

VI. RADIATION PROTECTION AND MONITORING

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1. Individual Monitoring

Internal and external radiation doses were monitored for radiation protection, according to the radiation safety regulations. In this FY 2013, total 547 workers (180 workers registered in this institute and 367 visiting workers of other institutions) were monitored individually. External exposure doses have been monitored every month with glass badges sensitive to beta-, gamma -rays, thermal and fast neutrons for staffs, students and researchers. Digital pocket dosimeters have been in use as supplement. The glass badges were used for monitoring one centimeter dose equivalent and a tissue dose equivalent at 70 μm deep. The trend of annual collective doses was summarized in Table 1. Internal exposure doses were estimated using the airborne radioactivity in air at work places, so that no internal doses were detected. The annual collective dose (for total of 180 workers) and the average effective dose per person were 11.4 $\text{man} \cdot \text{mSv}$ and 0.06 mSv/y , respectively. The maximum individual dose was 1.2 mSv/y . No worker was exposed to radiation beyond 20 mSv/y , or a dose limit regulated by the law. According to the law and orders by the regulation authorities, necessary reports were prepared and submitted.

2. Indoor Radiation Control

The Section of Indoor Radiation Control monitored the external radiation dose, the airborne radioactivity in air and the surface contamination in the controlled areas, regularly. The monitoring for the external radiation dose rate in the controlled areas was carried out with both fixed-position monitors and survey meters which can measure beta-, gamma-rays and neutrons during the period of the reactor operation. Ionization chambers, NaI scintillation counters and BF_3 counters are mainly used as the detectors for the fixed-position monitoring systems. The alert level for the radiation dose rate has been generally set at 20 $\mu\text{Sv/h}$ in the controlled area. The external radiation dose accumulated for a week/month was also measured with glass badges at more than 30 locations in the KUR, KUCA containment buildings and other radiation facilities such as Linac and radioactive waste management.

Fixed-position monitors for radioactive gases and/or dust are installed both in work areas and exhaust lines. The dominant radionuclide resulting from the reactor operation is ^{41}Ar . The concentration of radionuclides released from facilities was monitored continuously. There was no significant release, that is beyond the regulation levels.

3. Environmental Radiation Control

The Section of Environmental Radiation Control worked for assessing the radiation dose in the vicinity of the nuclear facility and monitoring the radioactivity in environmental samples. In FY 2010, the KUR re-started, so we carefully monitor the radiation doses to the public. The effective dose on the public resulting from exposure by the effluent gas from reactor was estimated to be enough below the regulation levels.

The environmental monitoring and meteorological observation was continuously performed to obtain safety assurance data. Dose rates of the external radiation in the field were continuously measured by using NaI scintillation detectors set at five locations inside the KURRI area and four locations outside. The thermo-luminescence dosimeters (TLDs) are set up for measuring the radiation dose accumulated during the period of three months at locations outside the KURRI. No significant increase of the radiation level was recognized in relation to the reactor operation at any monitoring location. Temporary increases in the dose rate were attributed to events with the rainfall that entrains radon daughters. The external radiation doses for every three months at nine locations around the site are shown in Table 2.

Environmental samples including surface water, river and pond sediments, field soils, dusts and plants were collected in the vicinity of the KURRI twice a year during spring and autumn. Typical data on the environmental radioactivity are given in Table 3. The total activities in beta- and gamma-nuclides, which were measured with a low background counter using a windowless gas flow and/or a Ge(Li) detector, showed the ordinary natural radioactivity levels in any samples mentioned above. The content of ^{40}K in plants has a wide variation ranging from 3.1×10^1 to 2.6×10^2 Bq/kg-wet weight .

Liquid waste from the radioactive waste management facility or KURRI is discharged into a retention pond (named Imaike) after treatment process. Neither the content of radionuclides beyond the regulation level was observed in the effluent water, nor radioactivity in any environmental samples exhibited tendency to increase with time.

Table 1 Number of radiation workers, collective dose, and average effective dose, per year, in FY 2009-2013.

	FY 2009	FY 2010	FY 2011	FY 2012	FY 2013
Collective dose (man•mSv)	12.7	13.3	12.5	15.2	11.4
Number of registered radiation workers	191	184	193	190	180
Average effective dose (mSv)	0.07	0.07	0.06	0.08	0.06

Table 2 External doses accumulated quarterly by using thermo-luminescence detectors at nine locations around the KURRI site

Location	Period(quarter)	First	Second	Third	Fourth	Total
		(μSv/quarter)				(μSv/year)
KUR meteor. observ. tower		84	74	74	74	306
KUR south of ground		112	98	100	101	411
Bozu-Ike pond		60	60	57	57	234
KUR transformer station		73	71	67	79	290
KUR gate		72	69	68	69	278
Kumatori Wada st.		103	95	94	100	392
Izumisano Shimogawaraya st.		113	103	104	111	431
Izumisano municipal office st.		109	104	101	110	424
Izumisano Hieno st.		87	84	78	83	332

Table 3 Radioactivity concentration in environmental samples selected

Samples	Sanpling locations	Sampling date (D/M/Y)	Man-made nuclides			Natural nuclides			
			⁶⁰ Co	⁶⁵ Zn	¹³⁷ Cs	⁷ Be	⁴⁰ K	²⁰⁸ Tl	²¹⁴ Bi
Sediment (Bq/kg-dry)	Eiraku-dam	25/12/13	D.L.	D.L.	1	7	603	10	16
	Oo-ike	21/10/13	D.L.	D.L.	D.L.	D.L.	545	5	11
	Inakura-ike	21/10/13	D.L.	D.L.	1	D.L.	522	10	18
	Ameyama-gawa (Gomon)	22/10/13	D.L.	D.L.	1	16	643	8	15
Soils (Bq/kg-dry)	KUR Hot Lab.	22/10/13	D.L.	D.L.	D.L.	D.L.	698	12	17
	Kumatori-Wada	21/10/13	D.L.	D.L.	4	D.L.	497	D.L.	15
	Hine shrine	21/10/13	D.L.	D.L.	1	D.L.	527	11	17
	Aritoshi shrine	21/10/13	D.L.	D.L.	3	D.L.	595	D.L.	29
Vegetables (Bq/kg-dry)	Sweet potato(root)	04/10/13	D.L.	D.L.	D.L.	D.L.	77.0	D.L.	D.L.
	Radish(root)	10/12/13	D.L.	D.L.	D.L.	D.L.	76.8	D.L.	D.L.
	Chinese cabbage	10/12/13	D.L.	D.L.	D.L.	D.L.	56.4	D.L.	D.L.
	Lawn	04/10/13	D.L.	D.L.	0.2	5.3	95.4	D.L.	D.L.
Rain water (Bq/l)	Meteor. observ. tower at KURRI	Sep.13– Feb. 14	D.L.	D.L.	D.L.	D.L.	D.L.	D.L.	D.L.

* : D.L. denotes the measured values were below a detection limit.