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Radiological assessment of the decontaminated and decommissioned Korea Research Reactor-1 building

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A R T I C L E I N F O

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A B S T R A C T

The radiation dose of the Korea Research Reactor-1 (KRR-1), which had been decontaminated and decommissioned following shut down in 1995, was evaluated to assess the possibility of reusing the building as a memorial hall. The KRR-1 holds symbolic significance as the first reactor in Korean nuclear history and is designated as a registered cultural property of Korea. Exposure scenarios for visitors and the building manager were evaluated to examine the radiological safety of the building. Radioactive contamination inside the KRR-1 building was measured using gamma survey meter, surface alpha and beta contamination monitor, low level gas proportional counter, and semiconductor detector. The exposure dose rate for real radioactivity measurement was calculated using the RESRAD-BUILD code and uncertainty analysis was performed. The radionuclides of ^{60}Co, ^{137}Cs, and ^{152}Eu were in the ranges of 0.09–0.011, 0.005–0.041, and 0.013–0.097 Bq/g, respectively, on the surface of the reactor building. The external dose rate in the reactor building in the first year of the measurement ranged from 1.05×10^{-7} to 3.76×10^{-6} mSv/h. The maximum exposure doses on the building manager and visitors in the first year were 1.82×10^{-4} and 1.07×10^{-6} mSv/y, respectively, satisfying the dose limit for unrestricted release of the building. Thus, the radiological safety of the KRR-1 building was confirmed.

1. Introduction

The Korea Research Reactor-1 (KRR-1), located at the Korea Atomic Energy Research Institute (KAERI), is Korea's first research reactor and is of the Training Research Isotope General Atomic (TRIGA) Mark-II type (Fig. 1) (Kim et al., 2006). The KRR-1 reached first criticality in March 1962 and was shut down in January 1995. The research reactor was used for several diverse applications including radioisotope production and research regarding reactor characteristics during its operation over 33 years (Lee and Kim, 1970; Jun et al., 1990). During decommissioning, the equipment inside the reactor was dismantled (Park and Jeong, 1999; Lee et al., 2010) to prevent radionuclide contamination and the reactor's inside walls were decontaminated. Seniors at the nuclear society have recommended that KRR-1 should be commemorated and preserved as it initiated nuclear age in Korea. Additionally, KRR-1 was designated as registered cultural property No. 577 of Korea in 2013 due to its symbolic significance as the first reactor in Korea. Currently, KRR-1 is being considered as a site for the historic memorial hall of nuclear science and technology.

Radiological dose assessment of the reactor building and its environment is essential following decontamination and decommissioning due to the possibility of radiation exposure. Suitable scenarios are needed for dose assessment of each process to reflect different exposure environments. For example, radiological assessment was performed during dismantling in the other nuclear facilities (Hornáček and Nečas, 2016; Shimada and Sukegawa, 2015; Jeong et al., 2014a). Additionally, uncertainty analysis of the exposure dose of workers during decommissioning of the core cooling system pipes has been conducted (Simonis et al., 2015). In the case of KRR-1, radiological assessment of the hazards and risks during decommissioning were analyzed (Jeong et al., 2008, 2014b). Further, 3D virtual environments were studied to evaluate exposure dosages during decommissioning (Park et al., 2008). As the final phase of the decontamination and decommissioning process, the KRR-1 reactor building needs to be evaluated for radiation exposure of the building occupant scenario.

The Nuclear Safety Act of Korea (Nuclear Safety and Security Commission, 2016) restricts the reuse of all nuclear facilities. The effective dose threshold for unrestricted release of reactor sites and buildings is 0.1 mSv/y for all possible exposure pathways on critical groups. However, if the effective dose exceeds the threshold, restricted

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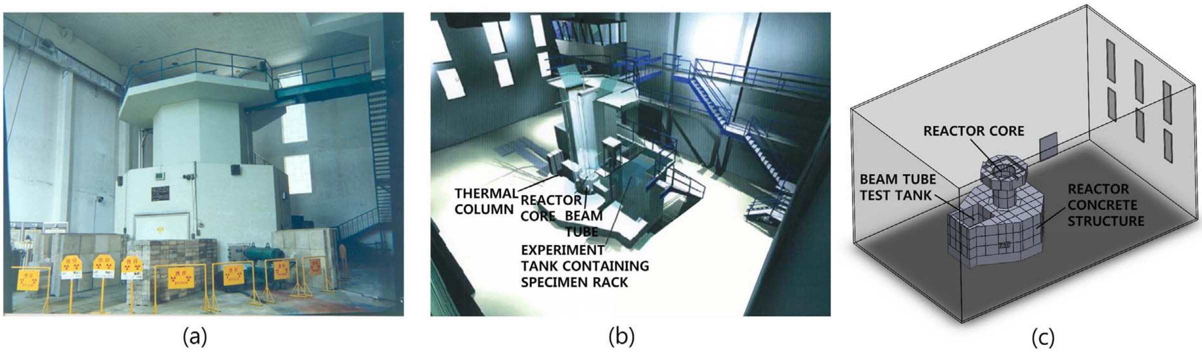

Fig. 1. KRR-1 structure images: (a) photograph of the reactor room, (b) 3D perspective image (Kim et al., 2006), (c) simplified 3D image.

reuse conditions to reduce the effective dose from the residual radionuclides are required and the effective dose criterion should not exceed 0.1 mSv/y, based on the As Low as Reasonably Achievable (ALARA) principle. Under restricted reuse conditions, the effective dose should not exceed 1 mSv/y even if the conditions are not met. The Nuclear Safety Act specifies that effective dose calculations should calculated for at least thousand years after the release of sites or buildings due to residual radioactivity.

In this research, the effective dose and its uncertainties on the KRR-1 research building occupier scenario were analyzed based on measurement of residual radioactivity to evaluate the possibility of reuse. The dose estimation after release was calculated for different intervals from one year to thousand years using memorial hall visitor and building manager occupant scenarios.

2. Materials and methods

Gamma dose rate, surface alpha, and beta contamination were assessed and gamma nuclides analysis was conducted. Subsequently, exposure dose assessment was conducted using the measured data.

2.1. Radioactivity measurement after decontamination

The KRR-1 reactor and reactor room were decontaminated following decommissioning. All structures except the reactor cavity walls were dismantled. The reactor structure surface and walls were divided into 319 sectors, each measuring 1 m^2 (1 m × 1 m), as shown in Fig. 2(a), and radioactive contamination of each sector was examined. The floor of the reactor room was divided into 26 zones, as shown in Fig. 2(b), and each zone was sampled. All measurements were conducted during 2013–2014.

Table 1
Radioactivity of concrete powder samples from the KRR-1 floor and reactor cavity surface.

Floor sector	Activity (Bq/g)		Reactor sector	Activity (Bq/g)
	^{60}Co	^{137}Cs		^{152}Eu
1	–	0.019	1–6	–
2	–	0.041	7 –12	–
3	–	0.016	13–18	0.043
4	–	0.024	19-24	0.065
5	–	0.037	25	0.037
6	–	0.005	26	0.097
7	0.008	0.02	27	0.038
8	–	–	28	0.013
9	–	–	29	0.06
10	0.011	0.016	30	0.07
11	0.009	0.014	31	0.03
12	–	–	32	0.091
13	–	0.009	33	0.076
14	–	0.01	34	0.074
15	–	–	35	0.078
16	–	0.019	36	0.096
17	–	–	37	0.018
18	0.011	0.026	38	–
19	–	0.011	39	0.034
20	–	–	40	0.072
21	–	0.034	41	0.018
22	–	0.011	42	–
23	–	0.013		
24	–	–		
25	–	0.039		
26	–	–		

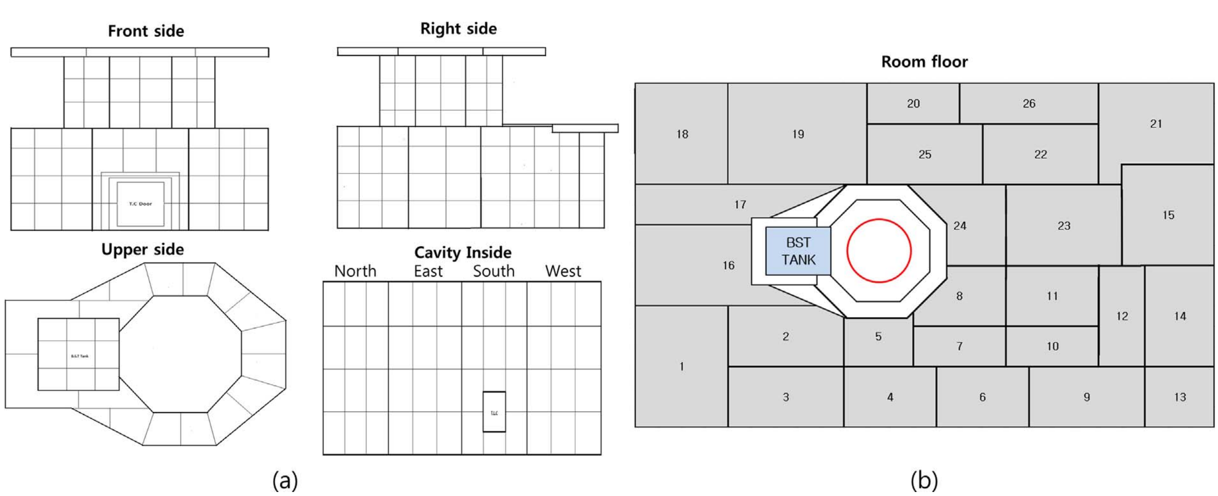

Fig. 2. Radioactivity measurement sections: (a) surface of the KRR-1 reactor structure and (b) room floor.