Internal radiation dose of KURRI volunteers working at evacuation shelters after TEPCO's Fukushima Daiichi nuclear power plant accident

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We report the radiation doses encountered by 59 Kyoto University Research Reactor Institute (KURRI) staff members who had been dispatched to screen refugees for radiation at emergency evacuation sites 45–80 km from the Tokyo Electric Power Co.'s (TEPCO's) Fukushima Daiichi nuclear power plant. From March 20 to April 30, 2011, 42 members in teams consisting of 2–4 staff members were dispatched 15 times to 7 emergency evacuation sites located 45–80 km from the power plant to examine the radioactive contamination affecting refugees. Continuously, from May 10 to May 23, 2011, 17 members in teams consisting of 2–5 staff members were dispatched 6 times to Fukushima Prefecture to establish the Kyoto University Radiation Mapping (KURAMA) system. Internal burdens of radioactive nuclides were estimated using a whole-body counter consisting of an iron room, NaI (Tl) scintillation detectors, and a digital multichannel analyzer (MCA7600; Seiko EG&G). The calibration of the whole-body counter and the conversion of the measured body burden to the committed effective dose by internal exposure were carried out in accordance with the Nuclear Safety Research Association (NSRA) technical manual. The external radiation dose to each staff member was measured using a personal dosimeter. The first dispatched team showed 1300–1929 Bq of internal radiation activity from cesium (including ^{137}Cs and ^{134}Cs) and 48–118 Bq of ^{131}I. The internal doses of four members of the first team were estimated to be 24–39 μSv. The doses from internal exposure were almost similar to the cumulative external doses for the dispatch period (March 20–22, 2011) when the radiation plumes following the explosions of Units 1 and 3 in TEPCO's Fukushima Daiichi nuclear plant had diffused around Fukushima City. The external radiation doses of members dispatched after the second team had decreased from one-third to less than one-tenth of the external doses of the first dispatched team. The internal radiation doses of 55 members dispatched after the second team was dispatched showed that 51 cases were undetectable, and 4 cases showed doses of 2–15 μSv. These decreases in the internal radiation doses after the second team was dispatched are attributable to the warning statement to the dispatched staff of KURRI regarding protection against internal radiation.

Key Words: *internal radiation, cesium 137, cesium 134, whole-body counter, iodine 131*

1. Background

On March 11, 2011, an earthquake and tsunami struck the Tohoku area of Japan, causing serious damage to Tokyo Electric Power Co.'s (TEPCO's) Fukushima Daiichi nuclear plant, and a significant amount of radionuclides was released into the surrounding environment [1,2] . The TEPCO radiation plume spread over the Fukushima Prefecture from March 11 to March 28, 2011. Fifty-nine members of the Kyoto University Research Reactor Institute (KURRI) had been dispatched to screen refugees for radiation at the emergency evacuation sites 45–80 km from TEPCO's Fukushima Daiichi nuclear power plant. From March 20 to April 30, 2011, 42 members in teams consisting of 2–4 staff were dispatched 15 times to 7 emergency evacuation sites located 45–80 km from the power plant to examine the radioactive contamination affecting refugees. Continuously, from May 10 to May 23, 2011, 17 members in teams consisting of 2–5 staff were dispatched 6 times to Fukushima Prefecture to establish the Kyoto University Radiation Mapping (KURAMA) system. These screening volunteers started to work immediately after the nuclear power plant disaster. The earlier groups risked internal radiation exposure because of the radioactive material in the environment.

2. Methods

The external radiation dose for each staff member was measured using a personal dosimeter (ADM-112; Hitachi-Aloka Medical K. K.). The internal radiation doses were determined using a whole-body counter consisting of an iron room, the 8 inches φ × 4 inches *t* NaI (Tl) with four photomultiplier tubes (Fuji Denki), and a digital multichannel analyzer (MCA7600; Seiko EG&G) (Fig. 1). Radiation levels were measured for 10 min using the whole-body counter, 3–4 days after returning from the dispatch. A spectral stripping method was used for the pulse amplitude analysis of ^{131}I, ^{134}Cs, and ^{137}Cs with the whole-body counter. The whole body counter was calculated using the human acryl phantom filled with KCl solution containing 40kBq of ^{40}K. The conversion from the measured body burden to the committed effective dose by internal exposure was evaluated with the MONDAL 3 (monitoring to dose calculation ver.3) from the National Institute of Radiological Science (NIRS). MONDAL is a user-friendly tool for internal dose calculation, by which the committed effective dose can be calculated based on the new ICRP dose estimation models from the resilts of the whole body counter results[3]. All the radioactivies were assumed to be taken by inhalation of 1.0 μm aerodynamic diameter particles in this calculation.

3. Results

The dispatched period, working distance from TEPCO's plant, air dose rate, and external radiation doses of KURRI volunteers are listed in Table 1. From May 10 to May 23, 2011, 17 members in teams were dispatched 6 times to Fukushima Prefecture to establish the KURAMA system. They did not measure the air dose rate and external radiation, because those were monitored around Fukushima City from a car 2 months after the TEPCO accident. The internal radiation doses of ^{131}I and ^{134}Cs + ^{137}Cs are listed in Table 2. The spectral stripping method for the NaI whole-body counter cannot distinguish between ^{134}Cs and ^{137}Cs. We estimated that the ratio of ^{134}Cs to ^{137}Cs was 1:1, on the basis of the data from the measurements of the protecting masks using a Ge counter. The first 4 dispatched volunteers showed, respectively, 1300, 1469, 1816, and 1929 Bq of internal radiation activity of Cs (including ^{137}Cs and ^{134}Cs), and 48, 52, 72, and 118 Bq of ^{131}I. The internal doses of 4 members of the first team were estimated to be 24, 26, 33, and 39 μSv, respectively. The doses from internal exposure were almost similar to the cumulative external doses for the dispatch period (March 20–22, 2011) when the radiation plumes following the explosions of Units 1 and 3 in TEPCO's Fukushima Daiichi nuclear plant had diffused over Fukushima City. The external radiation doses of the dispatched members after the second team was decreased from one-third to less than one-tenth of the external doses of the first dispatched team. The internal radiation doses of 55 members after the second team was dispatched showed that 51 cases were undetectable, and 4 cases showed doses of 2–15 μSv.

4. Discussion

We are not aware of any published report on internal exposure to cesium and iodine radiation measured with whole body counter in public after the early period following TEPCO's Fukushima Daiichi nuclear power

plant accident. The staff stayed in Fukushima Prefecture for 3–4 days per dispatch, working at evacuation sites during the day and staying at a hotel near Fukushima City in the night. As shown in Tables 1 and 2, Screening Team 1 had the largest accumulated dose from external exposure and internal exposure caused by iodine and cesium. Their dispatched period was the earliest; moreover, they used only simple masks with a casual dress so as not to make the evacuees anxious, so there was little difference in protection from internal exposure between staff members and evacuees. On the basis of the internal radiation dose of the first dispatched team, we gave the next dispatched team a warning to protect against internal exposure. The fallen down of the internal radiation doses after the second team was dispatched is attributable to the warning statement to the dispatched staff of KURRI regarding protection against internal radiation. Between September 2011 and March 2012, the internal radiation exposure of cesium in the 9498 evacuated residents of Minamisoma, located 23 km north of TEPCO's plant, was measured, and it was reported that the committed effective doses were less than 1 mSv in the 9497 residents[4]. We confirmed the internal exposure to cesium and iodine radiation soon after TEPCO's nuclear power plant accident was relatively low, i.e., the most largest effective dose was 39 μSv in the 59 dispatched KURRI volunteers.

References

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Fig. 1 KURRI whole body counter : (Left) Exterior. The iron walls, ceiling, and floor of the iron room are 20 cm thick, with the inner surfaces lined with 3-mm Pb sheet. (Right) Interior. The 8 inches φ × 4 inches *t* NaI (Tl) crystal scintillation counter and four photomultiplier tubes are 40 cm above the bed.

Table 1. External radiation doses of KURRI volunteers

Group	**Working day**	**Evacuation site (Distance from the plant in km)**	**Ambient dose rate (μSv/h)**			***External exposure (μSv/day)**
			indoor	under the eaves	outdoor	
Screening 1	March 20–22	62.7–79.2	1.5–2	-	2	16
Screening 2	March 23–25	67.9	-	0.11–0.13	-	1.5
Screening 3	March 26–28	67.9	-	0.08–0.1	-	2
Screening 4	March 29–31	47.0–67.9	0.25	0.1	0.4–1.5	2
Screening 5	April 1–3	59.9–67.9	0.07–0.13	0.08	0.35–0.43	5
Screening 6	April 4–6	59.9–67.9	0.05–0.09	0.08–0.1	0.29–0.43	1
Screening 7	April 7–9	67.9	0.04–0.05	0.07–0.08	0.32–0.36	1
Screening 8	April 10–12	67.9	0.04	0.07–0.1	0.32–0.33	3
Screening 9	April 13–15	44.6–46.7	0.1–0.15	0.26	0.3–1.5	2.5
Screening 10	April 16–19	46.7	0.08–0.12	-	1.8–1.9	6
Screening 11	April 20–23	24.9	-	0.34–0.41	0.55–0.61	6
Screening 12	April 24–27	24.9–38.2	0.12–0.13	0.43	0.23–0.25	3
Screening 13	April 28–30	24.9	0.12–0.18	0.44–0.45	-	3

* The maximum dose/day during the working days

Table 2. Internal radiation doses estimated with human counter at KURRI

Group	Volunteer's number	*Internal exposure caused by ^{137}Cs & ^{134}Cs		*Internal exposure caused by ^{131}I	
		(Bq)	(μSv)	(Bq)	(μSv)
Screening 1	4	1929	28	118	11
Screening 2	4	** ND	0	ND	0
Screening 3	4	ND	0	ND	0
Screening 4	4	688	11	27	4
Screening 5	3	ND	0	ND	0
Screening 6	2	593	9	ND	0
Screening 7	3	ND	0	18	2
Screening 8	3	ND	0	ND	0
Screening 9	4	ND	0	ND	0
Screening 10	3	ND	0	ND	0
Screening 11	3	ND	0	ND	0
Screening 12	3	ND	0	ND	0
Screening 13	3	ND	0	ND	0
KURAMA1	4	ND	0	ND	0
KURAMA2	2	ND	0	ND	0
KURAMA3	2	ND	0	ND	0
KURAMA4	2	594	9	ND	0
KURAMA5	2	ND	0	ND	0
KURAMA6	5	ND	0	ND	0

*The maximum internal dose of the each group

**ND : Not Detected