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 2012, total 556 workers (190 workers registered in this institute and 366 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 190 workers) and the average effective dose per person were 15.2 man・mSv and 0.08 mSv/y, respectively. The maximum individual dose was 1.4 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 20μSv/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 for the other facilities such as KUCA. 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 3.7×10^1 to 2.4×10^2 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 2008-2012.

	FY 2008	FY 2009	FY 2010	FY 2011	FY 2012
Collective dose (man･mSv)	12.0	12.7	13.3	12.5	15.2
Number of registered radiation workers	188	191	184	193	190
Average effective dose (mSv)	0.06	0.07	0.07	0.06	0.08

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

Period(quarter)	First	Second	Third	Fourth	Total
Location	(μSv/quarter)				(μSv/year)
KUR meteor. observ. tower	75	75	77	79	306
KUR south of ground	96	97	105	105	403
Bozu-Ike pond	56	59	60	63	238
KUR transformer station	76	78	75	77	306
KUR gate	68	69	69	74	280
Kumatori Wada st.	93	91	93	102	379
Izumisano Shimogawaraya st.	98	91	94	110	393
Izumisano municipal office st.	99	101	97	110	407
Izumisano Hieno st.	76	83	79	88	326

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	16/11/12	D.L.	D.L.	D.L.	D.L.	596	9	11
	Oo-ike	09/10/12	D.L.	D.L.	D.L.	D.L.	580	7	9
	Inakura-ike	09/10/12	D.L.	D.L.	D.L.	D.L.	524	10	13
	Ameyama-gawa (Gomon)	10/10/12	D.L.	D.L.	D.L.	D.L.	756	8	10
Soils (Bq/kg-dry)	KUR Hot Lab.	10/10/12	D.L.	D.L.	D.L.	D.L.	738	17	23
	Kumatori-Wada	09/10/12	D.L.	D.L.	3	D.L.	520	9	13
	Hine shrine	09/10/12	D.L.	D.L.	2	D.L.	567	13	15
	Aritoshi shrine	09/10/12	D.L.	D.L.	4	D.L.	641	14	22
Vegetables (Bq/kg-dry)	Sweet potato(root)	02/10/12	D.L.	D.L.	D.L.	D.L.	118.8	D.L.	D.L.
	Radish(root)	20/11/12	D.L.	D.L.	D.L.	0.1	69.7	D.L.	D.L.
	Chinese cabbage	20/11/12	D.L.	D.L.	D.L.	0.2	61.1	D.L.	D.L.
	Lawn	25/03/13	D.L.	D.L.	0.2	267.0	199.3	0.4	D.L.
Rain water (Bq/l)	Meteor. observ. tower at KURRI	Sep.12– Feb. 13	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.