Spent Fuel Pool and Release of Fission Products in Fukushima Daiichi Nuclear Power Plant Accident

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1. Background and Goal of the present work

Many residents in the Fukushima Prefecture and neighboring areas were exposed to significant doses of radiation as a result of the radioactive nuclides that were accidentally released from TEPCO'S Fukushima Daiichi nuclear power plant. In the days immediately following the accident, radiation exposure was caused by isotopes of iodine and short-lived radionuclides. As time progressed, radiocesium, that is cesium-134 and cesium-137, became the major source of radiation. The exposure pathways were external irradiation by radiocesium deposited in the environment and internal irradiation through consumption of foods contaminated with radiocesium. The spent fuel pool, storing 1,500 fuel assemblies, was designed such that the fuel elements would retain integrity for 30 days without active cooling.

Fission Products Release

We estimated the total amount of radioactive materials released to the environment. We estimated the total discharged amount from reactors on the basis of the analytical results with severe accident analysis code, AIREMN6 shown in Fig. 1. The estimated values summarized in Table 1 is for iodine-131 cesium-137. Values estimated by TEPCO are also shown in Table 1. Estimated release of iodine-131 by TEPCO is about three times larger than values by us. It is also noted that the estimated releases of iodine-131and cesium-137 of the Chernobyl accident are about one order of magnitude larger and about 6 to 10 times larger than those estimated us as shown in Table 1.

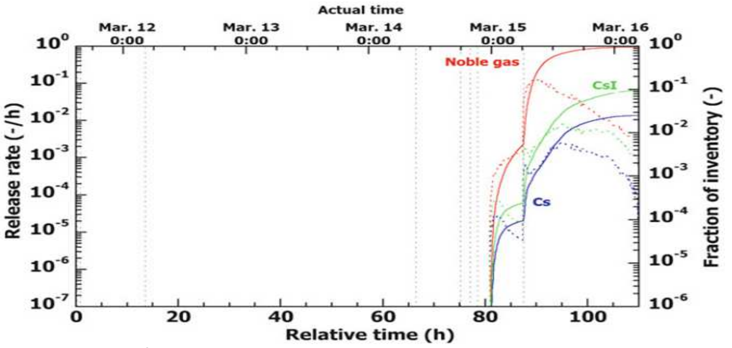

Fig1. Estimated fission products (FP) release ratio to the environment with AIREMN6 code (developed) (Unit 2). Solid lines and dotted lines represent cumulative release fraction and release rate, respectively.

Organization	iodine-131(10^{15} Bq)	cesium-137(10^{15} Bq)
We (Estimated by AIREMN6 Code (June 2012))	135	8
TEPCO (June 2012)	500	10
Chernobyl Accident	1760	85

Table 1. Estimated release of fission products to the environment

Estimation of External Dose

There are two main pathways in external exposure: exposure from a radioactive plume released from nuclear facilities into the atmosphere in the early stages after an accident, and exposure from radionuclides deposited in the surrounding environment, such as land and buildings, after the plume has passed through. A few approaches are generally used to estimate the external radiation doses. A direct and reliable method is personal monitoring with a dosimeter. Personal dosimeters, such as a glass badge and an electric dosimeter, can be used for this purpose. Such direct monitoring is most common for radiation workers in a radiation-controlled area. However, if such direct personal monitoring is not possible, the dose should be estimated using models with some assumptions and environmental monitoring data such as air radiation dose rates. If direct monitoring or measurement of a personal dose is difficult, it may be possible to estimate it using monitoring data and analyses of personal behavior, with relatively better accuracy than the estimation of internal doses. The Fukushima Prefecture carried out an estimation of personal doses on a large scale. In the later stages when the deposited radiocesium became the dominant radiation source, some trials began to include the direct monitoring of personal radiation doses, which was handled by local government, groups, and individuals using dosimeters.

Estimation of Internal Dose

Major routes of intake of radionuclides into the human body are by inhalation and oral ingestion. The ingestion of foodstuffs and water contaminated with radionuclides is a common route of oral intake, and additionally licking contaminated hands and daily items such as toys becomes a possible intake route, especially for infants and children. In the early stages after the accident, no attention was paid to internal radiation doses. It seemed that the government intentionally ignored internal exposure. The estimation of internal radiation doses resulting from inhalation of radionuclides is generally complex and difficult, compared with the estimation of external doses. At present, few data and little information are available for estimating the accurate internal doses of each resident resulting from the inhalation of radioactive gases and short-lived radionuclides such as radioiodine in the plume. Radiation exposure of the thyroid is an important issue for human health, especially for children, in the early period after a nuclear accident. Induction of thyroid cancer by the intake of radioiodine in the plume through inhalation had been a major concern because of the Fukushima accident. Tokonami et al. also measured radioiodine activity in thyroid in situ. Radioiodine activity determined by a whole-body counter in the volunteer workers at the shelter facilities is presented by Yamamotoi et al. It was revealed that human thyroid measurement data of the inhabitants were much fewer in this accident compared to those collected in the Chernobyl accident. Airborne sampling data are much needed because inhalation, rather than ingestion is a main route of the intake by most of the inhabitants. However, such data were also rarely obtained in the fi rst week after the accident. Continuous air sampling was performed only outside Fukushima Prefecture. Tsuruta et al. have reported the gaseous/aerosol ratio of 131 I and the activity ratio of 131 I/137 Cs in air from their analyses on existing information. Both items are of importance for reconstructing the thyroid dose.