by TEPCO)

[Table 1 Cumulative Effective Dose (by year)]

As of 31 December 2015

March 2011 - March 2012

| Effective dose (E) mSv | TEPCO | Contractors | Total |
|---|---|---|---|
| 250 < E | 6 | 0 | 6 |
| 200 < E≦250 | 1 | 2 | 3 |
| 150 < E≦200 | 26 | 2 | 28 |
| 100 < E≦150 | 117 | 20 | 137 |
| 75 < E≦100 | 186 | 65 | 251 |
| 50 < E≦75 | 257 | 258 | 515 |
| 20 < E≦50 | 630 | 2,660 | 3,290 |
| 10 < E≦20 | 491 | 2,892 | 3,383 |
| 5 < E≦10 | 377 | 2,557 | 2,934 |
| 1 < E≦5 | 589 | 4,621 | 5,210 |
| E≦1 | 735 | 4,632 | 5,367 |
| Total | 3,415 | 17,709 | 21,124 |
| Maximum (mSv) | 678.80 | 238.42 | 678.80 |
| Average (mSv) | 25.15 | 10.06 | 12.50 |

April 2012 - March 2013

| Effective dose (E) mSv | TEPCO | Contractors | Total |
|---|---|---|---|
| 250 < E | 0 | 0 | 0 |
| 200 < E≦250 | 0 | 0 | 0 |
| 150 < E≦200 | 0 | 0 | 0 |
| 100 < E≦150 | 0 | 0 | 0 |
| 75 < E≦100 | 0 | 0 | 0 |
| 50 < E≦75 | 1 | 0 | 1 |
| 20 < E≦50 | 62 | 675 | 737 |
| 10 < E≦20 | 129 | 2,000 | 2,129 |
| 5 < E≦10 | 266 | 1,875 | 2,141 |
| 1 < E≦5 | 579 | 3,326 | 3,905 |
| E≦1 | 589 | 4,240 | 4,829 |
| Total | 1,626 | 12,116 | 13,741 |
| Maximum (mSv) | 54.10 | 43.30 | 54.10 |
| Average (mSv) | 4.49 | 5.90 | 5.74 |

April 2013 – March 2014

| Effective dose (E) mSv | TEPCO | Contractors | Total |
|---|---|---|---|
| 250 < E | 0 | 0 | 0 |
| 200 < E≦250 | 0 | 0 | 0 |
| 150 < E≦200 | 0 | 0 | 0 |
| 100 < E≦150 | 0 | 0 | 0 |
| 75 < E≦100 | 0 | 0 | 0 |
| 50 < E≦75 | 0 | 0 | 0 |
| 20 < E≦50 | 31 | 629 | 660 |
| 10 < E≦20 | 95 | 2,067 | 2,162 |
| 5 < E≦10 | 195 | 1,897 | 2,092 |
| 1 < E≦5 | 670 | 3,739 | 4,409 |
| E≦1 | 701 | 4,722 | 5,423 |
| Total | 1,692 | 13,054 | 14,746 |
| Maximum (mSv) | 41.90 | 41.40 | 41.90 |
| Average (mSv) | 3.24 | 5.51 | 5.25 |

April 2014 – March 2015

| Effective dose (E) mSv | TEPCO | Contractors | Total |
|---|---|---|---|
| 250 < E | 0 | 0 | 0 |
| 200 < E≦250 | 0 | 0 | 0 |
| 150 < E≦200 | 0 | 0 | 0 |
| 100 < E≦150 | 0 | 0 | 0 |
| 75 < E≦100 | 0 | 0 | 0 |
| 50 < E≦75 | 0 | 0 | 0 |
| 20 < E≦50 | 11 | 997 | 1,008 |
| 10 < E≦20 | 60 | 2,599 | 2,659 |
| 5 < E≦10 | 158 | 2,775 | 2,933 |
| 1 < E≦5 | 637 | 5,313 | 5,950 |
| E≦1 | 822 | 7,358 | 8,180 |
| Total | 1,688 | 19,042 | 20,730 |
| Maximum (mSv) | 29.50 | 39.85 | 39.85 |
| Average (mSv) | 2.30 | 5.29 | 5.04 |

April 2015 - December 2015

| Effective dose (E) mSv | TEPCO | Contractors | Total |
|---|---|---|---|
| 250 < E | 0 | 0 | 0 |
| 200 < E≦250 | 0 | 0 | 0 |
| 150 < E≦200 | 0 | 0 | 0 |
| 100 < E≦150 | 0 | 0 | 0 |
| 75 < E≦100 | 0 | 0 | 0 |
| 50 < E≦75 | 0 | 0 | 0 |
| 20 < E≦50 | 2 | 387 | 389 |
| 10 < E≦20 | 29 | 1,433 | 1,462 |
| 5 < E≦10 | 95 | 1,944 | 2,039 |
| 1 < E≦5 | 424 | 5,079 | 5,503 |
| E≦1 | 1,089 | 6,548 | 7,637 |
| Total | 1,639 | 15,391 | 17,030 |
| Maximum (mSv) | 21.06 | 38.61 | 38.61 |
| Average (mSv) | 1.45 | 3.77 | 3.54 |

*The exposure dose is subject to change due to the replacement of the PAD-measured dose by the glass badge-measured dose. The number of workers is also subject to change due to the addition of workers who wore only glass badges (e.g., workers who work only indoors).

[Table 2 Radiation Exposure Dose Distribution (by month)]

As of 31 December 2015

| Month/ Year | | E≦1 | 1＜E≦5 | 5＜E≦10 | 10＜E≦20 | 20＜E≦50 | 50＜E≦75 | 75＜E≦100 | 100＜E≦150 | 150＜E≦200 | 200＜E≦250 | 250＜E | Total | Maximum (mSv) | Average (mSv) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| March 2011 | TEPCO | 40 | 66 | 239 | 529 | 539 | 119 | 77 | 65 | 16 | | 6 | 1,696 | 670.36 | 31.54 |
| | Contractors | 405 | 524 | 397 | 460 | 371 | 65 | 34 | 17 | 2 | 2 | | 2,277 | 238.42 | 14.16 |
| | Total | 445 | 590 | 636 | 989 | 910 | 184 | 111 | 82 | 18 | 2 | 6 | 3,973 | 670.36 | 21.57 |
| April 2011 | TEPCO | 228 | 323 | 857 | 186 | 62 | 1 | | | | | | 1,657 | 59.60 | 6.66 |
| | Contractors | 1,556 | 1,466 | 624 | 433 | 128 | | | | | | | 4,207 | 49.61 | 4.34 |
| | Total | 1,784 | 1,789 | 1,481 | 619 | 190 | 1 | | | | | | 5,864 | 59.60 | 5.00 |
| May 2011 | TEPCO | 437 | 782 | 171 | 73 | 14 | | | | | | | 1,477 | 33.42 | 3.14 |
| | Contractors | 2,216 | 2,369 | 806 | 349 | 80 | | | | | | | 5,820 | 48.80 | 3.37 |
| | Total | 2,653 | 3,151 | 977 | 422 | 94 | | | | | | | 7,297 | 48.80 | 3.32 |
| June 2011 | TEPCO | 513 | 723 | 85 | 30 | | | | | | | | 1,351 | 16.29 | 2.12 |
| | Contractors | 2,548 | 2,648 | 768 | 350 | 65 | 1 | 1 | | | | | 6,381 | 89.50 | 3.08 |
| | Total | 3,061 | 3,371 | 853 | 380 | 65 | 1 | 1 | | | | | 7,732 | 89.50 | 2.91 |
| July 2011 | TEPCO | 653 | 625 | 53 | 17 | 3 | | | | | | | 1,351 | 31.13 | 1.69 |
| | Contractors | 2,893 | 2,758 | 587 | 200 | 37 | 3 | | | | | | 6,478 | 61.97 | 2.44 |
| | Total | 3,546 | 3,383 | 640 | 217 | 40 | 3 | | | | | | 7,829 | 61.97 | 2.31 |
| August 2011 | TEPCO | 543 | 666 | 57 | 19 | 1 | | | | | | | 1,286 | 23.33 | 1.72 |
| | Contractors | 2,814 | 2,727 | 485 | 162 | 25 | 2 | | | | | | 6,215 | 66.50 | 2.20 |
| | Total | 3,357 | 3,393 | 542 | 181 | 26 | 2 | | | | | | 7,501 | 66.50 | 2.12 |
| September 2011 | TEPCO | 534 | 633 | 38 | 2 | | | | | | | | 1,207 | 11.35 | 1.45 |
| | Contractors | 2,840 | 2,583 | 399 | 140 | 23 | | | | | | | 5,985 | 33.40 | 2.02 |
| | Total | 3,374 | 3,216 | 437 | 142 | 23 | | | | | | | 7,192 | 33.40 | 1.92 |
| October 2011 | TEPCO | 564 | 552 | 45 | 15 | 3 | | | | | | | 1,179 | 36.35 | 1.57 |
| | Contractors | 2,812 | 2,350 | 337 | 103 | 8 | | | | | | | 5,610 | 23.50 | 1.85 |
| | Total | 3,376 | 2,902 | 382 | 118 | 11 | | | | | | | 6,789 | 36.35 | 1.80 |
| November 2011 | TEPCO | 853 | 280 | 37 | 10 | | | | | | | | 1,180 | 13.40 | 1.07 |
| | Contractors | 3,349 | 1,911 | 227 | 82 | 5 | | | | | | | 5,574 | 23.03 | 1.46 |
| | Total | 4,202 | 2,191 | 264 | 92 | 5 | | | | | | | 6,754 | 23.03 | 1.39 |
| December 2011 | TEPCO | 868 | 282 | 26 | 13 | 3 | | | | | | | 1,192 | 23.20 | 1.10 |
| | Contractors | 3,336 | 1,729 | 258 | 76 | | | | | | | | 5,399 | 19.20 | 1.44 |
| | Total | 4,204 | 2,011 | 284 | 89 | 3 | | | | | | | 6,591 | 23.20 | 1.38 |
| January 2012 | TEPCO | 761 | 284 | 37 | 13 | | | | | | | | 1,095 | 17.00 | 1.19 |
| | Contractors | 3,235 | 1,434 | 203 | 72 | 1 | | | | | | | 4,945 | 21.90 | 1.36 |
| | Total | 3,996 | 1,718 | 240 | 85 | 1 | | | | | | | 6,040 | 21.90 | 1.33 |
| February 2012 | TEPCO | 845 | 231 | 25 | 8 | | | | | | | | 1,109 | 17.63 | 0.91 |
| | Contractors | 2,944 | 1,578 | 221 | 100 | 2 | | | | | | | 4,845 | 20.91 | 1.50 |
| | Total | 3,789 | 1,809 | 246 | 108 | 2 | | | | | | | 5,954 | 20.91 | 1.39 |
| March 2012 | TEPCO | 874 | 220 | 23 | 2 | | | | | | | | 1,119 | 12.10 | 0.83 |
| | Contractors | 3,029 | 1,464 | 206 | 53 | 3 | | | | | | | 4,755 | 21.83 | 1.36 |
| | Total | 3,903 | 1,684 | 229 | 55 | 3 | | | | | | | 5,874 | 21.83 | 1.26 |
| April 2012 | TEPCO | 870 | 179 | 19 | 3 | | | | | | | | 1,071 | 13.00 | 0.75 |
| | Contractors | 2,836 | 1,304 | 151 | 75 | 3 | | | | | | | 4,369 | 23.90 | 1.30 |
| | Total | 3,706 | 1,483 | 170 | 78 | 3 | | | | | | | 5,440 | 23.90 | 1.19 |
| May 2012 | TEPCO | 853 | 177 | 10 | 1 | | | | | | | | 1,042 | 10.20 | 0.66 |
| | Contractors | 2,898 | 1,406 | 246 | 49 | | | | | | | | 4,599 | 18.22 | 1.41 |
| | Total | 3,752 | 1,583 | 256 | 50 | | | | | | | | 5,641 | 18.22 | 1.28 |
| June 2012 | TEPCO | 829 | 162 | 20 | 3 | | | | | | | | 1,014 | 12.10 | 0.78 |
| | Contractors | 3,086 | 1,652 | 220 | 29 | | | | | | | | 4,987 | 14.94 | 1.29 |
| | Total | 3,915 | 1,814 | 240 | 32 | | | | | | | | 6,001 | 14.94 | 1.21 |

| Month/ Year | | E≦1 | 1＜E≦5 | 5＜E≦10 | 10＜E≦ 20 | 20＜E≦ 50 | 50＜E≦ 75 | 75＜E≦ 100 | 100＜E≦ 150 | 150＜E≦ 200 | 200＜E≦ 250 | 250＜E | Total | Maximum (mSv) | Average (mSv) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| July 2012 | TEPCO | 854 | 150 | 9 | | | | | | | | | 1,013 | 6.60 | 0.62 |
| | Contractors | 3,065 | 1,621 | 222 | 38 | | | | | | | | 4,946 | 17.33 | 1.34 |
| | Total | 3,919 | 1,771 | 231 | 38 | | | | | | | | 5,959 | 17.33 | 1.21 |
| August 2012 | TEPCO | 835 | 144 | 7 | | | | | | | | | 986 | 7.20 | 0.62 |
| | Contractors | 3,299 | 1,341 | 120 | 4 | | | | | | | | 4,764 | 11.64 | 1.04 |
| | Total | 4,134 | 1,485 | 127 | 4 | | | | | | | | 5,750 | 11.64 | 0.97 |
| September 2012 | TEPCO | 850 | 123 | 9 | | | | | | | | | 982 | 8.20 | 0.57 |
| | Contractors | 3,272 | 1,274 | 163 | 29 | 1 | | | | | | | 4,739 | 20.50 | 1.15 |
| | Total | 4,122 | 1,397 | 172 | 29 | 1 | | | | | | | 5,721 | 20.50 | 1.05 |
| October 2012 | TEPCO | 826 | 145 | 7 | | | | | | | | | 978 | 6.30 | 0.61 |
| | Contractors | 3,307 | 1,325 | 136 | 31 | | | | | | | | 4,799 | 16.00 | 1.11 |
| | Total | 4,133 | 1,470 | 143 | 31 | | | | | | | | 5,777 | 16.00 | 1.03 |
| November 2012 | TEPCO | 812 | 149 | 7 | | | | | | | | | 968 | 9.50 | 0.61 |
| | Contractors | 3,306 | 1,222 | 145 | 27 | | | | | | | | 4,700 | 18.70 | 1.09 |
| | Total | 4,118 | 1,371 | 152 | 27 | | | | | | | | 5,668 | 18.70 | 1.01 |
| December 2012 | TEPCO | 846 | 149 | 10 | | | | | | | | | 1,005 | 7.50 | 0.58 |
| | Contractors | 3,469 | 1,363 | 180 | 10 | | | | | | | | 5,042 | 15.00 | 1.10 |
| | Total | 4,335 | 1,512 | 190 | 10 | | | | | | | | 6,047 | 15.00 | 1.01 |
| January 2013 | TEPCO | 870 | 96 | 3 | | | | | | | | | 969 | 7.39 | 0.42 |
| | Contractors | 3,768 | 1,310 | 115 | 7 | | | | | | | | 5,200 | 12.90 | 0.96 |
| | Total | 4,638 | 1,406 | 118 | 7 | | | | | | | | 6,169 | 12.90 | 0.88 |
| February 2013 | TEPCO | 870 | 105 | 2 | | | | | | | | | 977 | 5.43 | 0.45 |
| | Contractors | 3,916 | 1,415 | 263 | 35 | | | | | | | | 5,629 | 18.50 | 1.21 |
| | Total | 4,786 | 1,520 | 265 | 35 | | | | | | | | 6,606 | 18.50 | 1.29 |
| March 2013 | TEPCO | 845 | 140 | 10 | 2 | | | | | | | | 997 | 11.03 | 0.60 |
| | Contractors | 3,907 | 1,706 | 335 | 35 | | | | | | | | 5,983 | 19.30 | 1.35 |
| | Total | 4,752 | 1,846 | 345 | 37 | | | | | | | | 6,980 | 19.30 | 1.24 |
| April 2013 | TEPCO | 948 | 108 | 4 | | | | | | | | | 1,060 | 5.90 | 0.49 |
| | Contractors | 4,029 | 1,165 | 111 | 5 | | | | | | | | 5,310 | 14.40 | 0.88 |
| | Total | 4,977 | 1,273 | 115 | 5 | | | | | | | | 6,370 | 14.40 | 0.81 |
| May 2013 | TEPCO | 896 | 100 | 4 | | | | | | | | | 1,000 | 8.60 | 0.45 |
| | Contractors | 3,920 | 1,141 | 92 | 5 | | | | | | | | 5,158 | 15.80 | 0.85 |
| | Total | 4,816 | 1,241 | 96 | 5 | | | | | | | | 6,158 | 15.80 | 0.78 |
| June 2013 | TEPCO | 931 | 87 | 6 | | | | | | | | | 1,024 | 7.40 | 0.42 |
| | Contractors | 3,731 | 1,182 | 85 | 7 | | | | | | | | 5,005 | 17.50 | 0.87 |
| | Total | 4,662 | 1,269 | 91 | 7 | | | | | | | | 6,029 | 17.50 | 0.79 |
| July 2013 | TEPCO | 891 | 96 | 1 | | | | | | | | | 988 | 5.50 | 0.43 |
| | Contractors | 3,752 | 1,128 | 107 | 9 | | | | | | | | 4,996 | 14.80 | 0.89 |
| | Total | 4,643 | 1,224 | 108 | 9 | | | | | | | | 5,984 | 14.80 | 0.81 |
| August 2013 | TEPCO | 834 | 118 | 4 | | | | | | | | | 956 | 6.1 | 0.49 |
| | Contractors | 3,665 | 1,211 | 142 | 40 | | | | | | | | 5,058 | 19.89 | 1.03 |
| | Total | 4,499 | 1,329 | 146 | 40 | | | | | | | | 6,014 | 19.89 | 0.94 |
| September 2013 | TEPCO | 933 | 102 | 3 | | | | | | | | | 1,038 | 5.60 | 0.44 |
| | Contractors | 3,525 | 1,420 | 247 | 61 | 1 | | | | | | | 5,254 | 20.58 | 1.28 |
| | Total | 4,458 | 1,522 | 250 | 61 | 1 | | | | | | | 6,292 | 20.58 | 1.14 |
| October 2013 | TEPCO | 893 | 146 | 8 | | | | | | | | | 1,047 | 9.50 | 0.55 |
| | Contractors | 3,460 | 1,556 | 343 | 47 | | | | | | | | 5,406 | 19.36 | 1.43 |
| | Total | 4,353 | 1,702 | 351 | 47 | | | | | | | | 6,453 | 19.36 | 1.29 |

| Month/ Year | | E≦1 | 1＜E≦5 | 5＜E≦10 | 10＜E≦ 20 | 20＜E≦ 50 | 50＜E≦ 75 | 75＜E≦ 100 | 100＜E≦ 150 | 150＜E≦ 200 | 200＜E≦ 250 | 250＜E | Total | Maximum (mSv) | Average (mSv) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| November 2013 | TEPCO | 954 | 120 | 5 | | | | | | | | | 1,079 | 9.20 | 0.48 |
| | Contractors | 3,700 | 1,533 | 303 | 32 | | | | | | | | 5,568 | 16.91 | 1.28 |
| | Total | 4,654 | 1,653 | 308 | 32 | | | | | | | | 6,647 | 16.91 | 1.15 |
| December 2013 | TEPCO | 968 | 116 | 2 | | | | | | | | | 1,086 | 5.40 | 0.44 |
| | Contractors | 3,852 | 1,627 | 199 | 23 | | | | | | | | 5,701 | 16.81 | 1.13 |
| | Total | 4,820 | 1,743 | 201 | 23 | | | | | | | | 6,787 | 16.81 | 1.02 |
| January 2014 | TEPCO | 997 | 84 | | | | | | | | | | 1,081 | 4.50 | 0.37 |
| | Contractors | 4,112 | 1,505 | 221 | 53 | | | | | | | | 5,891 | 15.80 | 1.16 |
| | Total | 5,109 | 1,589 | 221 | 53 | | | | | | | | 6,972 | 15.80 | 1.04 |
| February 2014 | TEPCO | 1,018 | 56 | 4 | | | | | | | | | 1,078 | 6.50 | 0.34 |
| | Contractors | 4,611 | 1,611 | 168 | 30 | | | | | | | | 6,420 | 17.29 | 1.02 |
| | Total | 5,629 | 1,667 | 172 | 30 | | | | | | | | 7,498 | 17.29 | 0.92 |
| March 2014 | TEPCO | 1,012 | 85 | | | | | | | | | | 1,097 | 4.80 | 0.36 |
| | Contractors | 4,940 | 1,867 | 227 | 23 | | | | | | | | 7,057 | 18.49 | 1.07 |
| | Total | 5,952 | 1,952 | 227 | 23 | | | | | | | | 8,154 | 18.49 | 0.98 |
| April 2014 | TEPCO | 999 | 94 | 1 | | | | | | | | | 1,094 | 5.70 | 0.38 |
| | Contractors | 5,449 | 1,743 | 234 | 19 | | | | | | | | 7,445 | 16.00 | 0.98 |
| | Total | 6,448 | 1,873 | 235 | 19 | | | | | | | | 8,539 | 16.00 | 0.91 |
| May 2014 | TEPCO | 1,053 | 65 | 1 | | | | | | | | | 1,119 | 5.60 | 0.31 |
| | Contractors | 5,974 | 1,794 | 209 | 47 | 1 | | | | | | | 8,025 | 20.70 | 0.95 |
| | Total | 7,027 | 1,859 | 210 | 47 | 1 | | | | | | | 9,144 | 20.70 | 0.87 |
| June 2014 | TEPCO | 1,056 | 66 | 1 | | | | | | | | | 1,123 | 6.80 | 0.32 |
| | Contractors | 6,774 | 1,790 | 329 | 26 | | | | | | | | 8,919 | 16.89 | 0.95 |
| | Total | 7,830 | 1,856 | 330 | 26 | | | | | | | | 10,042 | 16.89 | 0.88 |
| July 2014 | TEPCO | 1,092 | 39 | 1 | | | | | | | | | 1,132 | 5.40 | 0.27 |
| | Contractors | 7,292 | 1,728 | 258 | 49 | | | | | | | | 9,327 | 18.69 | 0.89 |
| | Total | 8,384 | 1,767 | 259 | 49 | | | | | | | | 10,459 | 18.69 | 0.82 |
| August 2014 | TEPCO | 1,062 | 39 | | | | | | | | | | 1,101 | 3.40 | 0.25 |
| | Contractors | 7,818 | 1,388 | 214 | 9 | | | | | | | | 9,379 | 17.13 | 0.71 |
| | Total | 8,880 | 1,377 | 214 | 9 | | | | | | | | 10,480 | 17.13 | 0.67 |
| September 2014 | TEPCO | 1,110 | 51 | 1 | | | | | | | | | 1,162 | 6.00 | 0.27 |
| | Contractors | 8,010 | 1,634 | 288 | 36 | | | | | | | | 9,968 | 18.22 | 0.84 |
| | Total | 9,120 | 1,685 | 289 | 36 | | | | | | | | 11,130 | 18.22 | 0.78 |
| October 2014 | TEPCO | 1,112 | 62 | | | | | | | | | | 1,174 | 2.70 | 0.29 |
| | Contractors | 7,950 | 1,766 | 234 | 18 | | | | | | | | 9,968 | 14.92 | 0.80 |
| | Total | 9,062 | 1,828 | 234 | 18 | | | | | | | | 11,142 | 14.92 | 0.74 |
| November 2014 | TEPCO | 1,141 | 45 | | | | | | | | | | 1,186 | 3.00 | 0.21 |
| | Contractors | 8,197 | 1,644 | 269 | 19 | | | | | | | | 10,129 | 15.92 | 0.78 |
| | Total | 9,338 | 1,689 | 269 | 19 | | | | | | | | 11,315 | 15.92 | 0.72 |
| December 2014 | TEPCO | 1,099 | 60 | | | | | | | | | | 1,159 | 4.30 | 0.24 |
| | Contractors | 8,270 | 1,912 | 283 | 34 | | | | | | | | 10,499 | 16.74 | 0.85 |
| | Total | 9,369 | 1,972 | 283 | 34 | | | | | | | | 11,658 | 16.74 | 0.79 |
| January 2015 | TEPCO | 1,111 | 37 | | | | | | | | | | 1,148 | 4.20 | 0.22 |
| | Contractors | 8,514 | 1,513 | 56 | 1 | | | | | | | | 10,084 | 12.80 | 0.56 |
| | Total | 9,625 | 1,550 | 56 | 1 | | | | | | | | 11,232 | 12.80 | 0.53 |
| February 2015 | TEPCO | 1,096 | 74 | 6 | | | | | | | | | 1,176 | 8.00 | 0.33 |
| | Contractors | 8,497 | 2,214 | 285 | 36 | | | | | | | | 11,032 | 16.80 | 0.89 |
| | Total | 9,593 | 2,288 | 291 | 36 | | | | | | | | 12,208 | 16.80 | 0.83 |

| Month/ Year | | E≦1 | 1＜E≦5 | 5＜E≦10 | 10＜E≦ 20 | 20＜E≦ 50 | 50＜E≦ 75 | 75＜E≦ 100 | 100＜E≦ 150 | 150＜E≦ 200 | 200＜E≦ 250 | 250＜E | Total | Maximum (mSv) | Average (mSv) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| March 2015 | TEPCO | 1,060 | 79 | 3 | | | | | | | | | 1,142 | 6.40 | 0.32 |
| | Contractors | 8,034 | 2,464 | 555 | 118 | | | | | | | | 11,171 | 19.90 | 1.22 |
| | Total | 9,094 | 2,543 | 558 | 118 | | | | | | | | 12,313 | 19.90 | 1.13 |
| April 2015 | TEPCO | 1,100 | 66 | | | | | | | | | | 1,166 | 4.80 | 0.27 |
| | Contractors | 7,694 | 2,413 | 248 | 20 | | | | | | | | 10,375 | 15.60 | 0.93 |
| | Total | 8,794 | 2,479 | 248 | 20 | | | | | | | | 11,541 | 15.60 | 0.86 |
| May 2015 | TEPCO | 1,092 | 42 | | | | | | | | | | 1,134 | 2.12 | 0.20 |
| | Contractors | 8,100 | 1,747 | 97 | 4 | | | | | | | | 9,948 | 11.40 | 0.66 |
| | Total | 9,192 | 1,789 | 97 | 4 | | | | | | | | 11,082 | 11.40 | 0.61 |
| June 2015 | TEPCO | 1,128 | 64 | | | | | | | | | | 1,192 | 3.90 | 0.25 |
| | Contractors | 8,185 | 1,737 | 167 | 12 | | | | | | | | 10,101 | 11.50 | 0.72 |
| | Total | 9,393 | 1,801 | 167 | 12 | | | | | | | | 11,293 | 11.50 | 0.67 |
| July 2015 | TEPCO | 1,116 | 56 | 1 | | | | | | | | | 1,173 | 5.10 | 0.26 |
| | Contractors | 8,140 | 1,646 | 134 | 7 | | | | | | | | 9,927 | 10.72 | 0.66 |
| | Total | 9,256 | 1,702 | 135 | 7 | | | | | | | | 11,100 | 10.72 | 0.62 |
| August 2015 | TEPCO | 1,083 | 53 | | | | | | | | | | 1,136 | 3.38 | 0.21 |
| | Contractors | 8,369 | 1,040 | 36 | 1 | | | | | | | | 9,446 | 10.30 | 0.43 |
| | Total | 9,452 | 1,093 | 36 | 1 | | | | | | | | 10,582 | 10.30 | 0.41 |
| September 2015 | TEPCO | 1,144 | 51 | 1 | | | | | | | | | 1,196 | 5.60 | 0.24 |
| | Contractors | 8,034 | 1,590 | 140 | 16 | | | | | | | | 9,780 | 15.30 | 0.67 |
| | Total | 9,178 | 1,641 | 141 | 16 | | | | | | | | 10,976 | 15.30 | 0.63 |
| October 2015 | TEPCO | 1,130 | 52 | | | | | | | | | | 1,182 | 3.20 | 0.22 |
| | Contractors | 7,864 | 1,699 | 145 | 9 | | | | | | | | 9,717 | 14.42 | 0.70 |
| | Total | 8,994 | 1,751 | 145 | 9 | | | | | | | | 10,899 | 14.42 | 0.64 |
| November 2015 | TEPCO | 1,119 | 48 | | | | | | | | | | 1,167 | 4.96 | 0.22 |
| | Contractors | 7,924 | 1,447 | 110 | 7 | | | | | | | | 9,488 | 13.88 | 0.61 |
| | Total | 9,043 | 1,495 | 110 | 7 | | | | | | | | 10,655 | 13.88 | 0.57 |
| December 2015 | TEPCO | 1,014 | 43 | | | | | | | | | | 1,057 | 2.59 | 0.18 |
| | Contractors | 7,989 | 1,256 | 66 | 4 | | | | | | | | 9,315 | 13.27 | 0.51 |
| | Total | 9,003 | 1,299 | 66 | 4 | | | | | | | | 10,372 | 13.27 | 0.47 |

*The exposure dose is subject to change due to the replacement of the PAD-measured dose by the glass badge-measured dose.
The number of workers is also subject to change due to the addition of workers who wore only glass badges (e.g., workers who work only indoors).

[Table 3 Radiation Exposure Dose Distribution (by age)]

As of 31 December 2015

Ages 18 to 19

| Effective dose (E) mSv | TEPCO | Contractors | Total |
|---|---|---|---|
| 250 < E | 0 | 0 | 0 |
| 200 < E≦250 | 0 | 0 | 0 |
| 150 < E≦200 | 0 | 0 | 0 |
| 100 < E≦150 | 0 | 0 | 0 |
| 75 < E≦100 | 0 | 0 | 0 |
| 50 < E≦75 | 0 | 0 | 0 |
| 20 < E≦50 | 0 | 3 | 3 |
| 10 < E≦20 | 0 | 10 | 10 |
| 5 < E≦10 | 0 | 7 | 7 |
| 1 < E≦5 | 0 | 15 | 15 |
| E≦1 | 0 | 20 | 20 |
| Total | 0 | 55 | 55 |
| Maximum (mSv) | 0.00 | 30.80 | 30.80 |
| Average (mSv) | 0.00 | 5.80 | 5.80 |

Ages 20 to 29

| Effective dose (E) mSv | TEPCO | Contractors | Total |
|---|---|---|---|
| 250 < E | 2 | 0 | 2 |
| 200 < E≦250 | 0 | 0 | 0 |
| 150 < E≦200 | 3 | 0 | 3 |
| 100 < E≦150 | 8 | 0 | 8 |
| 75 < E≦100 | 75 | 9 | 84 |
| 50 < E≦75 | 43 | 93 | 136 |
| 20 < E≦50 | 67 | 529 | 596 |
| 10 < E≦20 | 90 | 567 | 657 |
| 5 < E≦10 | 58 | 532 | 590 |
| 1 < E≦5 | 72 | 898 | 970 |
| E≦1 | 73 | 1,009 | 1,082 |
| Total | 491 | 3,637 | 4,128 |
| Maximum (mSv) | 477.01 | 99.25 | 477.01 |
| Average (mSv) | 31.77 | 10.28 | 12.84 |

Ages 30 to 39

| Effective dose (E) mSv | TEPCO | Contractors | Total |
|---|---|---|---|
| 250 < E | 1 | 0 | 1 |
| 200 < E≦250 | 1 | 2 | 3 |
| 150 < E≦200 | 0 | 1 | 1 |
| 100 < E≦150 | 27 | 1 | 28 |
| 75 < E≦100 | 89 | 44 | 133 |
| 50 < E≦75 | 86 | 318 | 404 |
| 20 < E≦50 | 138 | 1,178 | 1,316 |
| 10 < E≦20 | 148 | 1,001 | 1,150 |
| 5 < E≦10 | 93 | 949 | 1,042 |
| 1 < E≦5 | 161 | 1,613 | 1,774 |
| E≦1 | 217 | 2,019 | 2,236 |
| Total | 962 | 7,126 | 8,088 |
| Maximum (mSv) | 310.97 | 238.42 | 310.97 |
| Average (mSv) | 25.52 | 12.24 | 13.82 |

Ages 40 to 49

| Effective dose (E) mSv | TEPCO | Contractors | Total |
|---|---|---|---|
| 250 < E | 2 | 0 | 2 |
| 200 < E≦250 | 0 | 0 | 0 |
| 150 < E≦200 | 9 | 0 | 9 |
| 100 < E≦150 | 33 | 5 | 38 |
| 75 < E≦100 | 79 | 73 | 152 |
| 50 < E≦75 | 90 | 517 | 607 |
| 20 < E≦50 | 206 | 1,841 | 2,047 |
| 10 < E≦20 | 223 | 1,648 | 1,871 |
| 5 < E≦10 | 188 | 1,560 | 1,748 |
| 1 < E≦5 | 361 | 2,653 | 3,014 |
| E≦1 | 456 | 3,556 | 4,012 |
| Total | 1,647 | 11,853 | 13,500 |
| Maximum (mSv) | 678.80 | 133.24 | 678.80 |
| Average (mSv) | 19.05 | 11.75 | 12.64 |

Ages 50 to 59

| Effective dose (E) mSv | TEPCO | Contractors | Total |
|---|---|---|---|
| 250 < E | 1 | 0 | 1 |
| 200 < E≦250 | 0 | 0 | 0 |
| 150 < E≦200 | 13 | 0 | 13 |
| 100 < E≦150 | 45 | 10 | 55 |
| 75 < E≦100 | 64 | 89 | 153 |
| 50 < E≦75 | 93 | 510 | 603 |
| 20 < E≦50 | 189 | 1,764 | 1,953 |
| 10 < E≦20 | 148 | 1,534 | 1,682 |
| 5 < E≦10 | 135 | 1,442 | 1,577 |
| 1 < E≦5 | 257 | 2,533 | 2,790 |
| E≦1 | 459 | 3,481 | 3,490 |
| Total | 1,404 | 11,363 | 12,767 |
| Maximum (mSv) | 353.12 | 147.90 | 353.12 |
| Average (mSv) | 21.10 | 12.00 | 13.00 |

Ages 60 to 69

| Effective dose (E) mSv | TEPCO | Contractors | Total |
|---|---|---|---|
| 250 < E | 0 | 0 | 0 |
| 200 < E≦250 | 0 | 0 | 0 |
| 150 < E≦200 | 1 | 1 | 2 |
| 100 < E≦150 | 4 | 4 | 8 |
| 75 < E≦100 | 7 | 53 | 60 |
| 50 < E≦75 | 17 | 276 | 293 |
| 20 < E≦50 | 33 | 1,013 | 1,046 |
| 10 < E≦20 | 9 | 874 | 883 |
| 5 < E≦10 | 20 | 827 | 847 |
| 1 < E≦5 | 28 | 1,752 | 1,780 |
| E≦1 | 53 | 2,361 | 2,414 |
| Total | 172 | 7,176 | 7,333 |
| Maximum (mSv) | 197.00 | 176.00 | 197.00 |
| Average (mSv) | 21.90 | 10.86 | 11.12 |

Ages 70 and over

| Effective dose (E) mSv | TEPCO | Contractors | Total |
|---|---|---|---|
| 250 < E | 0 | 0 | 0 |
| 200 < E≦250 | 0 | 0 | 0 |
| 150 < E≦200 | 0 | 0 | 0 |
| 100 < E≦150 | 0 | 0 | 0 |
| 75 < E≦100 | 0 | 2 | 2 |
| 50 < E≦75 | 0 | 3 | 3 |
| 20 < E≦50 | 0 | 22 | 22 |
| 10 < E≦20 | 1 | 31 | 32 |
| 5 < E≦10 | 1 | 43 | 44 |
| 1 < E≦5 | 0 | 87 | 87 |
| E≦1 | 1 | 112 | 113 |
| Total | 3 | 300 | 303 |
| Maximum (mSv) | 16.19 | 89.50 | 89.50 |
| Average (mSv) | 8.37 | 6.64 | 6.65 |

Number of workers

| | TEPCO | Contractors | Total |
|---|---|---|---|
| Ages 18 to 19 | 0 | 55 | 55 |
| Ages 20 to 29 | 491 | 3,637 | 4,128 |
| Ages 30 to 39 | 962 | 7,126 | 8,088 |
| Ages 40 to 49 | 1,647 | 11,853 | 13,500 |
| Ages 50 to 59 | 1,404 | 11,363 | 12,767 |
| Ages 60 to 69 | 172 | 7,161 | 7,333 |
| Ages 70 and over | 3 | 300 | 303 |
| Ages unknown* | 0 | 7 | 7 |
| Total | 4,679 | 41,502 | 46,181 |
| Maximum (mSv) | 678.80 | 238.42 | 678.80 |
| Average (mSv) | 22.43 | 11.57 | 12.67 |

* Seven people, who cannot be contacted, are treated as "ages unknown", because it is impossible to put them into any group.

# 2. Decontamination Works Resulting from the Accident of the TEPCO Fukushima Daiichi NPP and Necessary Radiation Protection Measures

## 2.1 Radiation protection of workers involved in decontamination works

The accident at the Fukushima Daiichi Nuclear Power Plant (NPP) released large amounts of radioactive materials. For rehabilitation of the contaminated areas, the Japanese Government has decided to carry out decontamination works (e.g., clean-up of buildings and remediation of soil and vegetation) and to manage the wastes resulting from decontamination works and clean-up of unmarketable contaminated goods. Prevention of radiological contamination of the workers has required that the Government ensure sufficient radiological protection is provided to them.

### 2.1.1 Radiation protection for workers engaged in decontamination works

The Act on Special Measures Concerning the Handling of Environmental Pollution by Radioactive Materials Discharged by the Nuclear Power Station Accident Associated with the Tohoku District Off the Pacific Ocean Earthquake That Occurred on 11 March 2011 (Act. No.110, 2011, hereinafter referred to as the "Act on Disaster Special Measures") was passed into law in August 2011, and fully implemented starting from 1 January 2012.

(1) The regulations established by the Act on Disaster Special Measures are as follows:
   a) Treatment of wastes contaminated with radioactive materials; and
   b) Actions such as decontamination of soil contaminated with radioactive materials.

   However, the Act on Disaster Special Measures does not include measures for protecting workers engaged in these tasks from health hazards caused by exposure to ionizing radiation.

(2) In addition, in the current Ordinance on Prevention of Ionizing Radiation Hazards (Ordinance No. 41 of the Ministry of Labour, 1972, hereinafter referred to as the "Ionizing Radiation Ordinance"), measures are established on the premise that the radioactive sources are located at a certain place, such as at medical facilities or at NPPs, where workers mainly work indoors (planned exposure situations).

   Measures for responding to the types of decontamination works that involve collection of wastes stipulated in the Act on Disaster Special Measures are not included. Furthermore, this Act was not established on the premise that the radioactive sources are dispersed over wide areas and that workers mostly work outdoors (existing exposure situations).

(3) Further, under the fundamental policies, based on the Act on Disaster Special Measures, approved by the cabinet on 11 November 2011, it is stated that "ensuring the safety of workers is the highest priority when handling environmental decontamination. Therefore, the employers should take great care regarding the safety and health of workers engaged in duties concerning decontamination of the environment, for example, by providing radiological protection guidance. In addition, they should manage the radiation doses received by the workers and provide workers with opportunities to enhance their knowledge of safety and health."

   Considering the situation, a new ordinance was formulated that regulates measures to properly protect workers from health hazards caused by ionizing radiation based on the nature of the works such as decontamination works and waste collection works; this is the "Ordinance on Prevention of Ionizing Radiation Hazards at Works to Decontaminate Soil and Wastes Contaminated by Radioactive Materials Resulting from the Great East Japan Earthquake and Related Works" (hereinafter referred to as the "Decontamination Ordinance." This Ordinance was formulated separately from the current Ionizing Radiation Ordinance.

### 2.1.2 Radiation protection for workers engaged in restoration and reconstruction works

The Nuclear Emergency Response Headquarters and the National Reconstruction Agency revised the classification of the evacuation areas around the TEPCO Fukushima Daiichi NPP (restricted areas and deliberate evacuation areas) into 3 types of areas on 1 April 2012: (1) Areas for which evacuation orders are ready to be lifted; (2) Areas in which the residents are not permitted to live; and (3) Areas where it is expected that the residents will have difficulties in returning for a long time.

In the "Areas in which evacuation orders are ready to be lifted", activities can be started for:

(1) Restoring local infrastructures other than those requiring decontamination;
(2) Restarting businesses such as manufacturing industries;
(3) Preparing to reopen hospitals and welfare facilities;
(4) Restarting agriculture and forestry industries; and
(5) Restarting transportation services associated with these activities.

The Decontamination Ordinance which came into force on 1 January 2012 was applicable only for decontamination operations (decontaminating soil, and collecting, transporting and storing wastes). For applications of the above activities, revision of the Ordinance was required.

Therefore, the expert meeting originally organized to discuss decontamination operations was reorganized to discuss measures to protect workers from radiation hazards in the evacuation areas. The committee compiled their discussions and issued a second report on 27 April 2012.

Based on this report, the Decontamination Ordinance was amended and guidelines were prepared that summarize relevant laws and regulations comprehensively and in an easy way to understand manner.*1)

*1) Under the amended Decontamination Ordinance definitions were given for: "specified contaminated soil handling work (tasks handling soil with a cesium concentration exceeding 10,000 Bq/kg)" and "work under a designated dose rate (tasks performed

in the areas where the average ambient dose rate exceeds 2.5 μSv/h" (excluding decontamination operation, etc.)

### 2.1.3 Radiation protection for workers engaged in disposal of accident-derived waste

The Ministry of the Environment estimated that approximately 15 - 31 million tons of soil and wastes had been generated from decontamination works and clean-up of unmarketable contaminated goods had reached approximately 0.56 million tons in Fukushima Prefecture alone. The Ministry was expected to start deploying full-scale activities to dispose of those wastes in the summer of 2013.

Activities for accident-derived waste disposal*2) were subject to the Ionizing Radiation Ordinance; however, this ordinance did not contain sufficient regulations for employers involved in disposal work.

The expert meeting on radiation protection and waste disposal was held to consider measures to prevent radiological hazards. The report of the expert meeting was published on 14 February 2013.

Based on the report, the Ionizing Radiation Ordinance was amended and the new guidelines were developed that summarize relevant laws and regulations.

*2) These include e.g., final disposal (landfill), interim storage, and interim treatments (incineration, crushing, etc.)

## 2.2 Outline of ordinances which provide radiation protection during decontamination works and restoration and reconstruction works, etc.

Measures to prevent ionizing radiation hazards for each step are outlined below.

### 2.2.1 Outline of radiation protection measures during decontamination works

The Decontamination Ordinance specifies actions to be taken by the employer to prevent radiation exposure of workers engaged in decontamination of soil, collection of removed soil/waste in the areas contaminated by radioactive materials released from the accident at the Fukushima Daiichi NPP. Actions are largely divided into three types as follows:

**(1) Actions to reduce exposure**

- The dose limit for the workers shall be 100 mSv for five years, and not exceed 50 mSv for any one year (it shall not exceed 5 mSv for three months for potentially pregnant workers)
- In areas where dose rates are higher than 2.5 μSv/h (equivalent to 5 mSv/y)*3), the external dose shall be measured with a personal dosimeter (it should be noted that, in areas where dose rate is in the range of 0.23 μSv/h -2.5 μSv/h (1 mSv - 5 mSv/y), simple methods of measurement may be acceptable.)
- Measured data shall be kept for 30 years*4), as well, workers shall be notified of their doses.
- The decontamination shall be started after measuring dose rates, and conducted under the direction of an operation leader in accordance with the work plan. The decontamination in areas where the dose rate is higher than 2.5 μSv/h in particular, requires submitting a work plan to the relevant Labour Standards Inspection Office.

*3) This approximately corresponds to the areas that cover the deliberate evacuation areas and the restricted areas.

*4) After 5 years, the stored data may be transferred to the organization designated by the MHLW .

**(2) Actions to prevent spread of contamination**

- When dust containing a high concentration of radioactive cesium may be generated, dispersion of soil shall be prevented by moistening the soil. When works are involving soil with a high radioactivity concentration or the possibility that a high concentration of dust may be generated, workers shall wear proper respiratory protective equipment and protective clothes.
- Removed soil shall be stored in a container that meets certain requirements*5) and access to the containers shall be restricted.
- Smoking, drinking or eating in working areas that may have a risk of ingestion or inhalation of radioactive material shall be prohibited.
- Contamination inspection areas shall be set up where contamination surveys are conducted for the body and clothing of workers.

*5) The requirements are: no risk of dispersal or leaking of container contents; and the 1 cm dose equivalent rate at 1 m from the container surface shall be 0.1 mSv/h or less.

**(3) Education and health care of workers**

- Education shall be provided to workers who will be engaged in the decontamination works with respect to radiation effects, radiation dose control, work methods, etc.
- Special medical examinations shall be provided to workers when they are employed, their jobs are changed, and once every six months. The records of the medical examinations implemented for each worker shall be kept for 30 years*6) and notified to each worker. When any abnormalities are found in the medical examination of any workers, some consideration in their work shall be made, such as a change of workplace.
- When the workers leave the job or the companies terminate their decontamination business, the records of radiation doses of the workers and their individual medical examination records shall be delivered to the organization designated by the MHLW, and copies shall be given to the workers.
- The results of periodical special medical examinations shall be reported to the relevant Labour Standards Inspection Office.

*6) After 5 years, the data may be transferred to the organization designated by the MHLW.

### 2.2.2 Outline of radiation protection measures during restoration and reconstruction work

The MHLW published the ministerial ordinance which partially revises the "Ordinance on Prevention of Ionizing Radiation Hazards at Works to Decontaminate Soil and Wastes Contaminated by Radioactive Materials Resulting from the Great East Japan Earthquake and Related Works" (hereafter referred to as the "Ionizing Radiation Ordinance for Decontamination"). It was put into effect on 1 July 2012.

The revision was made anticipating the start and resumption of "restoration of life infrastructures (excluding decontamination works) and manufacturing industries"*7) in "special decontamination areas"*8) in response to the readjustment of the evacuation areas.

*7) This includes preparations for restarting hospitals and welfare facilities, agriculture and forestry operations, and associated transportation services.

*8) Specified by Article 25, Paragraph 1, of the Act on Disaster Special Measures.

The revision focuses on the following points:

1. Work involving contaminated soil with radioactivity higher than 10,000 Bq/kg (designated contaminated soil handling work) shall also be included in the decontamination operation, and
2. The Ionizing Radiation Ordinance for Decontamination shall also be applied to work other than decontamination at areas with an average ambient dose rate higher than 2.5 μSv/h (works under a designated dose rate).

Employers are required to take radiological protection measures for the types of works described above.

In conjunction with the above, the "guidelines on decontamination works, etc." was also revised, and "guidelines on work under a designated dose rate" were newly formulated. These guidelines summarized the content of the Ionizing Radiation Ordinance for Decontamination in a comprehensive manner and described provisions specified in the Industrial Safety and Health Act and other relevant regulations; as well they described recommended actions for employers to take in order to prevent workers from encountering radiological hazards . Specifically, the guidelines summarize the following items:

1. Identification of personnel for whom radiation dose needs to be controlled, and prescribe methods to control the radiation dose;
2. Measures to reduce radiation exposure;
3. Measures to prevent spread of contamination and internal exposure;
4. Worker education programs;
5. Actions for health care; and
6. Safety and health control system.

It should be noted that the guidelines are also expected to be useful for local residents or volunteers who are in the special decontamination areas, though their original purpose was to ensure safety of workers engaged in decontamination works or works under a designated dose rate. In addition, a textbook for special education of workers as specified in the Ionizing Radiation Ordinance for Decontamination was also prepared, and is available from the MHLW website.

### 2.2.3 Outline of radiation protection measures during disposal of accident-derived waste

The MHLW published a ministerial ordinance to revise the Ionizing Radiation Ordinance for Decontamination on 12 April 2013, and put the revised ordinance into effect on 1 July 2013.

This revision was made in light of the fact that disposal of wastes contaminated with radioactive materials discharged by the NPP accident associated with the 11 March 2011 earthquake and tsunami is expected to increase in scale with the progress of decontamination project.

Disposal business employers were recommended to take radiological hazard prevention measures for the 5 revised points shown below. It should be noted that definitions of controlled area, dose limits, dose measurement and recording and measures for health care shall follow the provisions in the current Ordinance on Preventing Ionizing Radiation Hazards.

1. Requirements to be satisfied by such facilities as incineration plants and landfills where the disposal of accident-derived wastes will be performed.
2. Measures to prevent the spread of contamination, such as the use of dust masks and protective clothing, as well as making contamination inspection.
3. Operation management by, for example, preparing operation manuals.
4. Special education for workers engaged in disposal work.
5. Exemptions when the disposal facility is constructed in special decontamination areas.

In parallel with the revision, "Guidelines on prevention of radiation hazards for workers engaged in the accident-derived waste disposal" were also prepared. These guidelines summarize the provisions specified in the Industrial Safety and Health Act and other relevant regulations, including the Ordinance for Preventing Ionizing Radiation Hazards, as well as recommended actions that employers shall implement in order to prevent workers from encountering radiological hazards. Specifically, the following subjects were included:

1. Methods for defining radiation controlled areas and controlling radiation doses
2. Education of workers
3. Dose limits in facilities
4. Actions for health care
5. Requirements for facilities to prevent contamination
6. Safety and health control system
7. Measures to prevent contamination
8. Exemptions in the special decontamination areas
9. Work management, etc.

A textbook for special education of workers engaged in the disposal works, as specified in this revision, was also prepared. This textbook is available from the MHLW website. The MHLW is making public the textbook so that it will be widely utilized by employers and workers in taking appropriate measures at work sites.

## 2.3 Status of the implementation of radiation protection corresponding to decontamination works

### 2.3.1 Results of inspection and instructions provided to employers engaged in decontamination works, etc.

The Fukushima Prefectural Labour Bureau (PLB) has conducted inspections and given instructions within the jurisdiction of the Labour Standards Inspection Offices to employers in order to ensure proper conditions of employment and safety, and the health of workers engaged in decontamination works, etc.

The investigations were focused on conditions of employment such as clear indications of conditions of employment, payment of wages, and working hours, reflecting the circumstances that some inquiries were raised about wages and other conditions of employment such as the special duty (decontamination) allowance.

As a result of inspections for 1,152 employers from January to December 2014, a total of 774 were recognized as being in violation (violation rate: 67.2%) of applicable laws such as the Labour Standards Act or the Industrial Safety and Health Act. The same inspections for 342 employers from January to June 2015 found a total of 233 were recognized as being in violation (violation rate: 68.1%). Corrective recommendations were issued to these employers to correct the said violations accordingly.

### 2.3.2 Voluntary activities towards compliance with laws and ordinances

On 30 October 2015, the Fukushima PLB formulated its own "General Measures toward Improvement of Level of Compliance with Laws and Ordinances for Decontamination Works, etc." Its contents include provision of focused supervision and instruction for decontamination worksites and promotion of voluntary activities towards compliance with the related laws and ordinances by the relevant employers.

On 9 November 2015, the Fukushima PLB held an information session on the General Measures. At the information session, the Bureau provided all the primary contractors of decontamination works ordered by the National Government (Ministry of the Environment) with detailed information on the General Measures, provided them with instruction on ensuring proper working conditions, safety and health of workers engaged in decontamination works as well as maintaining and improving the fairness in subcontracting relations, and requested them to thoroughly comply with the related laws and ordinances in collaboration with the Fukushima Office for Environmental Restoration.

# 3. Overview of Guidelines and Notifications

## 3.1 Overview of the Guidelines on Maintaining and Improving Health of Emergency Workers at Nuclear Facilities

These guidelines were issued on 11 October 2011 as "Guidelines on Maintaining and Improving Health of Emergency Workers at the TEPCO Fukushima Daiichi Nuclear Power Plant". The purpose of the guidelines is to support appropriate and effective implementation of measures to maintain and improve the health of workers who have engaged or had engaged in the emergency works or radiation works at the TEPCO Fukushima Daiichi NPP (hereinafter referred to as "emergency workers."). The guidelines require that the following measures are implemented appropriately to maintain and improve the health of emergency workers.

**(1) Actions for long-term health care**

- An on-site health care system should be established, appropriate to the scale of each workplace to implement the relevant medical examinations.
- The following examinations should be performed for those workers whose exposure doses (effective doses) during emergency works fall in the following ranges:
  (a) Higher than 50 mSv, a cataract examination once a year.
  (b) Higher than 100 mSv, a cancer screening once a year.
- Health guidance should be provided to all emergency workers

**(2) Development of a database for workers who have engaged in emergency works**

- Employers who assign their emergency workers to be engaged in the emergency works or radiation works should report to the Japanese Government the results of their medical examination and provide status reports on their radiation dose control.
  The same rule on the reporting requirement should apply to employees who had been emergency workers but were transferred to radiation works.
- A registration card for the database established by the Japanese Government should be issued to emergency workers. The emergency workers should be able to obtain transcripts of their records for exposure doses and medical examination results by presenting the card at the national support service.
- The emergency workers whose exposure doses are higher than 50 mSv are eligible to receive a record book describing the doses.

**(3) Support provided by the Japanese Government**

- Recommendations for cancer screenings and other examinations to emergency workers.
- Health consultations and guidance to emergency workers at the support services.
- Full or partial financial support for the expenses incurred by emergency workers who fall into the categories described in Section 2 of "Actions for long-term health care".

On 31 August 2015, the MHLW promulgated the partial revision of the Ministerial Ordinance on Prevention of Ionizing Radiation Hazards that defines actions to prevent workers from encountering radiation hazards, etc. In accordance with the partial revision of the ordinance, the above guidelines were revised (to be applied from 1 April 2016) as shown below.

- Modification of the name to "Guidelines on Maintaining and Improving Health of Emergency Workers at Nuclear Facilities".
- Enhanced long-term healthcare (examination items such as cancer screenings were added and a stress check will be provided).
- Mid-term exposure dose control for workers who were exposed to radiation beyond the dose limit for regular radiation works.
- Exposure dose control for the regular radiation works during the exposure dose control period including the time of the accident.

Further information is available on the following sites.
http://www.mhlw.go.jp/english/topics/2011eq/workers/tepco/rp/pr_150831_attachment06.pdf
http://www.mhlw.go.jp/english/topics/2011eq/workers/tepco/rp/pr_150831_attachment05.pdf (Overview)

## 3.2 Overview of the Ordinance on Prevention of Ionizing Radiation Hazards at Works to Decontaminate Soil and Wastes Contaminated by Radioactive Materials Resulting from the Great East Japan Earthquake and Related Works

The Ordinance on Prevention of Ionizing Radiation Hazards at Works to Decontaminate Soil and Wastes Contaminated by Radioactive Materials Resulting from the Great East Japan Earthquake and Related Works specifies the actions below to be taken by employers to prevent radiation exposure of workers engaged in decontamination works.

**(1) Fundamental principles and definitions**

- Employers shall strive toward minimizing worker exposure to ionizing radiation.

**(2) Measuring doses and monitoring the maximum dose levels**

- The exposure doses shall not exceed 100 mSv per five years and 50 mSv per one year.
- The exposure doses received by workers shall be monitored,

recorded, and the records kept for 30 years.
- The external exposure doses shall be monitored.
- The workers handling contaminated soil shall receive examinations for internal exposure doses.

**(3) Measures for implementation of decontamination works**
- Exposure doses in workplaces shall be surveyed and recorded before commencing works.
- A work plan shall be established and disseminated to every worker.
- An operation leader shall be appointed to lead the project.
- The work plan shall be submitted to the Head of the relevant Labour Standards Inspection Office.
- When the radiation doses exceed the maximum standardized levels, employers shall promptly consult a physician and report the case to the relevant office.

**(4) Prevention of contamination**
- For suppression of dust, measures shall be taken to keep contaminated soil and wastes in a wet condition.
- Contaminated soil and wastes shall be stored in containers.
- When workers leave their workplaces, their bodies and belongings shall be screened for contamination.
- When workers are engaged in certain designated works, they shall wear protective equipment.
- When protective equipment is contaminated, it shall not be used until it is decontaminated.
- In the workplaces, eating, drinking, and smoking shall be prohibited.

**(5) Education**
- Workers engaged in decontamination works shall receive special education.

**(6) Health care**
- Special medical examinations for workers engaged in decontamination works shall be conducted.
- The medical examination cards shall be created, and the examination results recorded on them and the cards kept for 30 years.
- Opinions of physicians shall be received and recorded on the medical examination cards.
- Workers shall be informed the results of the special medical examinations and the results shall be submitted to the Head of the relevant Labour Standards Inspection Office.
- Based on the medical examination results, workers shall receive needed measures to protect their health.

**(7) Others**
- Radiation dosimeters, which are indispensable to abide by the ordinance, shall be provided.
- When employers terminate their businesses, the records of radiation dose measurements and medical examination cards shall be transferred to the organization designated by the MHLW.
- When workers leave their jobs, such records shall be issued to the workers.
- Exposure doses shall be added to those received during other decontamination works.

Further information is available on the following site.
http://www.mhlw.go.jp/english/topics/2011eq/workers/ri/rl/rl_130412.pdf

## 3.3 Overview of the Guidelines on Prevention of Radiation Hazards for Workers Engaged in Decontamination Works

These guidelines specify actions to be taken by the employers to prevent radiation exposure for workers engaged in decontamination works. The guidelines were issued on 22 December 2011, partially revised on 15 June 2012 and again on 18 November 2014.

**(1) Objectives**
- These guidelines aim at collectively providing the essence of the actions that employers should take and the provisions specified in the Industrial Safety and Health Act (Act No. 57, 1972) and other relevant laws and regulations, in addition to the provisions specified in the revised Ionizing Radiation Ordinance for Decontamination.

**(2) Scope**
- "Decontamination works" refers to the works in performing decontamination of soil, etc., handling of designated contaminated soil, and wastes and collecting wastes, etc.
- Employers should follow applicable matters from each section of the guidelines, as needed.

**(3) Targets and methods for radiation exposure dose control**
- Employers for decontamination works, etc., should conduct effective exposure dose monitoring during decontamination works.
- Employers for decontamination works, etc., should ensure that the individual total effective dose does not exceed the limits defined in the guidelines. The records of exposure data should be kept for 30 years.

**(4) Measures to reduce radiation exposure**
- Employers for decontamination works, etc., should make surveys of workplaces in advance and formulate a work plan, according to which works should be conducted, based on the information from the preparatory survey.

**(5) Measures for preventions of contamination spreading and internal exposure**
- Control of dust generation by wetting soil, contamination screening for workers when leaving the controlled area, use of dust mask or other protective equipment etc., are required.

**(6) Education for workers**
- Education for operation leaders and special education for the workers are defined.

**(7) Measures for health care**
- Employers for decontamination works, etc., should provide workers with the special and general health examinations once every 6 months. The examination results should be recorded in the medical examination cards and the cards kept for 30 years.

**(8) Safety and health management system**
- The safety and health management system should be established by the primary contractors, by appointing a

general safety and health manager and a radiation administrator to conduct radiation dose control, and related activities.

Further information is available on the following site.
http://www.mhlw.go.jp/english/topics/2011eq/workers/dr/dr/pr_120615_a03.pdf

## 3.4 Overview of the Guidelines on Prevention of Radiation Hazards for Workers Engaged in Works under a Designated Dose Rate

These guidelines specify actions to be taken by the employers to prevent radiation exposure for workers engaged in works, such as restoration and reconstruction works, under a designated dose rate.

**(1) Purpose**

The Ionizing Radiation Ordinance was partially revised to regulate measures for appropriately protecting workers from health hazards caused by radiation, according to the types of restoration and reconstruction works.

**(2) Application**

These guidelines apply to employers who provide services other than the decontamination works at the sites where the average ambient dose rate exceeds 2.5μSv/h.

**(3) Recipients of radiation dose control and methods**

The total effective exposure doses should not exceed 100 mSv per five years and 50 mSv per year for male workers, 5 mSv per three months for female workers having the possibility to become pregnant. The dose records should be preserved for 30 years.

**(4) Measures for reducing radiation exposure**

The employers should measure the average ambient dose rate of the work sites to determine the appropriate measures for radiation exposure dose control. The appropriate health services and consultations by physicians should be provided to the workers.

**(5) Worker Education**

The employers should provide special lectures intended to enhance workers' knowledge and understanding in the following areas before assigning them to the high risk operations: the effects of ionizing radiation, radiation measurement methods, relevant laws and regulations, etc.

**(6) Health care measures**

The employers of workers under a designated dose rate should provide general medical examinations to the workers and should seek advice from a physician about the results of the medical examinations.

**(7) Safety and health control system**

Primary contractors who conduct operations under a designated dose rate should appoint a radiation manager who is responsible for consolidated management of dose control. Employers should appoint health managers or safety and health promoters, who are expected to oversee technical issues associated with measuring radiation exposure doses and recording the measurement results.

Further information is available on the following site.
http://www.mhlw.go.jp/english/topics/2011eq/workers/dr/dr/pr_120615_a04.pdf

## 3.5 Overview of the notice, "Improvement of the safety and health management system of radiation and emergency works at nuclear facilities"

On 10 August 2012, the MHLW issued a circular notice ("Improvemnt of safety and health management measures of radiation works and emergency works at nuclear facilities", Labour Standard Bureau Notification No. 0810-1, issued on 10 August 2012) to the directors of the relevant Prefectural Labour Bureaus with a directive to enhance instruction to relevant employers with respect to safety and health measures in preparation for emergency works at nuclear facilities (nuclear power plants, reprocessing facilities and fuel fabrication facilities).

The MHLW has provided instructions via circular notices since 2000 regarding safety and health management of radiation works in nuclear facilities, including radiation exposure dose control. In consideration of the lessons learned from the accident at the TEPCO Fukushima Daiichi NPP associated with the Great East Japan Earthquake, measures in preparation for emergency works to be taken by the employers are also considered important. Accordingly, the Ministry decided to improve the instructions thoroughly.

Points where instructions are improved:

(1) Provisions in preparation for emergency works should be taken not only at nuclear facilities, but also at corporate offices and primary contractors;

(2) In making prior preparations for emergency works, nuclear facility operators, etc. are required to conduct the voluntary inspections listed below. The facilities will be instructed to implement those matters that are difficult to implement immediately in a step-by-step manner.

(a) Radiation dose control

Improvement of the framework of the dose management system should be undertaken, including securing availability of dosimeters by making advance borrowing agreements with other facilities, managing dosimeter-lending records of workers, and notifying workers of their doses and measurements of internal exposure, etc.

(b) Protective equipment and clothing

Protective equipment and clothing should be made available and workers should be shown the correct way to wear the

respiratory protective equipment. Employers should measure airborne concentration at waiting stations (stand-by areas) and other places

(c) Safety and health education

Textbooks should be prepared and classrooms for educating new workers should be provided.

(d) Health care and medical care systems

The medical care system should be established, measures against heat stroke should be implemented, special medical examinations should be conducted, and a patient transportation system should be established.

(e) Work plans and others

A system to prepare work plans should be established, preparation of proper work plans should be promoted, the actual status of contracted work should be assessed, and arrangements for proper accommodations (lodging) and meals, etc. should be made in advance.

(3) The Ministry will clarify the items for the relevant Prefectural Labour Bureaus to ensure that nuclear facilities are properly instructed in the case of implementing emergency works.

Further information is available on the following site.
http://www.mhlw.go.jp/english/topics/2011eq/workers/ri/pr/pr_120810.html

## 3.6 Overview of the Guidelines on Prevention of Radiation Hazards for Workers Engaged in Accident-derived Waste Disposal

These guidelines, prepared for disposal of accident-derived waste, summarize the provisions specified in the Industrial Safety and Health Act and other relevant regulations, including the Ordinance for Preventing Ionizing Radiation Hazards.

**(1) Scope**

The guidelines aim at collectively providing the actions that the disposal operators handling accident-derived waste should take.

**(2) General principles**

The disposal operators should strive to minimize the amount of ionizing radiation. The disposal operators should strive to decontaminate the area around the disposal site in advance in order to reduce radiation exposure to workers.

**(3) Methods on setting radiation controlled areas and radiation dose control**

The disposal operators should clearly specify the radiation controlled areas with posted signs and prohibit access to the area. The dose measurements should be recorded basically every three months, every year, and every five years, and the records should be kept for 30 years.

**(4) Dose limit at facilities**

The disposal operators should ensure that the dose rate is restricted so that the sum of the external dose and committed effective dose from radioactive materials in air should not exceed 1mSv per week.

**(5) Requirements on equipment for preventing contamination**

The disposal operators should use materials and structures that prevent spread of contamination, and ensure that workers in the facilities are not exposed to radiation.

**(6) Measures to prevent spread of contamination**

The disposal operators should use containers in order to prevent spread of contamination, should create an inspection area to check the contamination levels of workers, and should make available effective respiratory protective equipment and protective clothing for workers to prevent body contamination.

**(7) Work management**

The disposal operators should define rules on work methods and procedures, etc. that should be disseminated to the workers. The disposal operators should submit a "work permit" to the head of the relevant Labour Standards Inspection Office.

**(8) Education for workers**

The disposal operators should provide workers with special education on the following topics: what accident-derived wastes are and how they should be disposed.

**(9) Measures for health care**

The disposal operators should provide workers with special and general medical examinations once every 6 months. The examination results should be recorded on medical examination cards and the cards kept for 30 years.

**(10) Safety and health management system**

The safety and health management system should be established by the primary contractors by assigning a general safety and health manager, a responsible person for safety and health management by involved subcontractors, and so on. Safety and health coordinating meetings consisting of all of the involved subcontractors will be held once a month.

Further information is available on the following sites.
http://www.mhlw.go.jp/english/topics/2011eq/workers/dr/wd/pr_130412_a04.pdf
http://www.mhlw.go.jp/english/topics/2011eq/workers/dr/wd/pr_130412_a03.pdf (Overview)

## 3.7 Overview of the establishment of radiation exposure doses registration systems for decontamination and related works

The primary contractors of decontaminator works came to an agreement on establishing the Organization for registration control of radiation exposure doses for decontamination and related works from April 2014 as follows:

**(1) Objectives**

The registration system aims to achieve the following: Establish a registration system in coordination with the existing system for nuclear facilities to verify past exposure doses when decontamination workers are successively employed by different employers.

**(2) Systematic operation of the radiation passbook control**

- Obtaining the radiation passbook
- Control of radiation passbooks and notification of exposure doses
- Obtaining the result of medical examinations and recording it in radiation passbooks
- Obtaining implementation status of special education and recording it in radiation passbooks

**(3) Methods for dose registration and past record inquiry**

- Registration of work sites
- Periodical registration of exposure doses
- Inquiry and registration of records prior to 2014
- Cross-reference of data with system for nuclear facilities

**(4) Transfer of records of exposure dose and medical examination**

- Statutory transfer of exposure dose records
- Statutory transfer of medical examination records

**(5) Operation of dose control system**

- Expense for participating in dose control system
- Development of work procedures and manuals
- Establishment of governance council to maintain the system

Further information is available on the following site.
http://www.mhlw.go.jp/english/topics/2011eq/workers/ors/oi/pr_131115.html

## 3.8 Overview of the Guidelines on Occupational Safety and Health Management at the TEPCO Fukushima Daiichi Nuclear Power Plant

The MHLW formulated the Guidelines on Occupational Safety and Health Management at the TEPCO Fukushima Daiichi Nuclear Power Plant (Labour Standards Bureau Notification No. 0826-1, 26 August 2015). This guideline summarizes transparently actions to be conducted by TEPCO and the primary contractors according to the subjects shown below in taking measures for occupational safety and health management toward decommissioning of the TEPCO Fukushima Daiichi NPP.

**(1) Establishment of a system for occupational safety and health management undertaken by TEPCO and the primary contractors**

- Selecting a general health and safety manager, etc. and holding safety and health coordinating meetings by TEPCO
- Providing instructions to, and support of, relevant subcontractors by the primary contractors

**(2) Implementation of risk assessment and measures to be taken for enhancement of safety and health education based on the results**

- Implementing a risk assessment (identifying dangers or hazards caused by the works, estimating occurrence of occupational injuries and diseases that may be caused by them, and considering measures to reduce the risks) and taking measures to reduce the possibility of occupational injuries and diseases based on the results
- Enhancing education of new workers or operation leaders

**(3) Consideration and implementation of effective exposure dose reduction measures from the stage of placing orders**

- Preparing an "Exposure dose reduction specification" by TEPCO for radiation works that may cause one man-sievert of total exposure dose for all workers, and preparing a "Dose control plan" by the primary contractors, etc., and submitting them to the Director of the Labour Standard Inspection Office

**(4) Healthcare measures, etc.**

- Providing health guidance based on medical examination results, establishing an emergency medical system, taking heat stroke measures and long-term healthcare measures, improving the work environment, etc.

Further information is available on the following site.
http://www.mhlw.go.jp/english/topics/2011eq/workers/tepco/rp/pr_150826_attachment03.pdf

# 4. Results of Epidemiological Studies on Emergency Workers

## 4.1 Overview of the Report of the Expert Meeting on Epidemiological Studies Targeting Emergency Workers at the TEPCO Fukushima Daiichi Nuclear Power Plant

MHLW compiled a report of the expert meeting series held since February 2014 in which discussions were made about how to make plans for epidemiological studies targeting emergency workers concerning radiation effects on human health.

The purpose of the report is to compile the basic concept and matters of note in establishing the abovementioned plans.

**(1) Study targets and method**

- Around 20,000 emergency workers should be covered with the study period lasting throughout their respective lifetimes.
- Follow-up for the target group should be done and the current-state survey conducted by the MHLW should be utilized and maintained in the course of the long-term health care database management.
- Health and psychological effects to be examined should cover cancers (tumors), leukemia and non-cancerous diseases.
- The cumulative dose should be set as an exposure factor. Dose-response relationships of health effects are to be examined, and classification by exposure conditions should be done.
- The prospective cohort study method should be employed.
- When compiling study results, analysis results that show both presence and absence of statistically significant differences using a suitable statistical test should be reported.

**(2) Health effects examinations**

- The abovementioned diseases, for which radiation effects have been previously suspected, should be covered broadly. In addition to health checkups, other systems and data should also be referred to.
- Examination items and frequencies should be determined based on the MHLW Minister's guidelines, while referring to the examinations targeting WWII atomic bomb survivors. However, these may be changed or added to in accordance with technological advancement.
- Questionnaires to ascertain psychological effects should be used.

**(3) Ascertaining cumulative doses**

- Primary source materials for both internal and external exposures should be preserved as original documents where possible for data verification in the future.
- A chromosomal test to biologically measure exposure doses should be conducted for workers whose effective doses exceed 100mSv.

**(4) Control of confounding factors**

- As the epidemiological studies take time and cover cancers and various other diseases, it is important to control confounding factors.
- In addition to examinations of items adopted in previous studies in Japan, examinations of each worker's history of exposure to toxic substances and work details should be collected.

**(5) Implementation system of the studies**

- A controlling research institute should first be designated and cooperative research institutions in respective sectors should be selected thereunder.
- Consigned health check organizations should be selected.

**(6) Study period, evaluation and publication of study results**

- As the studies will take time, research institutions should be evaluated by an international third-party panel at 5-year intervals.
- Research institutions should regularly report their results to the MHLW and publicize them in the controlling research institute's publications, and compile and publish achievements in international academic journals.

Further information is available on the following sites.
http://www.mhlw.go.jp/english/topics/2011eq/workers/tepco/lhc/pr_140604.html

## 4.2 Overview of the report results, Research on Thyroid Gland Examinations, etc. of Workers at the TEPCO Fukushima Daiichi Nuclear Power Plant (Sobue et al. 2014)

A report was compiled regarding the Research on Thyroid Gland Examinations, etc. of Workers at the TEPCO Fukushima Daiichi Nuclear Power Plant (chief researcher: Tomotaka Sobue (Professor, Environmental Medicine and Population Sciences, Graduate School of Medicine, Osaka University)).

This research funded by the Health and Labour Science Research Grants aims to epidemiologically analyze radiation effects on the thyroid gland by setting an exposed group (emergency workers exposed to radiation exceeding a thyroid equivalent dose*1) of 100 mSv) and a control group (thyroid equivalent dose of 100 mSv or less), performing ultrasonic examinations for both groups and comparing the results. The results of the analysis are to be evaluated from the viewpoint of clinical medicine in terms of radiation effects on the thyroid gland. Major findings and discussion was as follows.

*1) Thyroid equivalent dose: Dose only focusing on thyroid exposure, which is calculated as the total of internal exposure and external exposure (including exposure prior to the accident); 1/20 of the whole-body exposure dose (effective dose)

(1) No difference was found in the percentages of workers assigned as level B (a secondary examination was recommended) and level C (secondary examination was necessary) between the exposed group and the control group, and there was no correlation with thyroid equivalent doses. However, the percentage of workers assigned as level A2 (a secondary examination was unnecessary) was relatively high for people with high doses, and the same trend was observed in analysis using re-evaluated thyroid equivalent doses.

(2) While no correlation was found between nodule size and

thyroid equivalent dose, the incidence of relatively larger cysts[*2)] was high for workers with high doses.

*2) Cysts themselves need not be treated. However, as large cysts may cause neck symptoms, a cyst 20.1mm or larger is judged as level B (only one case).

(3) This is an interim report based only on the ultrasonic examination and prepared before definite diagnoses have become available. Conclusions drawn based only on the results of this research could be faulty due to the following uncertainties.

- According to the research results, the percentage of workers who received ultrasonic examinations before the present ultrasonic examinations was high for the exposed group while that for the control group was low, and the percentage of workers who received the present examination was low for the exposed group. This suggests the possibility of considerable bias in cyst and nodule incidence among workers with high doses.
- Namely, there is a possibility that workers judged as level A2 in earlier ultrasonic examinations selectively participated. Also, workers judged as level B or level C in their ultrasonic examinations might have selectively dropped out of the research program.
- For workers whose internal exposure evaluation results are considered less reliable, quantitative evaluation of internal exposure should be conducted.

(4) Efforts need to be made to collect and analyze the detailed examination results where abnormalities were detected in the examination and for past thyroid gland ultrasonic examinations for the exposed group.

- The ultrasonic examination results and secondary examination results have not been collected.

Further information is available on the following sites.
http://www.mhlw.go.jp/english/topics/2011eq/workers/tepco/ort/pr_140805.html

# 5. Good Practices in Radiation Exposure Control at the Fukushima Daiichi NPP

This section introduces good practices implemented by TEPCO and primary contractors related to radiation exposure dose management, exposure reduction and health management at TEPCO's Fukushima Daiichi NPP.

To collect and facilitate the sharing of information about good practices, the Workshop on Radiation Exposure Control at the Fukushima Daiichi NPP was held in cooperation with TEPCO and primary contractors at J-Village in Futaba County, Fukushima Prefecture on 10 November 2015.

The workshop consisted of three sessions: (i) working environment improvement activities, (ii) radiation exposure reduction, and (iii) technological research and development. Presentations were given by TEPCO and primary contractors, followed by an exchange of opinions between participants and experts.

The details of the presentations are compiled and introduced below.

## 5.1 Improving working environment activities at the Fukushima Daiichi NPP

### 5.1.1 Initiatives for improving the working environment in the Fukushima Daiichi NPP

**Tokyo Electric Power Company, Incorporated.**

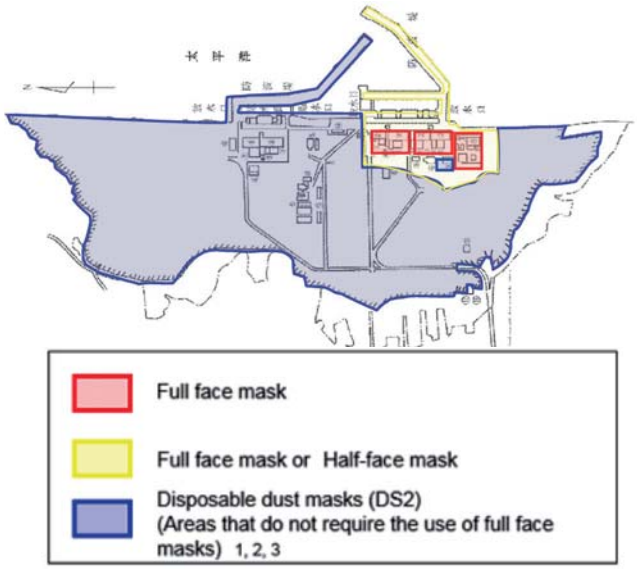
TEPCO has been improving the working environment at the Fukushima Daiichi NPP from various perspectives, such as making it more convenient and comfortable for the workers, reducing exposure dose and otherwise improving the onsite environment, and implementing strategies for heat stroke. TEPCO will continue their efforts to improve the working environment, while ascertaining workers' changing needs.

**(1) Reduction of radiation dose within the plant site**

After measuring and ascertaining the effect of contamination due to fallout that covered the entire plant site and direct radiation from the reactor units TEPCO has tried to reduce radiation dose by such means as tree trimming, removing surface soil, replacing surface soil with uncontaminated subsoil, and installing shielding.

**(2) Operations in areas that do not require wearing full face masks**

TEPCO has been expanding areas where workers can wear disposable dust masks (DS2) (where wearing a full-face mask is not mandatory) with the aims of reducing burden on workers by increasing conveniences to improve work efficiency.




1 Excluding solid waste storage facility and inside cask storage building
2 Only certain areas on 2nd and 3rd floors of the shared pool buildings
3 Work involving highly concentrated dust shall require full face masks or half-face masks, and work that has the risk of ingesting concentrated salt water shall require full face masks

**(3) Installation of dose rate monitors**

In order to monitor dose rates after radiation level reduction countermeasures have been implemented, TEPCO has installed dose rate monitors at the site. The installation of these monitors helps to make field dose rates more visible by displaying the values from those dose rate monitors on large display screens in the Seismically Isolated Building and other locations so as to enable workers to see real-time radiation levels in the field prior to going out.

Concept drawing of dose rate monitor

**(4) Change of exposure dose**

As a result of efforts to reduce the exposure dose rate, the monthly average exposure dose at the Fukushima Daiichi NPP showed a decrease in FY2012 compared to FY2011. The monthly exposure dose has been kept low since then.

**(5) Control of workers' doses**

Workers engaging in work on the site are registered as radiation workers in advance. They are required to wear a personal alarm dosimeter (PAD) and their doses are strictly controlled.

**(6) Activities to raise awareness about effects of radiation exposure**

In order to lessen concerns about health effects of radiation exposure, lectures have been provided to workers by experts.

**(7) Operations started at the large rest house and meal center**

In response to requests for a rest house from workers, a large rest house was constructed so that 1,200 workers can use it at the same time, and operations started on May 31 of this year. In addition to the resting areas and cafeteria, it now includes office space, TBM/KY space, WBC, vending machines, etc., and a newsstand will also be constructed in the near future. In addition, a meal center was constructed at the O-kawara area in Okuma Town near the Fukushima Daiichi NPP in response to requests from the workers there for a meal facility. The facility started to supply meals from April at the new administrative office building and from June at the Large Rest House.

Rest space

**(8) Strategies for heat stroke**

Workers need to wear coveralls on the site and are at risk for heat stroke especially during the summer. Therefore, to prevent heat stroke TEPCO encourages workers to stay well-hydrated and wear a cool vest. New rules to prevent heat stroke have been specified and enforced.

**(9) Emergency response for injured or sick workers**

An emergency doctor, an emergency life-saving technician, and a nurse are stationed on a 24 hour basis in the emergency room at the entry control facility on site, thereby ensuring an organized system for making prompt emergency responses in the case of injured or sick workers.

## 5.2 Good practices in radiation exposure reduction, technological research and development

### 5.2.1 Activities concerning radiation control for the treatment of accumulated water at the Fukushima Daiichi NPP

**Hitachi-GE Nuclear Energy, Ltd.**

Hitachi-GE Nuclear Energy, Ltd. (HGNE) has been involved in various construction works at the Fukushima Daiichi NPP since the Tohoku Pacific Ocean Earthquake that occurred on 11 March 2011. The construction of facilities for treatment of the accumulated radionuclide-contaminated water conducted this year was the largest project yet since the start of the emergency works.

**(1) Exposure reduction measures for key persons**

In this construction work where a large exposure dose is expected, it was assumed in the analysis of the expected exposure dose for job type that the supervisors and group leaders would have a high exposure dose. Among these supervisors and group leaders, many of them who will need to engage in works at Fukushima Daiichi NPP after the treatment of contaminated water as key persons will already have had a large cumulative exposure dose; hence it was assumed they had reached the exposure dose control limit for the radiation exposure during the work. Since this would have an impact on the overall work there was a need to reduce the exposure dose of these workers.

In order to reduce exposure dose of key persons, measures were taken in two aspects: individual dose control and environmental aspects.

**1) Individual dose control**

Measures described below were taken to reduce the exposure dose of key persons.

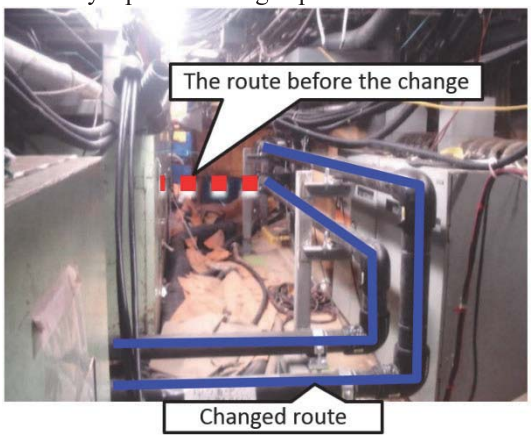
- Set a target value of the control for each of the workers taking into consideration their cumulative exposure dose and expected engagement in future works.
- Allocation of workers considering the dose rate of the work place and importance level of the work, in order to achieve the control target value.

**2) Exposure dose reduction with respect to the environment**

Measures described below were taken from the view point of reducing environmental dose rate

- Reduction by modifying design of the constructed facilities (e.g. change of piping routes)
- Reduction by improving methods (e.g. employing a remote monitoring method)
- Reduction by utilizing shielding (e.g. installing shielding)
- Other measures (e.g. visualization)

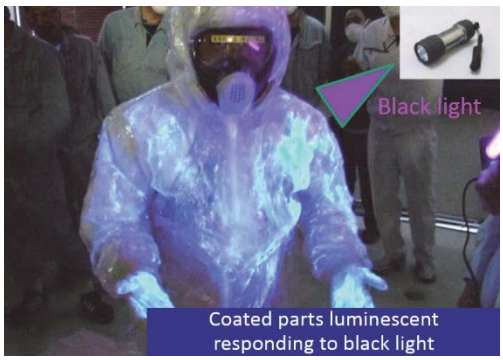
These measures allowed significant reduction in the dose rate of work places, leading to the reduction of the exposure dose of key supervisors and group leaders.




**Exposure reduction measure**: Change of piping routes (exposure dose has been reduced by about 510 man-mSv).

**(2) Measures to prevent problems related to radiation control**

Workers without any previous work experience at Fukushima Daiichi NPP or other nuclear facilities are expected to be engaged in this work. There was a concern that problems related to the radiation control may occur with such novice workers. Therefore, in addition to lectures, the hands-on "experience education of radiation control related




**Experience of body contamination**: Recognizing contamination using fluorescent paints to represent contamination.

dangers" was developed as a type of "physical experience education" and provided to the workers at the site. The education experiences included "Experience of body contamination", "Experience of APD alarming sound", "Experience of exposure dose reduction" and "Experience of checking for full-face mask leaks". The workers' understanding of radiation control was improved through these experiences, thus preventing radiation control problems from occurring.

Works toward the Fukushima Daiichi NPP decommissioning have steadily been implemented, however, a lot of the works planned from now on will be done in high dose rate areas. Thus the radiation control activities including the reduction of exposure dose will become even more important. HGNE will continuously make efforts for ensuring the radiation safety of workers through the development of radiation control methods corresponding to the changing works.

### 5.2.2 Evaluation of the total exposure reduction measures during construction of the land-side impermeable walls using the frozen soil method

**Kajima Corporation**

As a part of the Project for the Contaminated Water Issue at the Fukushima Daiichi NPP, Kajima Corporation is involved in the construction of the land-side impermeable walls using the frozen soil method. This method restricts the inflow of the groundwater into the reactor buildings by continuously freezing the soil for a long period of time.

The construction has been conducted under the following severe conditions:

- Construction area of 1.6 km in length encircling the nuclear reactor buildings and turbine buildings of Units 1 to 4
- High radiation dose rate since hardly any decontamination works have been undertaken in this area following the accident
- Necessity of coordination with other construction works around the site, leading to reduction of the work efficiency
- Investigation of underground installations along the construction line (1.6 km) in preparation for the borehole drilling
- Unexpected increase of manpower with the increased volume of the construction works due to changes in the construction plan, reaching 200,000 workers in total, which is significantly more than the originally planned number of workers

**Exposure reduction measure**: Placing L-shaped protection walls at the work area (Radiation source: left side building).

Taking into account such conditions, which included several factors that would increase the total exposure dose of the workers, Kajima Corporation has undertaken measures to reduce the air dose rate and to shorten working hours by improvement of the construction methods, and has evaluated the reduction of the total exposure dose based on a quantitative analysis of the trade-off between "exposure dose" and "prevented potential exposure dose."

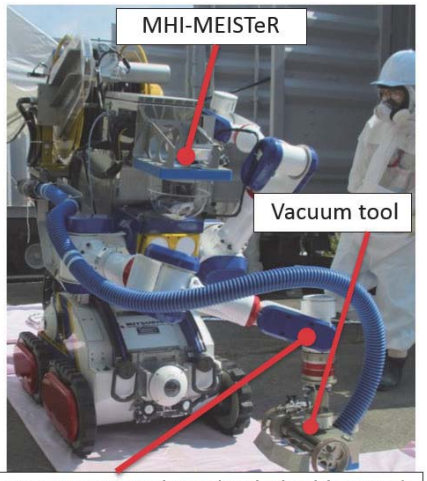
The construction of the impermeable wall is still in progress as a key measure for control of contaminated water at Fukushima Daiichi NPP and Kajima Corporation is determined to continue their efforts in reducing the total exposure dose until the wall is completed.

**Exposure reduction measure**: Installation of working platforms and RC shielding plates (air dose rate has been reduced to 1/4 – 1/3).

### 5.2.3 Introduction of examples for reducing exposure dose during the decontamination at the reactor building in the Fukushima Daiichi NPP Unit 3

**Mitsubishi Heavy Industries Ltd.**

Activities toward decommissioning have been promoted at the Fukushima Daiichi NPP. However, the dose rate inside buildings, especially in the reactor building, is still high, and long-time activities by human workers are not realistic. Under the initiative of the Ministry of Economy, Trade and Industry, Mitsubishi Heavy Industries Ltd. (MHI) has participated in the national project, called "Development of Remote Decontamination Technology in the Reactor Building". MHI has developed a




**Exposure reduction measure**: Transport of the equipment into and from the reactor building was limited to Mondays and Fridays. This reduced workload of the workers for moving and laying cables and hoses, leading to reduction in daily radiation exposure.

remote decontamination machine and a remote handling robot, "MHI-MEISTeR". MHI have been engaged in decontamination works and in investigation of decontamination measures (based on sampling of materials) at Unit 1, Unit 2 and Unit 3 using these machines.

The MHI-MEISTeR was developed as a remote handling decontamination machine; however, the decontamination processes cannot be conducted entirely remotely, human intervention is needed. Human workers are required to support the activities of the robot: e.g., workers must transport the robot into or from buildings and assist its movement inside buildings. Human workers were working near the entrance of the buildings, and that was the major cause for exposure during the work period. Therefore, in the decontamination works at Unit 3, efforts were made to reduce the number of times it was necessary to transport the robot by getting cooperation among relevant parties, and the rest area for workers was changed (common use of a rest area for workers engaged in other works). As a result, the exposure dose was reduced.

**Exposure reduction measure**: Development and utilization of wheeled platforms to lessen the work load for workers moving and laying the hoses.

### 5.2.4 Dose rate reduction by decontamination of the reactor building at the Fukushima Daiichi NPP Unit 2

**Toshiba Corporation**

For decommissioning of the reactor buildings at the Fukushima Daiichi NPP, the reduction of dose rate for the 1st floor will be important since all works start from there. Toshiba Corporation has started activities on the 1st floor of Unit 2.

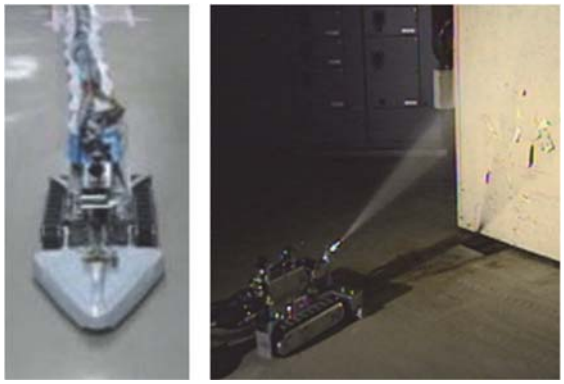
**(1) Air dose rate before the decontamination works**

The air dose rate before the decontamination measured on 22 March 2013 was as high as 13.3 mSv/h (a geometric mean of 26 points). This would allow workers to spend only 10 minutes in the area, even when the special control level was set as a planned daily exposure limit of 2.5 mSv/d. No complicated work could be done.

**(2) Details of the decontamination works**

The investigation of contamination conditions identified the need for three-dimensional decontamination in order to effectively reduce the exposure dose. Therefore decontamination was conducted according to the following procedures;

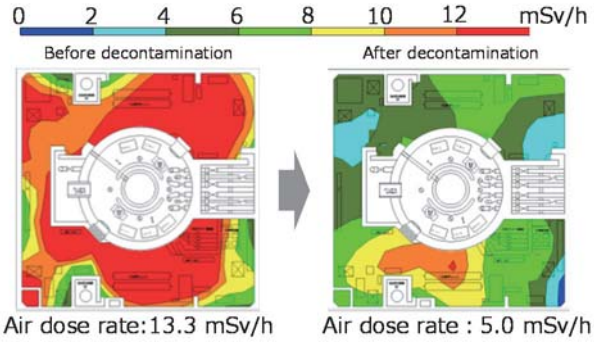
1) Removal of interfering objects from the 1st floor (materials and equipment existing from the time of the earthquake, and those transported in to carry out works after the earthquake)
2) 3-D laser scanning using a remote handled robot
3) Floor decontamination with a remote handled decontamination machine
4) Decontamination of low and medium height places with the remote handled decontamination machine
5) Installation of shielding at places where it is difficult to carry out decontamination
6) Removal and decontamination of ducts in high places.



**Exposure reduction measure**: Spraying by a remote controlled robot to remove contamination from floor and wall surfaces (Developer: ATOX Co., Ltd.).

**(3) Results of decontamination**

The air dose rate of 13.3 mSv/h before the decontamination was reduced significantly to 5.0 mSv/h after decontamination at floor level and low and medium level heights, installation of shielding, and removal and decontamination of ducts. This compares favorably to the air dose rate of 13.0 mSv/h which had been achieved after removing interfering materials only. The reduction rate was 40 % or higher even considering the radioactive decay of the radiation source.




**Confirmation of decontamination results**: The dose rate at the floor has been reduced by 40% or more even when taking into account natural radioactive decay of the radiation source.

**(4) Future decontamination plans**

There are a variety of structural components (walls, ceilings, pipes, supports, cable trays, etc.) in high places to be decontaminated from now, and their location will make the decontamination difficult. Continued efforts will be paid to further reduce the air dose rate by utilizing a 3-D laser scanning, gamma camera, developing a remote handled decontamination machine, etc.

## 5.2.5 Activities to reduce exposure doses during disassembly of bolted type tanks

**Taisei Corporation**

Since March 2011, about 300 bolt assembled type tanks have been constructed to store contaminated water at the Fukushima Daiichi NPP. Associated with the change to use of welded type tanks, disassembly of the bolt assembled tanks was started from the end of May 2015. The inner surfaces of the latter tanks are contaminated with the stored RO (reverse osmosis) concentrate. The dose rate on the surfaces after draining off the contaminated water is as high as 40- 50 mSv/h, which requires taking special measures in order to reduce the exposure dose of workers.

**(1) Shortening of working hours by development of a balloon-type temporary roof**

The tank disassembly work requires first installing a roof at the crown of each tank before carrying out the disassembly in order to prevent scattering of contaminated dust and entry of rain water. To complete one tank disassembly, 150 minutes are needed to install and remove a full-fledged steel roof with a five-block construction. However, the lightweight construction (300 kg/unit) of a balloon-type temporary roof can be put into place immediately using a crane. This significantly reduces the roof installation and removal working hours, leading to the reduction of exposure dose of workers.

**Exposure reduction measure**: A light-weight balloon type roof allowed a whole roof to be lifted into place in one operation using a crane, leading to significant shortening of installation and removal working hours, resulting in the reduction of the exposure dose of workers.

**(2) Implementing an unattended disassembly task by development of a pre-painting machine**

The tank disassembly requires the task of spraying an agent on the inner surface of the tank to prevent scattering of dust Normally scaffolding must be installed in the tank or a device that can be used for work at changing heights must be brought into the tank and then workers manually spray the surface with the scatter-prevention agents. However because of the high dose rate of 40-50 mSv/h ($\beta + \gamma$) inside these highly contaminated tanks, Taisei Corporation developed a pre-painting machine that can be operated unattended to reduce the exposure dose of workers. The machine is able to rotate 360 degrees, using the principle of a balancing bar by extending two beam bars, as it sprays the scatter-prevention agent on the inner tank surface. Since the machine is controlled from the top of the tank, the scatter-prevention agent is applied without workers entering the tank.

**(3) Installation of shielding materials for work inside the tank**

When the basement of the tank is dismantled, workers must be inside the tank. The work is conducted after installing a rubber mat on the floor and composite panels on the wall for shielding, by which the air dose rate is cut 90% or more.

**Exposure reduction measure**: Shielding materials were installed before workers enter inside the tank.

**(4) Safety measures for workers**

The workers who are engaged in the disassembly work wear Tyvek clothing, an anorak and a mask. Since this places workers at high risk for heat stroke during the summer when the temperature is high, all tasks are conducted at night when the temperature is low, by which occurrence of heat strokes is reduced significantly.

**(5) Actions to prevent body contamination and spread of contamination**

Since the inside of the tank is contaminated significantly, the disassembly work has a risk for body contamination and spreading of the contamination by the workers. Efforts are made to reduce the risk by utilizing a building for changing out of work clothes and for changing shoes as well as allocating persons to act as managers for the changes of clothing and shoes.

### 5.2.6 Efforts for reducing radiation exposure during facing construction of slope areas

**Shimizu Corporation**

The facing construction of slope areas is intended to reduce radiation and the inflow of groundwater into buildings. This work consists of weeding, topsoil stripping, and shotcrete. The areas to be covered in the construction include all slopes around the reactor buildings at Unit 1 to Unit 4. The total area is approximately 55,500 $m^2$. Among them, the west side slope from the buildings of Units 1 and 2 and a part of the west side slope from the buildings of Units 3 and 4 have a high dose rate of 0.3 - 1.6 mSv/h. The measures described below were taken to reduce radiation exposure of workers.

**(1) Remote recovery of debris using a large magnet**

A large quantity of debris with a high radiation level was distributed on slopes due to explosions of the reactor buildings. The debris was collected remotely by using a lifting magnet equipped with a strong magnet, by which efficient works and reduction of radiation exposure were achieved.


**Exposure reduction measure**: Using lifting magnets for efficient removal of high radiation debris on a slope.

**(2) Wearing a shielding vest**

The workers engaged in weeding and spraying in the high radiation areas each wore a shielding vest on their protective clothes to reduce the radiation exposure from the gamma-rays.

**(3) Automated RCM (Rock Climbing Machine)**

In order to reduce the radiation exposure of the operator of the RCM which was used in removing the top soil in the high radiation areas, the top soil was removed while operating the RCM remotely from a low radiation area which was some distance from the stripping area. The operation room was surrounded with shielding plates to further reduce the radiation exposure.


**Exposure reduction measure**: Topsoil stripping was conducted by a remotely operated RCM in high radiation areas.

**(4) Setting of topsoil stripping depth and shotcrete thickness**

The radiation level was reduced after topsoil stripping in the preliminary survey of a slope area. Surface radiation below 5μSv/h could be achieved by setting the topsoil stripping thickness and shotcrete thickness appropriately.

**(5) Mechanization of shotcrete**

The shotcrete had been conducted manually. However, from the viewpoint of reducing the radiation exposure of workers, efficiently implementing works, and shortening the working period, the shotcrete was applied using a machine equipped with the injection nozzle on the tip of a long arm when the machine could be installed at the bottom of the slope (Roboshot Method).

By taking these exposure reduction measures, radiation exposure of workers were reduced by 30% compared to cases with no measures.

31 January 2016
Office for Radiation Protection of Workers
Ministry of Health, Labour and Welfare
1-2-2 Kasumigaseki Chiyoda-ku Tokyo 100-8916, Japan

URL:http://www.mhlw.go.jp/english/topics/2011eq/workers/index.html