VI. Discharge of Radioactive Materials to the Environment

1. Evaluation of the amount of radioactive materials discharged to the air

(1) Discharge of radioactive materials to the air

In this nuclear accident, along with the development of events, incidents such as the pressure venting of PCVs, explosions at reactor buildings and others resulted in radioactive materials being discharged to the air.

On May 5, TEPCO installed four ambient air filtration systems to reduce the concentration of radioactive materials in the reactor building, and also partly opened the double doors on the north side from May 8 to 9 to ventilate the building, to improve the working environment of the reactor building of Unit 1. As this raised the possibility of charges of small amounts of radioactive materials, environmental monitoring was strengthened both in and outside the site, but no change was detected in the either radiation dose rate or the concentration of radioactive materials in the air.

(2) Estimation of the discharge of radioactive materials to the air

1) Analysis-based estimation

In order to conduct an INES estimation, NISA conducted an estimation using the result of an analysis on the reactor situation, etc. by the Incorporated Administrative Agency Japan Nuclear Energy Safety Organization (JNES) and estimated that the total discharge amounts from the reactors of Fukushima Dai-ichi NPS were approx. $1.3x10^{17}$Bq for Iodine 131, and approx. $6.1x10^{15}$ Bq for Cesium 137. Later, when JNES conducted another analysis of the reactor situation, etc. as described in Chapter IV, using the plant data, etc. obtained immediately after the earthquake, which NISA collected from TEPCO in a report on May 16, NISA estimated that the total discharge amounts from the reactors of Fukushima Dai-ichi NPS were approx. $1.6x10^{17}$Bq for Iodine 131 and approx. $1.5x10^{16}$Bq for Cesium 137.

This chapter, compares these estimated values compared with mainly monitoring data obtained from the site of Fukushima Dai-ichi NPS, and how radioactive materials discharged from the reactors were dispersed and how they had an impact on the surrounding environment.

After earthquake, the discharge of radioactive materials became evident early on the morning of March 12 when the air dose rate measured by a monitoring car near

MP-6(monitoring post No. 6 in the site of Fukushima Dai-ichi NPS) increased. It can be estimated that there was a leakage of radioactive materials from the PCV and a discharge of such materials to the air, as a slight decrease in the PCV pressure was observed in Unit 1 after an abnormal rise at this point. According to an analytical result, that fuel meltdown had already started.

Monitoring measurements performed afterwards at the same point found that the dose rate had increased until the noon of March 12, and D/W pressure had not significantly decreased until around 14:00 despite the venting operation that continued in Unit 1. It could be considered that non-condensable gases, such as noble gases, continued to be discharged from the melted fuel in the reactor into the environment through the S/C.

TEPCO judged at 14:30 on March 12 that D/W pressure decreased and venting succeeded. At this point, it is believed that radioactive materials including iodine, which was neither deposited on the reactor vessel and others, nor absorbed by the S/C, were discharged to the air and, as a result, due to a plume effect, a reading of about 1 mSv/h was observed from a measurement made near MP-4. In addition, a reading of 20 μSv/h was observed from a measurement made at the joint government building of City of Minami Soma by the Fukushima prefectural government that started in the evening, and it is believed that the plume was first blown south by a weak northerly wind and then diffused to the north by a strong southerly wind.

From 08:00 to 09:00 on March 13, the dose rate near MP-1, 4 and 6, increased significantly, and it is estimated that this was caused by the vent operation of Unit 3 performed after its fuel was exposed due to a decrease in the reactor water level. Also, this plume is assumed to have spread to the north under the weather conditions prevailing during this period, in which a weak westerly wind turned southerly. A measurement by Minami-soma City indicated a rise of about 1 μSv/h in the dose rate. A significant rise in the dose rate was confirmed near MP-1, 4 and 6 corresponded to the multiple decreases in the D/W pressure of Unit 3.

A rise in multiple dose rates was confirmed in the morning of March 14, but no information was obtained on events that might have been related to the discharges from each plant. For this reason, although causes of the dose rate increases are uncertain, it is plausible to consider that one of the causes can be the re-floating of deposited radioactive materials because the background dose rate increased at each measuring point due to radioactive materials discharged up to March 13.

An air dose rate of about 3 mSv/h was measured near MP-6 at 21:00 on March 14. This rate decreased once but increased again after 06:00 on March 15, and a dose rate of about 12 mSv/h was measured at 09:00 on the same day. In Unit 2, a decrease in D/W pressure was observed due to a wet venting at 21:00 on March 14, and it is estimated that radioactive materials were discharged from Unit 2 because of a blast sound from the unit at around 06:00 on March 15 and a subsequent S/C pressure decrease. At around the same time, however, an explosion occurred in the reactor building of Unit 4, thus a clear distinction cannot be made between them. Since wind often blew from the north in this period, the plume was very likely to have blown to the south, and agencies including the Japan Atomic Energy Agency (JAEA) in Tokai village, Ibaraki prefecture observed a rise in the dose rate and detected radioactive iodine, etc. in the atmosphere.

In addition, an increase in the air dose rate was observed near MP-6 at 23:00 on March 15 and at 12:00 on March 16. D/W pressure decreases were observed in Unit 3 and Unit 2 at respective times. It is estimated, therefore, that discharges occurred from Unit 3 and Unit 2 at these respective times.

2) Estimation by SPEEDI

Regarding the accident, the System for Prediction of Environmental Emergency Dose Information (SPEEDI) was unable to be utilized for some time to calculate the concentration of radioactive materials or air dose rates around the power station because information about the discharge sources was not obtained through measurements performed at reactor facilities. From March 16, the Nuclear Safety Commission of Japan (NSC Japan) considered an alternative method for measuring at reactor facilities through trial and error with assistance from researchers of JAEA, the independent administrative institution that had developed SPEEDI, and dispatched staff from the Nuclear Safety Technology Center under the instructions of MEXT. The NSC Japan combined the measurement (dust sampling) results of radioactive materials concentration in the environment with diffusion simulations by SPEEDI from the power station to measuring points, which enabled it to perform with a certain degree of reliability an inverse estimation on discharge source information as of the time the radioactive materials caught by dust sampling were discharged. The NSC Japan entered such estimated discharge source information into SPEEDI to obtain prior radioactive material concentrations and air dose rate distributions, and on March 23, April 11, 25 and 27 it announced the trial results of accumulated internal and external exposure doses from the time the accident occurred. (See Attachment VI-1: SPEEDI trial estimation of total discharge of radioactive nuclides.)

2. Evaluation on the amount of radioactive materials discharged to the sea

(1) Leakage of radioactive materials from the power station

In Fukushima Dai-ichi NPS, the water containing dissolved radioactive materials that were released from inside the RPV leaked into the PCV. In addition, as a result of injecting water from outside in order to cool the reactors and Spent Fuel Pools, some of the injected water leaked out of the PCV and accumulated inside the reactor buildings and the turbine buildings. The management of the contaminated water in the reactor and turbine buildings became an important issue from the viewpoint of workability inside the buildings, and the management of contaminated water outside the buildings became an important issue from the viewpoint of preventing the release of radioactive materials into the environment.

TEPCO found at around 09:30 on April 2 that water with a reading of over 1,000 mSv/h had accumulated in a pit storing electric cables near the Intake Channel of Unit 2 and that there was a crack (about 20 cm) on the lateral surface of the pit, from which water was flowing out into the sea. From this reason, TEPCO took some measures such as pouring concrete, etc. and injecting soluble glass to stop water discharge and confirmed that the water outflow stopped at 05:38 on April 6.

TEPCO evaluated the amount of contaminated water that had flowed into the sea from Unit 2, including highly-concentrated radioactive materials (hereinafter referred to as “contaminated water”) and the Nuclear and Industrial Safety Agency (NISA) also confirmed it. (See Attachment VI-2: Outflow of radioactive water off the site near water intake of Unit 2 at Fukushima Daiichi Nuclear Power Station.)

On April 1, the day before the outflow was detected, the air dose rate near the sea surface around Unit 2 screen was confirmed as 1.5 mSv/h, which was the same as the surrounding background level. Immediately after the outflow was confirmed, the air dose rate measured at almost the same place was 20 mSv/h. This makes it reasonable to assume that contaminated water flowed out in a period from April 1 to 6. The outflow rate was calculated as about 4.3 m^3/h based on photos, etc. The total amount of radioactive materials contained in the outflow of the contaminated water can be estimated at 4.7×10^{15} Bq using measured values obtained via sampling.

TEPCO confirmed that the outflow from a pit near the Intake Channel of Unit 3 into the sea at 16:05 on May 11 and that it stopped around 18:45 on the same day.

TEPCO evaluated the amount of contaminated water that flowed out to the sea from Unit 3 and the NISA also confirmed it. (See Attachment VI-3: Outflow of radioactive water off the site near water intake of Unit 3 at Fukushima Daiichi Nuclear Power Station.)

As a result of the evaluation, the amount of radioactive materials discharged from Unit 3 was calculated as 250 m^3 in an outflow period of 41 hours (from 02:00 on May 10 till 19:00 on May 11). As for the concentration of contaminated water that flowed out into the sea, the total amount of radioactive materials contained in the outflow of contaminated water can be estimated at 2.0×10^{13} Bq using a measured value of water that flowed into the pit.

To prevent further leakage of radioactive materials, TEPCO is taking measures such as securing storing places for waste water and installing treatment facilities for removing radioactive materials from waste water, closing off possible leaking places, and improving reactor cooling methods to reduce waste water.

(2) Discharge of radioactive materials to the sea from the power station

Because of a possible leakage of highly-concentrated radioactive waste water accumulated in the basement floor of the turbine building of Unit 2, TEPCO decided to discharge the low-level radioactive water accumulated in the Radioactive Waste Treatment Facilities to transfer the highly-concentrated radioactive waste water as an emergency measure, pursuant to Article 64 paragraph 1 of the Nuclear Regulation Act. In addition, to protect important equipment from the subsurface water entered into the building, TEPCO also discharged such subsurface water, including low-level radioactive waste water accumulated in the sub-drains of Units 5 and 6. Therefore, NISA requested TEPCO to report on the facts, and draw up an impact assessment and TEPCO’s view related to the discharge to the sea, pursuant to Article 67 paragraph 1 of the above Act. NISA confirmed the report details and obtained technical advice on the discharge to the sea from NSC Japan as an emergency measure.

TEPCO discharged about 10,393 tons from the Radioactive Waste Treatment Facilities and sub-drains of Units 5 and 6 from April 4 to 10. The total amount of radioactive materials is estimated at about 1.5×10^{11} Bq based on the amount discharged during this period. (See

Attachment VI-4: Result of discharge of low level radioactive accumulated water from Fukushima Daiichi Nuclear Power Station to the sea.)

To check the environmental impact of the above (1) and (2), TEPCO carried out some measures including strengthening coastal sea area monitoring and installing silt screens (leakage protective fences). (See Attachment VI-5: Countermeasures for preventing diffusion of liquid containing radioactive material.)

Regarding the above, the Japanese government deeply regretted that there was no choice but to discharge water that contained radioactive materials despite their low concentration. (Refer to Chapter IX. 4. (3).)

(3) Sea diffusion simulation

MEXT performed predictive calculations on the diffusion of radioactive materials using the supercomputer at the Japan Agency for Marine-Earth Science and Technology (JAMSTEC) based on prior measured values of coastal water monitoring performed on April 12, 16, 29, and on May 9 and 24, and announced the outcome of a simulation of the radioactive concentration distribution from the Fukushima Dai-ichi NPS for the coming 2 months or so.

The model used for the simulation calculates the way each floating particle given under initial conditions is diffused on the sea-surface divided into grids, each with the area of 8 km square, by tides and winds using a diffusion formula, which uses estimated data on tides for about the following two months from the day before a predictive calculation is made and forecast data of winds for a week from the day before the predictive calculation is made, as well as the average wind data of a period from a week after the day before the predictive calculation is made until two months after that week. In other words, the distribution of the radioactive concentration is estimated based on the estimated diffusion of floating particles on the sea surface.

It estimated that the distributed radioactive concentration in all sea areas in mid-May was below the initial detection limit (about 10 Bq/L for both radioactive iodine and cesium) (There would be no sea area where the distribution of radioactive concentration exceeded 10Bq/L.)

For this reason, to understand the distribution of radioactive concentration in more detail, MEXT decided to analyze a wider area with lower detection limits and selected new sampling points based on the above estimation. This “wider sea area monitoring” was announced on May 6.

The distribution of the concentration of the radioactive area after widening the sampling area was almost as estimated, and the detected radioactive concentration announced by MEXT on May 20 for the first time after widening fell almost between the old detection limit (10 Bq/L) and the new detection limit (6 Bq/L of cesium 134).

However, the simulation does not always guarantee the actual measured values of concentration themselves because it is a model that predicts distribution, not one that predicts the level of the concentration itself. In addition, differences between the distribution and the actually measured values are caused by that fact that errors become bigger as the predictive time gets longer, due to multiple restrictions including the impossibility of thorough reproduction of the actual flow even by incorporating observed values into the model, together with the generation of errors by using average winds of the period after using winds for estimation for about a week only. There is a need to perform constant reviews to realize estimates that are far closer to the real values, checking actually measured values of the latest monitoring results and obtaining a mutual evaluation on simulations by other calculation codes, too.