Method of estimation of the released amount of radioactive materials into the atmosphere [Overview]

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1 Estimation of the released amount

Before the accident, it was possible to estimate the released amount of radioactive materials into the atmosphere by using stack monitors. It became difficult, however, to estimate the amount of radioactive materials released into the atmosphere because of the unavailability of various instruments as a result of the earthquake. In addition, it was also difficult to estimate the amount by the analysis result of the reactor core, and by the quantity of radioactive materials attached on buildings. For this reason, environmental data (the wind direction, wind speed, precipitation, and air dose rate) measured by monitoring cars and other means, contamination densities in soil, and others were used to estimate the released amount.

In making an estimation, we used a method in which a calculation program is used to reproduce measured air dose rates.

2 Estimation of the radioactivity released into the atmosphere

2.1 Overview of the estimation method (Fig. 1)

- Our company's air dispersion calculation program (called DIANA[*1]) is capable of assessing the air dose rate and the amount of deposition on soil at a specified location and time by inputting the release rate (in Bq/10 min) of a 0.5 MeV-equivalent virtual particle (1 MeV = 1.6 x 10^{-13} J) and weather data.
- By assuming the release rate of a 0.5 eV-equivalent virtual particle (Bq/10 min), and comparing the result with the air dose rate measured by the monitoring cars that have run within the power station after the accident, the release rate of 0.5 MeV-equivalent virtual particles agreeing with measured air dose rates was determined by inputting weather data into DIANA.
- Since the DIANA assessment was set at 10-minute intervals, the operations described above were repeated between March 12 and 31 to estimate the release rate of the 0.5 MeV-equivalent virtual particle (Bq/10 min) during March.
- The released amount was assigned to the 0.5 MeV-equivalent virtual particle for rare gas, iodine, and cesium ,individually, to estimate the released amount by nuclide.
- The estimated Cs-137 release rate and the weather data are inputted to DIANA to calculate dispersion to determine the amount of deposition on soil in the environment.
- The results were compared with the amounts of deposition on soil measured by the Ministry of Education, Culture, Sports, Science and Technology to confirm the validity of the released amounts.

* DIANA (Dose Information Analysis for Nuclear Accident) is a calculation code to assess a 3D advection dispersion dose rate on the basis of released radioactive materials

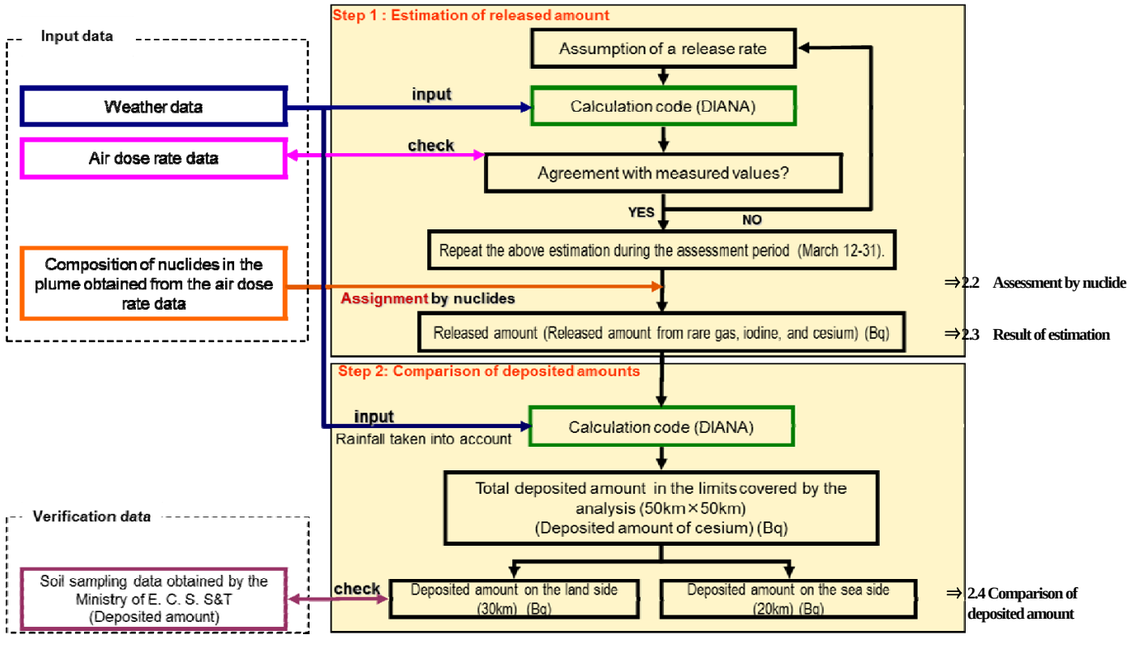

Fig. 1 Schematic overview of the estimation method

2.2 Assessment by nuclide (Attached Figures 1 and 2)

When released, radioactive materials are carried by the wind flow in the form of a plume, allowing air dose rate data to change. When a plume is formed by rare gas only, the air dose rate data returns to the value prior to the passage of the plume after the plume has passed by.

However, an actual plume contains not only rare gas but also iodine and particulate nuclides (such as cesium), with iodine and particulate nuclides depositing on the ground. This phenomenon increases the dose rate in the background on the periphery of the location of measurement, with the air dose rate measured on the ground increasing consequently. The deposited iodine and particulate nuclides decay according to their half life period.

The phenomena described above are shown in Attached Drawing 1.

For the assignment of 0.5 MeV-equivalent virtual particles by nuclide, several pieces of measurement data on the air dose rate (peak values) as shown in Attached Figure 1 were selected to determine the easiness ratio of emission from in-core inventory.

As a result of using DIANA to change the ratio showing the easiness of emission for different particulate nuclides that agrees with the curve of the decay of the air dose rate caused by deposited iodine and particulate nuclides, the ratio at which the decay curve is reproduced roughly was found to be 10:1.

Next, we decided to use the ratio of 100:10:1 as a ratio to indicate the easiness of emission for rare gas, iodine, and cesium for which the air dose rate agrees roughly with the dose rate of the background. On the basis of the above ratio and the in-core inventory at the time of assessment, 0.5 MeV-equivalent virtual particles were assigned by nuclide.

2.3 Result of estimation

The results of estimation are as shown in Table 1. About the same values as those obtained by the other organizations are obtained for Cs-137. As for the I-13, value obtained was about 3 times as large as those estimated by the other organizations. Since our company's estimation uses a constant value for the ratio of easiness of emission from the in-core inventory of units 1 to 3 for the entire period of estimation, it is possible that an increase in the released amount of I-131 is observed in the estimation.

Table 1 Result of estimation of released amounts

	Assessment period	Released amount PBq (10^{15}Bq)				
		Rare gas	I-131	Cs-134	Cs-137	INES assessment
Our company	March 12 - 31	**Approx. 500**	**Approx. 500**	**Approx. 10**	**Approx. 10**	**Approx. 900**
Japan Atomic Energy Agency Nuclear Safety Commission (April 12, 2011, May 12, 2011)	3/11-4/5	-	150	-	13	670
Japan Atomic Energy Agency Nuclear Safety Commission (Aug. 22, 2011)	3/12-4/5	-	130	-	11	570
Japan Atomic Energy Agency(March 6, 2012)	3/11-4/10	-	120	-	9	480
Nuclear & Industrial Safety Agency (April 12, 2011)	-	-	130	-	6.1	370
Nuclear & Industrial Safety Agency (April June 6, 2011)	-	-	160	18	15	770
Nuclear & Industrial Safety Agency (April Feb. 16, 2012)	-	-	150	-	8.2	480
IRSN (Institut de Radioprotection et de Sûreté Nucléaire)	3/12-22	2000	200	30		-
[Reference] Accident at the Chernobyl Nuclear Power Plant	-	6500	1800	-	85	5200

* Released amount in April is less than 1% of that in March. (Calculated on the basis of the concentration of radioactive materials in the air in the premises using the dispersion calculation method)
* The value estimated by our company is rounded off to one decimal place, being the amount of radioactivity at the time of being released. The value for a rare gas is one equivalent to 0.5 MeV,
* The INES-based assessment (International Nuclear Event Scale) is a value obtained by converting an amount of radioactivity into an iodine equivalent. In this paper, Cs-137 alone is taken up.(Example: Approx. 500 PBq + approx. 10 PBq × 40 (a conversion factor) = approx. 900 PBq)

2.4 Comparison of the deposited amount

On the basis of the values of soil contamination density of Cs-137 measured by the Ministry of Education, Culture, Sports, Science and Technology, the deposited amount of Cs-137 in the limits that DIANA can assess (30 km on the land side × 50 km north-to-south line) was calculated to be 1 PBq.

The deposited amount estimated by using DIANA was approx. 1 PBq. This result will allow one to regard the estimation as reasonable.

End

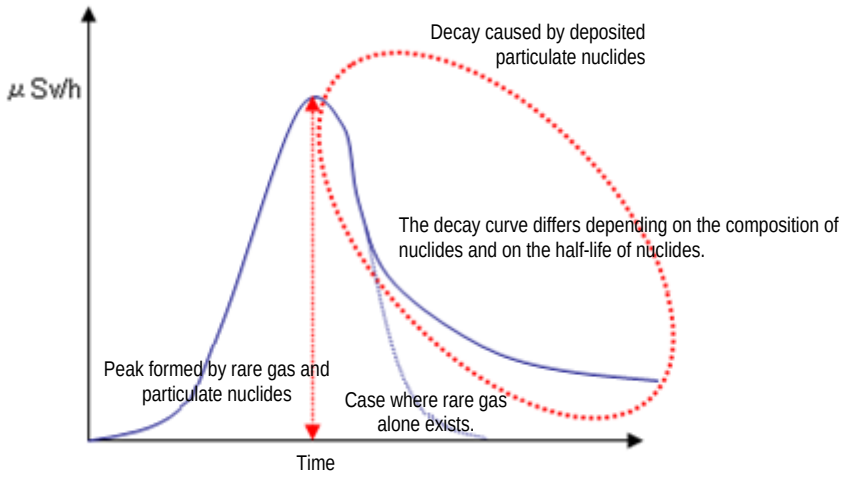

Fig. 1 Change in the air dose rate

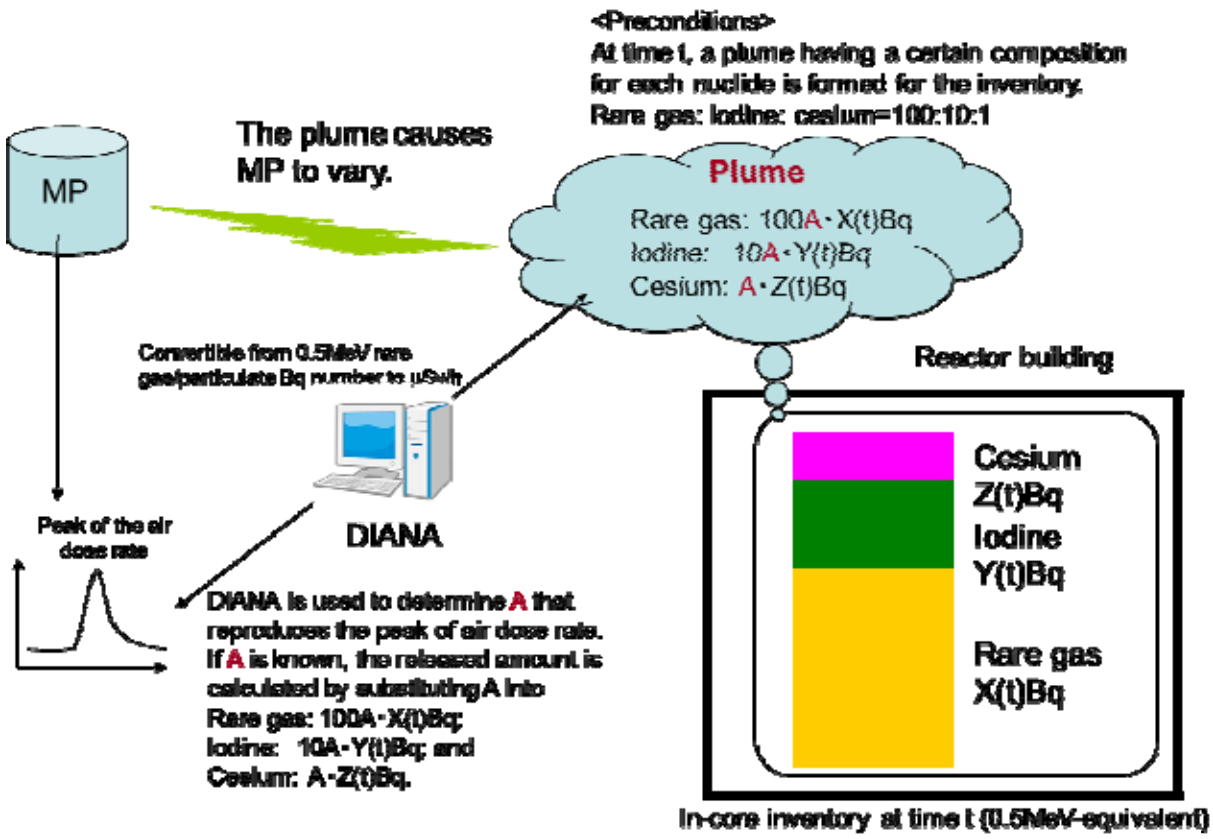

Fig. 2 Image of assessing