

Report on investigation of cause and development of preventive
measures regarding exposure exceeding dose limit to radiation
dose engaged person at Fukushima Daiichi Nuclear Power Station

May 2nd, 2011

The Tokyo Electric Power Company, Incorporated

1. Outline of the Event

When determining the exposure dose of each worker during emergency work at Fukushima Daiichi Nuclear Power Station, it was confirmed that the effective exposure dose of two female employees out of 19 who were engaged the restoration work after the Tohoku-Chihou-Taiheiyo-Oki Earthquake were exceeded the statutory dose limit (5 mSv / 3 months) from January 1st, 2011 to March 31st, 2011.

The effective exposure dose of female employee A (confirmed on April 27th, 2011; in her fifties) was 17.55 mSv, and that of female employee B (confirmed on May 1st, 2011; in her forties) was 7.49 mSv. As results of medical diagnosis of those employees, it was confirmed there were no impacts on their health.

Since March 23rd, it has been prohibited for female employees to work within the premise of Fukushima Daiichi Nuclear Power Station.

TEPCO investigated the cause, developed preventive measures, verify dose management system both at Fukushima Daiichi and Daini Nuclear Power Station regarding exposure exceeding dose limit and the emergency work.

2. Chronological Order

The chronological order of the event is shown in attachment 1.

(Attachment 1)

3. Contents of the Investigation

(1) Investigation on exposure dose

The investigation on exposure dose was conducted in terms of the exposure dose before the Tohoku-Chihou-Taiheiyo-Oki Earthquake, the exposure dose during local work, the exposure dose during the stay in the Main Anti-Earthquake Building, and the effective dose of internal exposure.

(Attachment 2)

a. Exposure dose before the Tohoku-Chihou-Taiheiyo-Oki Earthquake

As there were no female employees worked within the controlled area at the Tohoku-Chihou-Taiheiyo-Oki Earthquake, the exposure dose before the Earthquake was estimated from the individual record in the system from January 1st, 2011 to March 11th, 2011.

b. Exposure dose during local work

As workers works locally with alarm pocket dosimeter (hereinafter refer as APD), the exposure dose by local work was estimated by APD measurement from March 11th, 2011 to March 31, 2011.

Female employee A → 2.06 mSv

Female employee B → no APD measurement due to no local work

c. Exposure dose during the stay in the Main Anti-Earthquake Building

The rate of exposure dose in the Main Anti-Earthquake Building was measured everyday after March 12th, 2011. In addition, contractors uses Luxel badge in order to manage the individual exposure dose, so that it can be estimated the evaluation result for control. By using the estimation, the rate of exposure was calibrated and the exposure dose was calculated by the rate of exposure times staying time.

Female employee A → 1.89 mSv

Female employee B → 0.78 mSv

d. Internal exposure

Female employee A → 13.60 mSv

Female employee B → 6.71 mSv

e. Result of exposure dose estimation

As result of summation of the exposure dose before the Tohoku-Chihou-Taiheiyo-Okai Earthquake, the exposure dose during local work, the exposure dose during the stay in the Main Anti-Earthquake Building, and the effective dose of internal exposure, it was confirmed that the exposures dose of two female employees were exceeding the statutory exposure dose limit.

(2) Investigation on the Management Situation for Internal Exposure

As the internal exposures of the female employee alone were exceeding the statutory exposure dose limit, the investigation on the management situation for internal exposure was conducted.

a. Investigation on the local work

It was confirmed that Female employee A did the local work wearing appropriate personal protective equipment such as Tyvek, charcoal mask and rubber globe like other male workers do.

The survey indicated that it was not likely to intake the radioactive material during local work since her body was not contaminated when she removed the protective equipment.

Female employee B stayed in the Main Anti-Earthquake Building and didn't do any local work.

(Attachment 3)

b. Investigation in the Main Anti-Earthquake Building

The investigation on the density of radioactive materials in air in the Main Anti-Earthquake Building was conducted after March 24th, 2011. As the density of radioactive materials was exceed the

statutory limit (1×10^{-3} Bq/cm³, three month average), measures for improvement of radiation circumstance such as installation of exhauster, removal of dust adhesive OA floor mat, and cleaning of wall and floor were immediately carried out, so that the density of radioactive materials was fell below the statutory limit on April 4th, 2011.

The density of radioactive materials on the first floor was higher than that of the second floor in the Main Anti- Earthquake Building.

Before improvement radiation circumstance, it was likely that persons stayed in the Main Anti-Earthquake Building took in the radioactive materials to some extent as the persons worked inside the building without wearing mask.

(Attachment 4)

The possible reasons for high density of radioactive materials in the Main Anti-Earthquake Building would be as follows;

- Before setting up the buffer area to block to bring radioactive materials into the Main Anti-Earthquake Building when put on and take off the protective equipment, management of in-coming and out-going didn't properly work, so that the ambient very high radioactive materials flowed into the Main Anti-Earthquake Building when opened the door and/or those were brought in with workers, machinery or materials.
- The entrance of the Main Anti-Earthquake Building was structured as double door and instructed not to open at the same time; however, the door was not airtight.
- The double doors were distorted due to the impact of hydrogen explosion of Unit 1 & 3, so that there were some gaps on the doors.

From abovementioned reasons, it was thought difficult to perfectly prevent radioactive materials to flow in the Main Anti-Earthquake Building.

Since the air conditioner with charcoal filter in the Main Anti-Earthquake Building was working soundly and the filter was exchanged appropriately, it was not likely that the radioactive materials flowed in through the air conditioner.

(3) Evacuation Instruction for Female Employees

On March 15th, 2011, power station site general manager instructed for emergency measure employees to evacuate, so that most of female employees were evacuated. However, the instruction didn't force to go outside of the power station site, therefore, some female employees still worked at site according to their work scope.

Female employee A evacuated once on March 15th; however, she re-entered to the Main Anti-Earthquake Building from March 17th to 20th, then March 22nd to 23rd and stayed the office near entrance of the Main Anti-Earthquake Building. In addition, she carried out refuel to vehicles at site

from 18th to 20th, and 22nd.

Female employee B evacuated on March 15th. Until then, she stayed at office near entrance of the Main Anti-Earthquake Building.

On March 23rd, Safety manager instructed all female employees to evacuate in order not to be exposed too much radiation dose. After that date, female employees were restricted to stay within Fukushima Daiichi Nuclear Power Station site.

4. Causes

- (1) Confusion due to the disaster caused the delay in introducing and operating the relief area to prevent radioactive materials from entering into the Main Anti-Earthquake Building (e.g. Area for removing protective equipment).
- (2) After the explosion of hydrogen of Unit 1, the staff of security group has strictly controlled not to open the double gates of the entrance of the Main Anti-Earthquake Building at the same time. However, it was difficult to completely stop inflow of radioactive substances because the gates were not airtight and a little space existed due to the distortion by the explosion.
- (3) In order not to exceed the limitation level (5 mSv/3 months), female employees have been monitored not to exceed 4 mSv/3months. However, we could not strictly control the limitation level (5 mSv/3 months) due to the following reasons:
 - Radioactive monitoring system did not work due to the earthquake and tsunami.
 - Radioactive volume in the Main Anti-Earthquake Building was not considered.
 - Internal exposure was not considered.

From the reasons, we could not take an action before March 23 that the female employee was prohibited to work in Fukushima Daiichi Nuclear Power Station.

As a result, it is guessed that the female employees breathed the radioactive air in the Main Anti-Earthquake Building and exceeded the exposure level.

When we checked the situation of other female employees, a female staff working near the entrance of 1st floor of the building like Female employee A and B has high internal exposure. This result together with the trend of high radioactive level in the air suggests that they breathed the radioactive air in the Main Anti-Earthquake Building.

5. Countermeasures for Prevention of Recurrence

- (1) After March 23, female employees have been prohibited to work in Fukushima Daiichi Nuclear Power Station.
- (2) The following countermeasures have been taken for reduction of radioactive level in the air in the Main Anti-Earthquake Building.

- Exhauster system with charcoal filter was installed (March 26).
- Unit house was installed in the entrance of the Main Anti-Earthquake Building and the exhauster system was introduced in the house (March 26).
- OA floor mat that radioactive substances are easy to cling to was replaced for tiles that are easy to wash. And the floor was covered by sheets (April 1 – April 8).
- Lead boards have been installed on the windows of Main Anti-Earthquake Building for a countermeasure for reduction of external exposure (March 27).
- A rest room was newly installed at the first floor in the service building of Unit 5 and 6, in order for workers not to enter to the Main Anti-Earthquake Building for toilet or drinking (April 22).
- A rest room, that has a clean area, is constructing near the Main Anti-Earthquake Building, in order for workers not to wait at the entrance of the building (it will be operated in beginning of May).
- Rest rooms will be installed in the 2nd floor of the service building of Unit 5 and 6, the training building and the health building respectively.
- At this moment, we have continuously cleaned the Main Anti-Earthquake Building and make efforts to maintain a pollution free environment that is the same level as the other control area.

6. Review of Radiation Control System and Further Actions

It is thought that this accident was caused by the following reasons:

- Electric power was lost by earthquake and tsunami
- Prepared radiation control system in emergency was not fully functioned due to the large radioactive emission.

Especially the Main Anti-Earthquake Building was not enough airtight due to the hydrogen explosion of Unit 1 and Unit 3 and it was difficult to stop to take radioactive substances into the building. Under the circumstances, we will review the radiation control which was conducted at the time of earthquake and take the following actions in order to make a safer situation for the restoration work.

(1) Area to Conduct Radiation Control

【Issues】

By the large emission of radioactive substances, the radioactive level increased in the site of Fukushima Daiichi Nuclear Power Station as well as Fukushima Daiini Nuclear Power Station. For the reason, in Fukushima Daiichi Nuclear Power Station, the whole area was regarded as the control area. Besides, the Main Anti-Earthquake Building was regarded as

non-polluted control area. However, the radioactive level in the air increased and the building could not be used as non-polluted control area during a period of time.

The radiation level of Fukushima Daiichi Nuclear Power Station had exceeded the notification level for the control area. However, the radiation level has decreased under the notification level and the inside of building also decreased by about 1/10. So we have taken the normal operation way. Regarding internal exposure, harmful effects by radioactive substances could not be recognized by the results of evaluation.

【Countermeasures】

All the area of Fukushima Daiichi Nuclear Power Station is regarded as the control area, and radiation control and wearing protection equipment for prevention of pollution must be conducted. In the Main Anti-Earthquake Building and rest rooms of Fukushima Daiichi Nuclear Power Station, exhausters are installed and cleaning is conducted in order to avoid taking polluted substances and remove them. We periodically survey and maintain as non-polluted area.

As for Fukushima Daiichi Nuclear Power Station, for outside work, radiation control and wearing protection equipment for prevention of pollution must be conducted in accordance with a level of radiation, density of radioactive substances in the air and surface pollution density. For equivalent area to the control area, only radiation workers work..

(2) Radiation Protection Equipment and Control of Work

【Issues】

In Fukushima Daiichi Nuclear Power Station, all the area remain high density of radioactive substances and radiation protection equipment is required.

Due to confusion by effects of the earthquake and tsunami, measurement for density of radioactive substances had not been conducted by March 24 in the Main Anti-Earthquake Building. The density of radioactive substances in the air in the building had exceeded the legal limitation by April 3.

Fukushima Daiichi Nuclear Power Station has still a high radioactive level compared to the time before occurrence of Tohoku-Chihou-Taiheiyo-Oki Earthquake.

【Countermeasures】

In Fukushima Daiichi Nuclear Power Station, tyvek and glove must be wore for working, from the viewpoint of a management to prevent pollution to the body and not to take pollution substances into the Main Anti-Earthquake Building. Inhaler is to be wore when density of radioactive substances in the air exceeds the notification level.

In addition, anorack, rubber glove, and overshoes are also considered according to weather and pollution situation of a work site.

The Main Anti-Earthquake Building remains a good environmental condition. However, preventive measures (ex. a clean house is installed and mask must be wore) are prepared against unexpected situation such as increase of density of radioactive substances in the air.

Considering there were a time that we could not measure density of radioactive substances in the air, we raise awareness for measurement in emergency in all the nuclear power stations including Fukushima Daiichi Nuclear Power Station for the short term countermeasure.

In Fukushima Daiichi Nuclear Power Station, workers must use appropriate protection equipment according to work conditions.

When we make working plans for Fukushima Daiichi and Daiichi Nuclear Power Stations, we conduct thorough pre-survey such as environmental monitoring, etc., in order to secure safety and avoid exposure as much as possible by appropriate management such as indication of high radioactive area by rope.

We further make efforts to instruct protection of radiation exposure and raise awareness.

(3) External Radiation Dose Control

【Issues】

Regarding the radiation management for employees, we measure radioactive dose by individual dosimeters. In Fukushima Daiichi Nuclear Power Station we have conducted not only the key earthquake-proof building based management but also J-Village based one from the beginning. However, due to influences caused by the failure of power supply and other reasons, a system to automatically take in values of dosimeters and manage them cannot have been operated.

In addition, in the beginning, there were not enough individual dosimeters and only a representative carried a dosimeter and based on its values we evaluated overall radiation exposure.

In Fukushima Daiichi Nuclear Power Station, we have kept adopting regular management and have not managed radiation dose to which employees have been exposed outdoors or during their stay in the power station.

【Countermeasures】

In Fukushima Daiichi Nuclear Power Station, we have managed external radiation dose by registers, as a system to manage radiation dose did not work. Based on the fact that current data collection has not got along well, we will adopt the simplified radiation dose management system in which we will distinguish an individual dosimeter of one person from that of another one in order to accurately manage radiation dose in the short term. In the medium and long terms, we will switch in full scale to a system to automatically take in

radiation dose.

When employees move from the main gate of Fukushima Daiichi Nuclear Power Station to the key earthquake-proof building or work in the key earthquake-proof building or Administration Office Building where radiation level is lower than the radiation dose in the boundary of controlled areas stipulated in Announcement on Radiation Dose of Regulation on Commercial Reactors, we will add evaluated values (for a month) based on environment dose rate in the areas and radiation dose of a representative.

Also in Fukushima Daini Nuclear Power Station, when employees move its main gate to the key earthquake-proof building, we will add evaluated values to actual radiation dose.

When employees work outdoors, we will make them carry their dosimeters to manage their radiation dose. We will procure the required number of dosimeters soon and, until then, we will make a representative carry his dosimeter and we will conduct evaluations.

(4) Internal Radiation Dose Control

【Issue】

The internal radiation dose control could not be used in Fukushima Daiichi Nuclear Power Station due to not only the failure of power supply but also the increase in background level. Hence, we borrowed a vehicle WBC from Japan Atomic Energy Agency and have conducted management. However, evaluation did not proceed because number of data is not enough due to a limitation of measurement time.

In Fukushima Daiichi Nuclear Power Station, a background increased. However, it could meet by improvement of data accuracy (taking long time measurement).

【Countermeasure】

Staff staying the Main Anti-Earthquake Building of Fukushima Daiichi Nuclear Power Station are at first measured by WBC. And then all the staffs are periodically measured once in a month (normally once in 3 months). This is the management for internal exposure.

On the other hand, there is few WBC sets at this moment, evaluation of internal exposure for workers in Fukushima Daiichi Nuclear Power Station does not proceed. In the short term countermeasure, we use available WBC of Fukushima Daini Nuclear Power Station and requested Japan Atomic Energy Agency to additionally provide a vehicle WBC. We make efforts to secure enough WBC sets and increase number of treatment.

In the middle and long term countermeasure, a base point, which can control radiation management without an influence of increase of BG, will be established and the WBC of Fukushima Daiichi Nuclear Power Station will be moved to the base point.

(5) Compliance with Radiation Limitation

【Issues】

In Fukushima Daiichi and Daini Nuclear Power Stations, emergency work is added to normal work by happening of the accident.

So workers who were not appointed and registered were assigned for emergency work and they were managed within the limitation level of 250 mSV. They recognized a necessity of post procedure for the appointment and registration as radiation workers.

In Fukushima Daiichi Nuclear Power Station, the limitation level in emergency is raised by 250 mSv. Workers who exceed 100 mSv checked internal exposure and then confirmed that they did not exceed the limitation level. .

As for female employees, to manage the radiation level within 5 mSv/3 months, we tried to control external exposure within 4 mSv. However, unfortunately as a result of measurement of internal exposure, 2 female employees exceeded 5 mSv/3 months.

In Fukushima Daiichi Nuclear Power Station, some workers, who have worked in the Main Anti-Earthquake Building, do not appoint and register as radiation workers. Out of which, 4 female employees completed evaluation of actual exposure. 2 of them exceeded 1 mSv/year which is the limitation level outside of the control area (Female Employee C: 3.42 mSv, Female Employee D: 3.37 mSv).

In Fukushima Daini Nuclear Power Station, we confirmed that nobody exceeded the normal exposure level (external exposure, and internal exposure) by March.

【Countermeasure】

As for workers who took a post-procedure for appointment/registration for radiation workers, the name list is now preparing. After completion, the radiation workers are appointed and registered with an official procedure and check external radiation. When they are released from radiation workers, they will be monitored by WBC measurement for actual radiation exposure during the work period.

Male workers other than radiation workers who were exposed in the Main Anti-Earthquake Building of Fukushima Daiichi Nuclear Power Station are checked for estimation of radiation volume.

In addition, because the area of Fukushima Daiichi Nuclear Power Station is regarded as the control area, only radiation workers can work.

External exposure by radiation counter (measured), external exposure by movement within the site and work in the Main Anti-Earthquake Building (estimated), internal exposure (measured) and total exposure in Fukushima Daiichi and Daini Nuclear Power Stations are monthly informed to each worker. If a worker exceeds the following level, the worker is treated as follows.

In case that external exposure exceeds 100 mSV,

Internal exposure is evaluated by a whole body counter.

In case that external exposure exceeds 150 mSV,

Judgment for continuation of work is made.

In case that total exposure (external and internal) exceeds 200 mSv,

They are not assigned for work..

Female employees are not assigned for work in Fukushima Daiichi Nuclear Power Station (work in an area where does not have high radiation level such as a back office of Fukushima Daiichi Nuclear Power Station) and managed within the limitation level.

To conduct thorough radiation control for female employees, external exposure is managed within 3 mSV considering the above recording level (2 mSV) is monitored.

7 . Attachment

- (1) Time-line
- (2) Results of individual radiation dose evaluation
- (3) Field Operation of Female Worker A
- (4) Trends in Radioactive Density in the Air in the Main Anti-Earthquake Building
- (5) Trend of Radioactive Volume in the Main Anti-Earthquake Building (Before and After Installation of the Covers)
- (6) Overview and Effects of Countermeasures for Environment Improvement
In the Main Anti-Earthquake Building of Fukushima Daiichi NPS
- (7) Replacement of Floor Mat in the Main Anti-Earthquake Building (Plane)

End

Time-line

	<u>Implemented radiation control measures</u>	<u>Female workers' activities etc.</u>
Year 2011		
March 11	(2:46 pm The Tohoku-Chihou-Tauheiyo-Oki Earthquake occurred)	
March 12	7:00 am ~ We started measuring dose rate in the key earthquake-proof building (Thereafter, the measurement is conducted every day) (3:36 pm Hydrogen explosion occurred in Unit 1) 5:57 pm Plant Safety Team Leader instructed employees working outside of the key earthquake-proof building to wear their charcoal masks.	
March 14	(11 : 01 am Hydrogen explosion occurred in Unit 3)	
March 15	Approx. 6:30am Plant director instructed emergency countermeasure staff to evacuate.	Female worker A and B evacuated.
March 17		Female worker A went back to work in the key earthquake- proof building.
March 18 to 20		Female worker A was engaged in field operation.
March 20		Female worker A left the key earthquake-proof building.
March 22		Female worker A went back to work

in the key earthquake- proof building and was engaged in field operation.

From March 22~

Head office Safety Team Leader instructed female workers to serially receive WBC.

March 23

Arrox. 12:00pm Plant Safety Team Leader Instructed female workers to evacuate. Female worker A evacuated.

From March 24~

We started measuring the density of radioactive materials in the air in the key earthquake-proof building. (Thereafter, measurement is conducted every day)

April 1 We interviewed how long employees were to around 10 engaged in emergency countermeasures.

From approx. April 10

We were studying how to evaluate radiation dose while employees were working.

April 25 We completed evaluating radiation dose to which employees are exposed while they are in the key earthquake-proof building.

April 27 We completed evaluating internal exposure of radiation dose to female worker A. As a result of medical examination by an industrial physician

in Fukushima Daini Nuclear Power Station, we confirmed she had no health impact.

May 1 We completed evaluating internal exposure of radiation dose to female worker B.

May 2 As a result of medical examination by an industrial physician in the head office, we confirmed she had no health impact.

Results of individual radiation dose evaluation

[Female Worker A]

Breakdown			Exposed radiation dose (mSv)
After January 1 before the Earthquake			0.00
After the Earthquake	External exposure	APD measurement	2.06
		Stay in the key earthquake-proof building	1.89
	Internal exposure		13.60
Total			17.55

【Female Worker B】

Breakdown			Exposed radiation dose (mSv)
After January 1 before the Earthquake			0.00
After the Earthquake	External exposure	APD measurement	0.00
		Stay in the key earthquake-proof building	0.78
	Internal exposure		6.71
Total			7.49

Field Operation of Female Worker A

Date	Radiation dose	Work descriptions and places	Equipment for radiation protection
March 18	0.70mSv	Refueling company cars (beside a gymnasium)	Charcoal mask Tyvek Rubber glove
March 19	0.79mSv	Refueling fine engine trucks (at a shallow draft quay)	Charcoal mask Tyvek Rubber glove
March 22	0.57mSv	Refueling company cars (beside a gymnasium)	Charcoal mask Tyvek Rubber glove

Trends in Radioactive Density in the Air in the Main Anti-Earthquake Building

Unit: Bq/cm³

