The report on cause analysis on exposure of radiation workers exceeding dose limit and development of measures on recurrence prevention at emergency work in Fukushima Daiichi Nuclear Power Station

June 17, 2011

Tokyo Electric Power Company

1. Summary of the incident

On June 10, 2011, the operation to determine the exposure dose during the emergency work in Fukushima Daiichi Nuclear Power Station confirmed that evaluation of exposure dose of 2 male TEPCO employees exceeded 250mSv, the dose limit during the emergency work.

[Exposure dose of those two employees]
Employee A: 678.08 mSv (external exposure 88.08 mSv, internal 590 mSV)
Employee B: 643.07 mSv (external exposure 103.07 mSv, internal 540 mSV)

Note) the above amount does not include the potential exposure during the stay in the main anti-earthquake building and during the transportation as those exposures are under evaluation. These will be added after the completion of the evaluation.

Doctors diagnosed that there is no health impact on those employees.

2. Timeline

Timeline of the incident is as per attachment 1

(Attachment 1)

3. Survey result

(1) Survey of exposure dose

Survey of exposure dose was conducted for the exposure during the work at site, exposure during the stay in the main anti-earthquake building in March and April, exposure during the transportation from J-village which is the base camp for the access to power plant, to the main anti-earthquake building, and internal exposure. External exposure dose during the stay in the main anti-earthquake building and during the transportation will be evaluated and added afterwards.

(Attachment 2)

a. Exposure dose during the work at site

As employees wear APD during the work at site, exposure dose during the work at site was calculated using the measured data from March 11 to May 30.

Employee A: 73.71 mSv
Employee B: 88.70 mSv

b. Exposure during the stay in the main anti-earthquake building

Exposure during the stay in the main anti-earthquake building for each month was calculated using the data from the integral dosimeter for the control purpose (dosimeter installed to grasp the background exposure dose).

March: 3.56 mSv

April: 2.06 mSv

May: not calculated yet

c. Exposure during the transportation

Exposure during the transportation from J-village to the main anti-earthquake building was calculated by multiplying the average radiation dose during a month (mSv/h) measured near the main anti-earthquake building and time needed for the transportation from the main gate to the main anti-earthquake building (approx. 30minutes) together.

March: 5.00 mSv

April: 3.75 mSv

May: not calculated yet

d. Internal exposure dose

Regarding Internal exposure dose, committed effective dose was calculated by measuring the radioactive materials remained inside body by whole body counter (“WBC”) and by estimating timing of each employee’s intake of radioactive materials based on the analysis of their activity.

<Employee A>

On April 16, his first survey including body survey by the WBC rented from JAEA and set in Onahama coal center found the body contamination (1,300 cpm). He was instructed to take another survey on May 3.

The committed effective dose was evaluated to be 90 mSv with the assumption that radioactive material intake occurs on April 6, which is the median date of work period (March 11 to May 2) reported by himself.

As this amount exceeds 20 mSV, which requires detail evaluation, JAEA was asked to conduct evaluation.

As a result of the detailed survey of his activity, radioactive material intake was estimated to occur on March 17, which is the median date of work period (March 11 to March 23). Based on such assumption, the exposure dose was calculated to be 480 mSV, which

exceeds dose limit during the emergency work.

Additionally, medical diagnosis was provided by medical expert at NIRS and radioactive material intake was determined to occur on March 12.

*On March 12, radiation dose in the outside environment increased from the early morning. Vent was implemented in Unit 1 PCV and the explosion occurred in the upper part of Unit 1 reactor building on the same day.

Combined with the WBC data measured at NIRS, committed effective dose of employee A was estimated to be as follows. No medical impact was found during the medical diagnosis.

Employee A: 590 mSv

<Employee B>

On April 17, his first survey including body survey by the WBC rented from JAEA and set in Onahama coal center found the body contamination (1,200 cpm). He was instructed to take another survey on May 4.

The committed effective dose was evaluated to be 83 mSv with the assumption that radioactive material intake occurs on April 7, which is the median date of work period (March 11 to May 4) reported by himself.

As this amount exceeds the threshold which requires detail evaluation, JAEA was asked to conduct evaluation.

As a result of the detailed survey of his activity, radioactive material intake was estimated to occur on March 13, which is the median date of work period (March 11 to March 15). Based on such assumption, the exposure dose was calculated to be 540 mSV, which exceeds dose limit during the emergency work.

As in the case of employee A, medical diagnosis was provided by medical expert at NIRS and radioactive material intake was determined to occur on March 12. Combined with the WBC data measured at NIRS, committed effective dose of employee A was estimated to be as follows. No medical impact was found during the medical diagnosis.

Employee A: 540 mSv

e. Result of survey of exposure dose

Combining external exposure during the work at site, the stay in the main anti-earthquake building and the transportation from J-village to the main anti-earthquake building and

internal exposure, the total exposure dose was confirmed to exceed the stipulated dose limit during the emergency work.

(2) Survey of the cause to exceed the dose limit

As internal exposure of those two employees alone exceeded the dose limit, cause of internal exposure was surveyed.

a. Survey of work at site

Those two male employees are operator of Unit 3 and 4 and were in charge of data collection in main control room, equipment operation inside the plant, and outside work.

Employee A

March 11: data collection in main control room, Unit 4 T/B site survey

March 12: data collection in main control room, Unit 4 T/B site survey, fuel supply operation at the south side of Unit 1

March 13: data collection in main control room, line up of vent line, moved to the main anti-earthquake building around 16:00pm (afterwards, the data collection has been conducted by the shift)

March 14: move from the main anti-earthquake building, data collection in main control room (approx. 6hours)

March 15: moved to Fukushima Daini Nuclear Power Station during the early morning

Took off until March 18, afterwards, conducted data collection (30 min to 1 hour for each time) of Unit 3 and 4 main control room of Fukushima Daiichi NPS while his base was in Fukushima Daini NPS. Last work at the site was conducted on April 14.

He has not worked in Fukushima Daiichi NPS after May 23.

Employee B

March 11: data collection in main control room, Unit 4 T/B site survey

March 12: data collection in main control room, Unit 4 T/B site survey, fuel supply operation at the south side of Unit 1

March 13: data collection in main control room, line up of vent line, moved to the main anti-earthquake building around 16:00pm (afterwards, the data collection has been conducted by the shift)

March 14: move from the main anti-earthquake building, data collection in main control room (approx. 6hours)

March 15: move from the main anti-earthquake building, data collection in main control

room (approx. 6hours), moved to Fukushima Daini Nuclear Power Station during the early morning.
He took off until March 20. From March 21, he worked in the main anti-earthquake building and in Fukushima Daini Nuclear Power Station. Last work at the site was conducted on April 14.
He has not worked in Fukushima Daiichi NPS after May 30.

Accurate data of radiation dose and density of radioactive material in the air at the time of their work is not available as power supply and facilities were not available. Radiation dose rate and density of radioactive material in the air near March 12, which was estimated to be the day of radioactive material intake, are as follows.

（Main Control Room of Unit 3 and Unit 4）

Item	Date	Monitoring Point （Main Control Room of Unit 3 and Unit 4）
Radiation Rate	4/9	0.4mSv/h （Airborne radiation: MAX value）
Air radioactivity concentration	4/4	2.0E-1 Bq/cm^3（I-131） 8.8E-5 Bq/cm^3（I-132） 5.0E-4 Bq/cm^3（Cs-134） 2.5E-5 Bq/cm^3（Cs-136） 4.7E-4 Bq/cm^3（Cs-137）

（T/B of Unit 4）

Item	Date	Monitoring Point （T/B of Unit 4）
Radiation Rate	3/20	Entrance of materials of T/B of Unit 4 to Steps of South-east side (1F-B2F) 0.5mSv/h（all data are same）
Air radioactivity concentration	5/3	North P/C room of T/B of Unit 4 2.0E-3 Bq/cm^3（I-131） 8.1E-5 Bq/cm^3（Cs-134） 1.0E-4 Bq/cm^3（Cs-137）

（Outside Buildings）

Item	Date	Outside Buildings
Radiation Rate	3/20	West side of R/B of Unit 4 (before FPC water spray) 8.0mSv/h （Airborne radiation: MAX value）
Air radioactivity concentration	3/19	North side of Administration Office Building 7.0E-3Bq/cm^3（I-131） 2.4E-5Bq/ cm^3（Cs-137）

Instructions of use of mask are made as follows.

March 12

Around 4:00 am　A shift supervisor gave an order for preparation of masks in the Main Control Room considering effects of ventilation.

Around 4:50 am　A chief of security gave an order for use of charcoal masks from the entrance of Main Anti-Earthquake Building when staff/workers go to the site.

5:04 am　A shift supervisor gave an order for use of dust masks in the Main Control Room and charcoal masks on the site considering number of reserved masks.

(3:36 pm　Explosion of upper part of the reactor building of Unit 1)

Employee A and B used masks according to the above orders.

Regarding reserved masks, there were 15 charcoal masks in the entrance of control area of service building of Unit 3&4, 50 charcoal filters and about 300 masks. From 16:00 of March 13 to the time that additional masks were prepared in the Main Anti-Earthquake Building, these materials had been used for going out from the building for taking data in turn.

Besides, internal exposure of Employee (i), who worked with the Employee A, was 9.7 % of that of Employee A.

Internal exposure of Employee (ii) and (iii), who worked with the Employee B, was

respectively 1.6 % and 6.6 % of that of Employee B.

Internal exposure of Employee (iv), (v), (vi) and (vii), who worked with the Employee A and Employee B, was respectively 2.4 %, 2.8 %, 3.1 % and 4.5 % of average internal exposure of Employee A and Employee B.

According to an interview with Employee A, he used glasses and some radiation was often detected in his hair where was close to the temples of the glasses when he was checked in the entrance of the Main Anti-Earthquake Building. It is guessed that there was a possibility that the temples made some space between his skin and mask. The temple of Employee A has a wide shape and it was easy to make a space.

* There are no masks adjusting shape of temples of glasses. For the glass users, a mask can be adjusted only by a tightened band

According to an interview with Employee B, he worked around the emergency door (entrance to the outside) of the Main Control Room for taking data in the Main Control Room. The door was distorted by the explosion of Unit 1 and it could not be isolated from the outside circumstances. He used a dust mask until the explosion of Unit 1.

* The emergency door of the Main Control Room was not fully closed because all electric power sources were lost and it was a route of the external power sources. It is thought that the explosion of Unit 1 affected some distortion of the door.

According to interviews with Employee A and B, they took off their masks when having meals in the Main Control Room.

According to an activity survey for other operators who are colleagues of Employee A and Employee B, it was found that they took actions as follows in the Main Control Room or the site.

(i) They took off masks when they took meals in the Main Control Room, even though masks must be used in the room from March 11 to the timing they were released from stationing in the room.
(ii) There were some persons whose internal exposure was due to use of glassed.
(iii) Radiation level was high in the Main Control Room of Unit 3. It was observed at the time of explosion of Unit 3 that dusts, which were supposed

to come from the emergency door, were floating in the room.

(iv) There were some persons who did not use masks outside when the explosion of Unit 1 happened.
(Persons who were transported in the site by bus, persons who were waiting outside of the Main Anti-Earthquake Building, etc.)

The above (i) – (iii) were corresponding to the results of the interview with Employee A and B. Regarding the above (iv), the action was not corresponded to the actions of Employee A and B. Persons who did not use masks outside when the explosion of Unit 1 happened have internal exposure of 2.9 % - 17. 4 % compared to average internal exposure of Employee A and Employee B.

b. Survey in the Main Anti-Earthquake Building

Regarding a possibility to take radioactive materials in the Main Anti-Earthquake Building, “Investigation of causes and development of preventive measures regarding exposure exceeding dose limit to radiation workers at Fukushima Daiichi Nuclear Power Station” was reported on May 2, 2011 as “Genkan 23 No.46”. Employee A and Employee B worked on the second floor, not the first floor where female employees exceeding the exposure dose limit were working.

According to an activity survey for other operators who are colleagues of Employee A and Employee B, it was found that they took actions as follows in the Main Anti-Earthquake Building.

(i) There is a possibility that some persons took radioactive materials by a door open/close control at the entrance of the Main Anti-Earthquake Building.

This is corresponding to the assumed reason which the female employees exceeded the exposure dose limit.

c. Taking medicine of potassium iodide

30,000 tablets of potassium iodide have been prepared as materials of disaster in the Main Anti-Earthquake Building. On March 13, a medical chief gave an instruction to take tablets for persons under 40 years old and persons not less than 40 years old (as requested).

However, Employee A and B worked in the Main Control Room at that time and the tablets

were not distributed to the Main Control Room because the incidents proceeded too quickly. As a result, they could not take tablets until they reached the Main Anti-Earthquake Building.

After the movement to the Main Anti-Earthquake Building, it was recorded that the Employee B (Age: 40's) took 2 tables on March 14, 2 tablets on May 2, 1 tablet on May 3, 2 tablets on May 12, 2 tablets on May 20 and 1 tablet on May 21 (total 10 tablets). Even though the Employee A remembered that he took 2 tablets on March 13 according to an interview, it was not recorded.

d. Delay of Evaluation Results

Internal exposure of Employee A and B was confirmed on June 10. About 3 months have already passed from the day (March 12) which they were supposed to take radioactive materials.

(Employee A and B took the first check by WBC on April 16 and April 17 respectively. About 2 months have already passed from the check.)

Spent time from the first check for internal exposure during March was about 5 weeks. Spent time from the second check due to body exposure was about 2 weeks. In addition, the evaluation by JAEA spends 1 week and a survey period by National Institute of Radiological Sciences spends 2 weeks. Even if these external surveys were excluded, it can be said that total evaluation period spends 1 month.

（Attachment 3）

4. Cause analysis and Assumption

(1) Survey of Site Work

Significant intake of radioactive materials was not recognized for other employees and workers worked with Employee A and Employee B. However, regarding the Employee A, it is guessed that he made a space between mask and temples of his glasses when he use d mask.

Regarding the safety equipment, Employee A and Employee B installed dust masks according to the order. However, dust masks cannot remove volatile iodine and there was a possibility that they took such volatile iodine.

Especially Employee B worked for taking data at the emergency door of the Main Control Room when the explosion of upper part of the reactor building of Unit 1 happened. This means that there was a possibility that he took volatile radioactive iodine because he used a dust mask during the time outside air came there.

It was possible that the performance of iodine absorption by charcoals was fallen off as

the same charcoal filters had been used for long time due to the situation where it was difficult to supply additional masks and charcoal filters.

In addition, it would be also possible that Employee A and B took in the radioactive materials when they forced to have meals in the main control room in order to intensively cope well with the situation at the main control room before their work place was shifted from the main control room to the main anti-earthquake building.

(2) Survey in the Main Anti-Earthquake Building

Regarding the possibility to take in the radioactive materials in the main anti-earthquake building, the amount they possibly take in the radioactive materials would not be significant because the internal exposure doses of female employees, who stayed in the main anti-earthquake building at the time that the dust density was likely the highest from March 11 to 15, were between below measurable limit and 13.60 mSv, though Employee A and B basically worked at the main anti-earthquake building from March 13 to 15, thereafter Employee A worked at the main anti-earthquake building from March 20 (worked at Fukushima Daini Nuclear Power Station on March 19) after taking holiday, and Employee B worked at the main-earthquake building from March 25 (worked at Fukushima Daini Nuclear Power Station from March 21 to 24) after taking holiday.

(3) Time to take medicine of potassium iodide

There is a record for Employee B that he took the potassium iodine medicine after transferred to the main anti-earthquake building (March 14).

Employee A reportedly remembered that he took two tablets of potassium iodine medicine after transferred to the main anti-earthquake building (March 13).

The reason why it took so long time to take the medicine first was that it was unable to take the medicine during the work at the main control room since the potassium iodine medicine were stored in the main anti-earthquake building as materials for disaster, and it was difficult to bring the potassium iodine medicine into the main control room due to a great deal of confusion after the earthquake and tsunami.

The confused situation was also noted by the fact that the instruction to take the potassium iodine medicine by the medical chief was not right after the explosion in the upper part of Unit 1 reactor building when the density of radioactivity in the air was suppose to be high, but sometime later.

The effectiveness of the potassium iodine medicine may not be so great since it reported that it is not effective after 12 hours from the time when those who inhale the radioactive iodine or take in by oral (ICRP Pub-63).

(4) Delay of the determination of the evaluation result

WBC in Fukushima Daiichi and Daini Nuclear Power Stations were unable to use due to the earthquake, tsunami and subsequent the emission of a large quantity of radioactive materials.

Therefore, TEPCO was lent the in-vehicle WBC from JAEA and started the measurement, however, the number of the in-vehicle WBC was limited and it took longer for measurement.

As for the evaluation methodology of the internal exposure, the establishment of the methodology took long for consideration of the situation where the intake mode of radioactive materials was different from normal under the high and long radioactive dose level in the air.

The internal exposure dose administrative system was also unable to use affected by the earthquake and tsunami, therefore, the series of works for it, such as inputting data, analyzing, making database, checking data, extracting the list of person who haven't taken the measurement, sending notice and etc., was forced to be done by fully manual operation.

In addition, the individual data collection by the in-vehicle WBC at the early stage was not sufficient, which made the establishment of the database difficult.

(5) Presumption of the cause

While the main control room is designed to protect operators from radioactive exposure dose by main control room air ventilation system to considerable extent even in emergencies, the main control room air ventilation system didn't work in this accident since all AC power was lost. Thus, the operators in the main control room were forced to manage not only to operate the plants corresponded with the earthquake but also to protect by themselves from radioactive exposure dose as much as possible.

The correspondence was made on their best effort basis in limited time, however it resulted that they supposed to take in the radioactive materials by following multiple factors.

(i) Due to the rapid movement of the accident, situation was very difficult to properly manage the radiation dose administration, such as selecting, wearing and distributing appropriate masks, distributing and giving instruction of potassium iodine.

(ii) It was inevitable to have meals and drinks in the main control room as operators had to stay long hours there to manage the abnormal situation.

(iii) There was a gap between face and mask caused by shape of temples of glasses for Employee A when wearing mask

(iv) Employee B worked near the emergency door of the main control room (the

door connected to outside), where the density of radioactive material in the air was estimated high. He was in the situation where unable to correspond swiftly with the unforeseeable circumstances such as the explosion in the upper part of Unit 1 reactor building.

(v) The reasons why it took long time to determine the internal exposure dose were considered that the procurement of WBC was not progressed well, it took long time to establish the evaluation methodology, data processing was done by fully manual operation and so on.

6 employees other than Employee A and B were measured above 250mSv effective dose on temporally evaluation basis by Onahama Coal Center or JAEA.

The detailed evaluation and confirmation of exposure dose will be conducted hereafter. The breakdown of the 6 employees are as follows; one from operating department, four from maintenance department who in charge of restoration for power supply and instruments & controls, and one operational administration department who in charge of management of radiation exposure. All these employees worked with difficult tasks in the reactor building or its vicinity where the radiation exposure level was high at the early stage.

As the result of action survey for these 6 employees, three persons were wearing glasses, in which one person minded the gap of the mask at his temples.

It was also founded that four persons, including one person out of abovementioned three, worked without masks or with dust masks at very early stage that the environmental radiation dose began to rise.

Especially the employee of operational administration department confessed their was some time when he conducted body survey without mask at the entrance of the main anti-earthquake building at the beginning stage to monitor the comings and goings. That was consistent with the result of action survey of operators and cause of excess radiation dose limit by female employees.

From these evidences, it was estimated that the cause of the radiation exposure dose for 6 employees were similar to the abovementioned ones.

5. Measures for prevention of recurrence

Due to the scale of the event and its pace of the progress, workers did their best with regard to the radiation protection and considering the time limitation at that time, we could assume that they responded well as much as possible. However, in terms of prevention of recurrence, we would like to see this event as a good lesson and take measures as follows.

I. With regard to “Due to the rapid movement of the accident, situation was very difficult to properly manage the radiation dose administration, such as selecting, wearing and distributing appropriate masks, distributing and giving instruction of potassium iodine”,

a. Information sharing

Each group of emergency response organization share the information that they have with each other and confirm judgments or directions from several points of view (decided on March 15th).

b. Preparation and proper use of sufficient equipment

Considering this accident as a good lessen, we will prepare sufficient equipment and iodine medicine properly and use them smoothly in case that we could forecast significant changes in the plant.

II. With regard to “It was inevitable to have meals and drinks in the main control room as operators had to stay long hours there to manage the abnormal situation”

c. Restriction of drinking and eating

We will prohibit workers from drinking and eating in the areas under control by the national government (surface contamination and density of radioactive materials in the air) prescribed by the law as well as in the main control rooms of Unit 1 to 4 in Fukushima Daiichi Nuclear Power Station.

III. With regard to “There was a gap between face and mask caused by shape of temples of glasses for Employee A when wearing mask”

d. Educational campaign regarding protective equipment

We put on the bulletin board for the notice of protective equipment in J-Village, as the stronghold, as well as in the main anti-earthquake building in Fukushima Daiichi Nuclear Power Station.

e. Education regarding protective equipment

For those who enter and work for the first time in the site of J-Village of Fukushima Daiichi Nuclear Power Station, we will instruct them how to wear the protective equipment including breathing protection equipment and arrange simple education of radiation.

Also, in order to educate the workers repeatedly with regard to the necessity and effect of protective equipment, we will announce widely in our company and in the partner companies through Pricing and Power

Contract Department. We also announced for the companies through disaster restoration safety liaison council in Fukushima Daiichi Nuclear Power Station (on June 10th)

f. Assuring wearing the protective equipment

Make sure before starting to work, either the leader of each group or assistant of wearing confirm if the workers have wore the equipment properly.

g Adopting new masks

Considering the fact that some of the workers have failed to wear a mask properly due to the temple of glasses, we will plan to tighten the current masks or to adopt new type of mask that covers a face fully.

IV. With regard to Employee B worked near the emergency door of the main control room (the door connected to outside), where the density of radioactive material in the air was estimated high. He was in the situation where unable to correspond swiftly with the unforeseeable circumstances such as the explosion in the upper part of Unit 1 reactor building.

h. Sufficient surveys before working and information sharing

In addition to arranging a survey already explained in a previous report, we will put radiation maps etc. on the bulletin board and share the information with each other in order to decrease the exposure dose.

I. Wearing protective equipment properly

Based on the survey before working, we will surely choose the protective equipment appropriate for each of the work environment.

V. With regard to the fact of taking so much time to determine the dose of internal exposure

j. Failed to secure WBC

We will prepare and distribute necessary WBCs as soon as possible in J-Village in Fukushima Daiich Nuclear Power Station (4 will be arranged from July to August and more of 6 will be on and after November)

k. Took much time to establish the way of evaluation

In the primary evaluation, in order to implement screening properly, we will set a conservative and hard criteria and evaluate properly.

l. Restricted capacity of processing data which depends on human resources

We will reestablish the system including the internal organization, considering the

incoming change.

6. Inappropriate Occurrence regarding Masks before this Reporting

(1) Non-installation of Filter Cartridge to Mask (June 13)

a. Overview

It was found that a filter of mask had been taken off when workers, who installed sliding concrete plate of intake of Unit 2 in Fukushima Daiichi Nuclear Power Station, took a body check. After the body check, he took a check by WBC in Onahama Call Center. As a result, it was found that his internal exposure was lower than the detectable level.

b. Causes

As a result of survey, it was found that he worked without installation of the filter after he took off the filter to seal when he wore the safety equipment.

＜Timeline＞

About 8:00 am When he sealed up a gap by a tape between tyvek and mask for installation of the safety equipment in the Main Anti-Earthquake Building, he took off the filter from the mask to completely and easily seal up.

About 8:30 am He went out from the Main Anti-Earthquake Building without a filter and worked at the screen of intake of Unit 2.

About 10:30 am A body checker conducted a survey for him when he came back to the Main Anti-Earthquake Building after the work, the checker found he had not attached the filter.

After that, he took a radiation survey for his face and any abnormal condition was recognized. The result of external exposure was 0.51 mSv.

About 1:55 pm He took a check by WBC in Onahama Call Center. As a result, it was found that his internal exposure was lower than the detectable level.

The reasons why he entered without a filter in the mask are guessed as shown below.

- He or a person who sealed up forgot attachment of filter again after removal of filter from his protection mask.
- Members in the same working team did not become aware that he did not attach the filter.

- Check for proper attachment of the protection wear was not included in the checking process before working.

c. Preventive Measures for Same Accidents

The following preventive measures are taken.

- Announcement to completely conduct a check for leakage after attachment of mask is made. (Enlightenment and education for the protection equipment)
- Making a counterpart person to check proper attachment by pointing before going out. (Enlightenment for the protection equipment)
- In the Safety Communication Meeting for Disaster Recovery, this accident is announced and preventive measures are requested to be completed thoroughly. (Enlightenment for the protection equipment)

(2) Smoking in the Area to Wear Mask (June 15)

a. Overview

The shallow draft quay of Fukushima Daiichi Nuclear Power Station is located in the area to wear mask. TEPCO staff as a supervisor found that a worker smoked taking off his full face mask in the area when he had conducted an erection work of a crawler crane (heavy machine) for a covering work of the reactor building of Unit 1.

The area is prohibited from eating/drinking and smoking for protection from radiation exposure. However, he did not follow this rule.

The worker took a check by WBC in Onahama Call Center. As a result, it was found that his internal exposure was lower than the detectable level.

b. Causes

As a result of the survey for causes which the worker smoked taking off the full face mask in the warning area, it was found that the worker took off the mask by his judgment.

＜Timeline＞

About 9:00 am Start of an erection work of a crawler crane for a covering work of the reactor building of Unit 1 in the shallow draft quay

About 11:05 am TEPCO staff, who was a site supervisor covering from R/B area to the quay of Unit 1, found that the worker smoked in the operation seat of the crane.

About 11:08 am The TEPCO supervisor informed the manager of the

responsible group about it, and the work was interrupted.

About 3:35 pm The worker took a check by WBC in Onahama Call Center. As a result, it was found that his internal exposure was lower than the detectable level.

From an interview with the worker on the reason why he smoked taking off the mask, it was found that he judged by himself that there was no problem even though he took off the mask because he relaxed by misunderstanding that the density of airborne radioactive material was low.

c. Preventive Measures for Same Accidents

This accident was caused by an intentional violation of a rule under the radiation circumstance. The following preventive measures are taken.

- Through the Safety Communication Meeting for Disaster Recovery, etc., TEPCO reprimands sub-contractors as well as ourselves strictly and restores the discipline. (Enlightenment for the protection equipment)
- Education for knowledge on work rules (management of exposure dose and equipment, etc.) under the radiation circumstance and protection against radiation is thoroughly made. (Education for the protection equipment)

The preventive measures in the above (1) and (2) are managed in common with the preventive measures indicated in 5. d. e. f.. Properly implementation of these measures can prevent similar accidents

7. Attachment

(1) Timeline

(2) Evaluation Results of Individual Exposure Dose

(3) Verification of the Time for Evaluating Internal Exposure Dose

End

Attachment 1

Timeline

Date / Time	Radiational Administration	Concerned Employees' Action
2011 March 11, 2:46pm	(Tohoku - Pacific Ocean Earthquake)	
March 11		data collection in main control room, Unit 4 Turbine Building site survey
March 12		data collection in main control room
around 4 am	Prepared for masks considering the effects of ventilation	Unit 4 Turbine Building site survey
around 4:50 am	Instruction to wear charcoal masks when going to sites from Main Anti-earthquake Building (by Technical Support Center)	fuel supply operation at the south side of Unit 1
5:04 am	Instruction to wear dust masks at Main Control Room and charcoal masks in sites (by shift supervisor)	
around 2:30 pm	Unit 1 ventilation (Primary Containment Vessel pressure down)	
3:36 pm	(Unit 1 Explosion at upper part of Reactor Building)	
5:57 pm	Instruction to wear charcoal masks (by a Chief of Security)	
March 13		
around 9:30 am	Unit 3 ventilation (Primary Containment Vessel pressure down)	data collection in Main Control Room, line up of vent line (Employee A) move to Main Anti-earthquake Building around 4 pm
March 14		
11:01 am	(Unit 3 Explosion at upper part	data collection from Main

	of Reactor Building)	Anti-earthquake Building to Main Control Room (about 6 hours)
March 15		
around 6:30 am	Instruction to evacuate temporally by Chief Director of the Power Station	data collection in Main Control Room (Last work at the site for Employee B) moved to Fukushima Daini Nuclear Power Station during the early morning (Employee A: Took off until March 18) (Employee B: Took off until March 20)
March 22	establish WBC (owned by JAEA) at Onahama Call Centor	
March 24 –	Start measurement of radioactivity concentration in the Main Anti-Earthquake Building (The measurement has been conducted everyday since March 24.)	
April 1 – around April 10	Hearing survey of the length of stay targeting employees engaged in emergency works	
Around April 10 -	Study of evaluation method of radiation dose during the length of stay	
April 14		Last work at site for Employee A
April 25	finished evaluation of exposure dose during the stay in the Main Anti-Earthquake Building	
May 22		Last work at the Main Anti-Earthquake Building for

		Employee A
May 29		Last work at the Main Anti-Earthquake Building for Employee B
May 30	High radioactive level (iodine 131) of the two employees' thyroid was confirmed. Medical diagnosis was provided by medical expert at National Institute of Radiological Sciences (NIRS).	
June 10	The results of medical diagnosis from NIRS were received.	

Year 2011

Attachment 2

Evaluation Results of Individual Exposure Dose

【employee A】

Age: thirtieth	External exposure dose	APD figures	73.71mSv	88.08mSv
		At the main anti-earthquake building	5.62mSv (March 3.56mSv, April 2.06mSv)	
		During transportation	8.75mSv （March 5.00mSv, April 3.75mSv）	
	Internal exposure dose			590mSv
	Total			678.08mSv

【employee B】

Age: fourtieth	External exposure dose	APD figures	88.70mSv	103.07mSv
		At the main anti-earthquake building	5.62mSv (March 3.56mSv, April2.06mSv)	
		During transportation	8.75mSv （March 5.00mSv, April 3.75mSv）	
	Internal exposure dose			540mSv
	Total			643.07mSv

Attachment 3

Verification of the Time

for Evaluating Internal Exposure Dose

During this incident, we couldn't use the internal radiation dose evaluation system because of (i) loss of electricity caused by the earthquake and tsunami and (ii) large scale release of radioactive substances. As such, it took time in evaluating the internal radiation dose from the time of intake to determining the figures.

1. Issues to be identified

（1）Issues on WBC

At Fukushima Daiichi Nuclear Power Station, we installed four WBCs. Because of loss of electricity and the increase in background figures by the large scale release of radioactive substances, we couldn't use these.

Thus, from March 22, we borrower the movable WBC vehicle owned by (JAEA) Japan Atomic Energy Agency and installed this at Onahama Coal Center.

As to the operation of the WBC from JAEA, as we had to familiarize ourselves with the facility, initially the rate of measurement was 3 persons / hour. As we got used to it, we are measuring with 6-8 persons / hour.

However, as the initial number of the vehicle was one, we couldn't measure sufficient number of persons. From June 1, we borrowed one more vehicle to increase the rate.

Also, in order to measure the radiation dose of people in charge of the initial (March) work and already left the site, apart from the above two, we borrowed one more vehicle from May 9 and we began the measurement from May 11 at Kanto region including Tokyo.

At Fukushima Daini Nuclear Power Station, we installed four WBC. Because of the impact by tsunami and the increase in background figures by the large scale release of radioactive substances, we couldn't use these.

Thus, we took measures such as extension of measurement time. From April 11, two WBCs were operational. After the regular measurement of persons at Fukushima Daini Nuclear Power Station, from May 23, we began measurement of

persons at Fukushima Daiichi Nuclear Power Station (4-6 persons / hour).

At Kashiwazaki Kariwa Nuclear Power Station, we have four WBCs. Three out of four that are normally used are used for persons at Fukushima Daiichi Nuclear Power Station from the beginning. As the location was away from Fukushima, the frequency was low.

As such, just after the incident, we measured with 1 WBC from JAEA with the rate of 3 persons / hour. Right now, the rate is 30 persons / hour (disregarding Kashiwazaki Kariwa).

However, the capacity factor is around 50% because of the work schedule and the overlap of desired time.

We believe that the other factor is the location of WBC, at Onahama Coal Center with inconvenient transportation. We selected the location because of less influence by radioactive substances and high flexibility of operation close to Fukushima Daiichi Nuclear Power Station.

（2）Issues on the internal radiation dose administration system

The internal radiation dose administration system evaluates the internal radiation dose every three months as set out by regulations. Normally, we check the residual radioactive substances in the human body by WBC and evaluate the committed dose.

Under normal circumstances, the complete procedures are done by a system (import data, evaluate, construct a database, check data, screen people who have to take the measurement and notify). As we cannot use the system, we are doing all works by hand.

The WBC borrowed from JAEA does not have communication function and data analysis function. It took time from examination to the evaluation result.

- Transfer of data: once a day as this is by batch treatment
  Data analysis: up to May 13, done at JAEA (approx one week)
  From May 13: at TEPCO (approx one week)
- Construct at database: manual input (approx one week)
- Check data: As JAEA's WBC is for simplified measurement of ordinary citizens, the form of the check sheet is incomplete on personal info (without the company's name, the form personal name is not unified). It took around two weeks to identify persons. (From April 20, we relegated the operation of

WBC to Toden Kankyo Engineering, and increased the number of data collected).

Also, under normal circumstances, it is relatively easy to identify when the internal exposure dose occurred (whether there is external exposure dose / the monitoring result of the work site). However, under this incident with high density of aerial radioactive substances for a long time, it is difficult to identify when the internal exposure dose occurred. Also, because of scarcity of WBC, the lead time in having the measurement was long, so persons forgot when they worked. As such, it took time to determine when the internal exposure dose occurred.

On top of this, at the time of initial measurement, most of persons had external exposure dose. We had to repeat the measurement several times with two weeks interval (iodine on the skin flakes off by metabolism). It took time before we got data. The more it took time, the more persons forgot.

So, we decided to set the common time period for intake, do the initial evaluation for screening and will have detailed evaluation to people above the threshold.

As to this common time period for intake, on May 23, we decided to set this as the middle of self-reported work period for screening.

However, at that time, we could no longer detect the residual iodine. So, we evaluated the iodine intake based on the result of environmental monitoring (cesium-iodine ratio). This resulted in contradiction, the assumed Iodine should have been detectable but none.

So, on May 25, we adopted the lower of (i) the assumed figures based on the environment monitoring and (ii) lower detectable limit figures remained in the body at the time of measurement.

As a result, we confirmed that the internal exposure dose for two employees were high.

As to evaluation of data, we manually inputted to the database, checked and corrected data, checked and corrected personal data, then evaluated. From the standpoint of efficiency, we did by batch treatment. Also, before establishment of the above procedures, there was accumulated not yet processed data. As such, it took time in completing the initial evaluation of the first batch.

In the meantime, we evaluated (i) female employees' excess of radiation limit identified on April 27 and (ii) the radiation evaluation in excess of 100mSv by APD

announced on April 30 separately from the initial evaluation of the first batch. As such, nineteen people when announced female employees' excess of radiation and twenty one people in excess of 100mSv, in aggregate forty, were announced first. This gave the impression that it is taking a very long time.

（3）Issues on the organization

We intended to support Fukushima Daiichi Nuclear Power Station because of this incident with large scale release of radioactive substances. The initial number of support persons for radiation management was limited to three.

In the meantime, as the normal automated system was down, the manual workload was enormous. We increased the number of persons step by step and formed a temporary new team. The headcount is sixteen inclusive of temporary persons.

However, to construct the new team from scratch took time. This can be the reason for delay in establishing the evaluation method.

During this moment, we have been executing the work having assistance from JAEA. We believe that we could minimize the delay.

（4）Issues on the radiation limit administration

As for the radiation limit, based on "regarding 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" (nuclear admin report to the government 2011 No 46), taking account of the internal exposure dose, we are administrating the external exposure dose not to exceed 200mSv. But, this incident is presumably because of the initial several days of work in stopping the propagation of the accident. After the plants became stable, we evaluated the internal exposure dose. As a result, we exceeded the radiation limit.

2． Measures

（1）About WBC

We are constructing the WBC hub at J-Village. We are planning to use WBCs at Fukushima Daiichi Nuclear Power Station and Fukushima Daini Nuclear Power Station as much as possible. We will start 4 WBCs during July and August. At the beginning of July, we will transfer JAEA's WBCs at Onahama Coal Center to a shielded garage (under construction) at J-Village.

From November, we will introduce six more new WBCs.
After these are done, the capacity for measurement will be as follows:

July-August: 200 persons / day
After August: 480 persons / day
November-December: 520 persons/day
After December: 700 persons / day

From the above, based on the capacity factor of 50%, the frequency of measurement will be once in three months after August and every month after December,

（2）Internal exposure dose administration system

As the internal exposure dose is high, for administration purpose, we set the work start date as the date when the internal exposure dose occurred. (as for March 11, as there was no external release, we set the internal exposure dose date as March 12.) This is the strictest approach.

Based on this administration result and the behavioral investigation what we do at the same time, we do detailed evaluation to people above 20 mSv in cooperation with JAEA.

By setting strict conditions at the time of the screening, the evaluation will be conservative and persons subject to detailed evaluation will increase. We keep close coordination with JAEA. At the same time, in order to have a well-planned internal evaluation, we establish a behavioral investigation before evaluation at JAEA.

As to the appropriateness of the evaluation method by WBC, we will confirm by Bioassay etc.

If there is a risk that the effective dose is above the threshold or actually exceeds, we will have a medical check by a specialist physician.

As to the treatment of data, after April 20, we increased items of personal information and shortened the required time for checking data. We will expedite the evaluation.

（3）Organizational matter

As for data analysis, evaluation, notification and administration, we will newly setup an organization in charge of radiation administration at the safety and environment department at Fukushima Daiichi Stabilization Center that is due to open on June 28.

As for manpower. We will allocate as many persons who are used to radiation administration as possible in order to prevent delay in work.

（4）Administration of radiation limit

In order to prevent exceeding the radiation limit in the event of emergency, in addition to measures set out in “regarding 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” (nuclear admin report to the government 2011 No 46), from the viewpoint of ensuring to observe the radiation limit and clarify the rules, we will adopt the following measures.

- ○ If there is a person whose internal exposure dose exceeds 100mSv by the primary evaluation by WBC, persons working with the same schedule are prohibited from working at the field site until the evaluation by WBC is done.
- ○ Persons with the effective dose of over 170mSv must work within the main anti-earthquake building.

  “regarding 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” (nuclear admin report to the government 2011 No 46) set 150mSv as the point for consideration. We added 170mSv as the point for action to make clear (began implementation from June 6).

  <previous measures>
  - ○ Persons with the external exposure does of over 100mSv must be examined by WBC.
  - ○ Persons with the external exposure does of over 100mSv have to

consider whether to continue work.

○ Persons with the effective radiation of over 200mSv must not work at Fukushima Daiichi Nuclear Power Station.