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Technical article

Assessment Results to Determine Proficiency in Irradiation Procedures

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ABSTRACT The radiation sources in the irradiation facility operated by the Advanced Radiation Research Institute of the Korea Atomic Energy Research Institute were replaced on 7 November 23 and the new sources resulted in changes in the distance dose maps. Dosimetry and distance dose maps for dose mapping were obtained using an alanine dosimeter, and proficiency tests, which are intercomparison experiments conducted by the IAEA RCA's Dosimetry Group for quality control of survey services, were performed based on ISO/IEC 17025:2017 procedures. The dose distribution was measured as a function of distance from the irradiated plane. The dose flatness was calculated to be 16% on average. Based on the dose values obtained from the dose distribution in the plane of the irradiation table, a dose-response curve using an alanine dosimeter was obtained. To reduce the residual dose values as a function of distance, the dose-response function obtained from the measurements was calculated as $y = -0.1004x^3 - 0.0649x^2 + 0.052x + 1.37$, $R^2 = 0.9993$. Experiments were performed for 5, 10, 15, 30 kGy and unknown doses using alinine dosimeters and phantoms in all 13 laboratories. An inter-country ESR intercomparison assessment showed that South Korea achieved dosimetry system result reproducibility within 5%.

Key words: Proficiency testing, High Dose, Irradiation, Dose Response, Conformity Assessment, Dose Mapping

1. 서 론

The radiation source at the irradiation facility operated by the Advanced Radiation Research Institute of the Korea Atomic Energy Research Institute was replaced on November 7, 2023. When the new radiation source was added to the existing radiation source, the dose map by distance changed. As shown in Figure 1, an alanine dosimeter was used to measure the dose for dose mapping, and a dose map by distance was obtained.

Quality control of the survey services was subsequently performed in accordance with the proficiency test procedure, an intercomparison experiment conducted by the dosimetry group of the IAEA RCA.

A proficiency test (PT) is an objective assessment of a person's ability to perform a specific task in a field, or their proficiency. It is used to identify individual competencies and increase organizational efficiency, and is used in a variety of fields. It is a type of interlaboratory comparison in which multiple laboratories perform measurements or tests on the same or similar items and compare the results to determine the competency of each laboratory. Currently, ISO/IEC 17025:2017 mandates laboratories to participate in proficiency testing or interlaboratory comparisons [1].

2. Materials and Methods

2.1. Irradiation Zone Dose Mapping

This high-level irradiation unit was built by Nordion in Canada, installed in January 2006, and holds a ^{60}Co license (470,000 kCi). The maximum dose to the surface is 23.5 kGy per hour. To obtain the dose distribution, the surface of the planar irradiator was gridded at 10 cm intervals over an area 1 m across and 90 cm long, as shown in Fig. 1.

The radiation sources in the large gamma irradiation facility are 1 meter long and 1 meter wide. There are a total of 124 ^{60}Co radiation sources embedded in it. As of October 1, 2024, the radioactivity is 1.18×10^{16} Bq (364,936 Ci).

The measurements were performed using an alanine dosimeter, which is widely used to measure high doses of ionizing radiation. The figure on the left shows the surface of the irradiator

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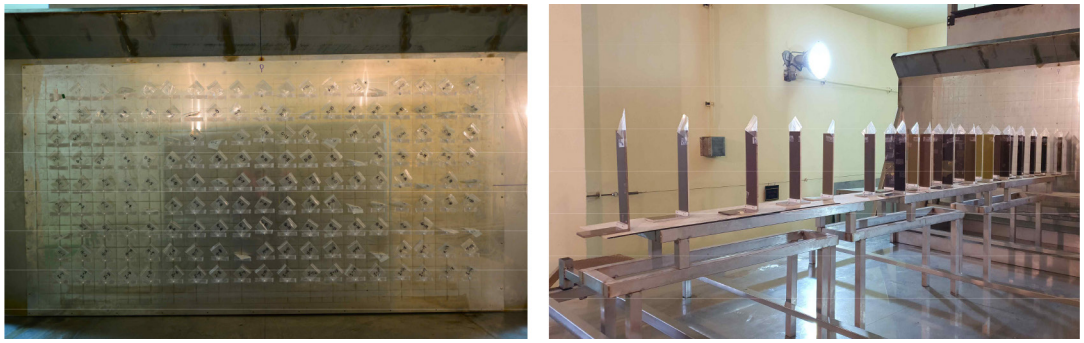


Fig. 1. Cobalt irradiator and dose distribution measurements: (left) irradiator surface divided into 171 grids, (right) dose measurements measuring the dose distribution as a function of distance from the highest dose point

divided into 171 grids, and the figure on the right shows a dosimetric image of the dose distribution as a function of distance from the highest dose point in the center of the irradiator.

2.2. Alanine dosimeters

Alanine dosimeters are highly reliable tools and are widely used to measure high doses of ionizing radiation, mainly in industrial and medical applications. They are based on the principle of electron paramagnetic resonance (EPR) spectroscopy, which detects free radicals produced in solid materials by radiation. Alanine dosimeters are composed primarily of L-alanine, which forms a stable radical when exposed to radiation, allowing for dose measurements over long periods of time. Alanine dosimeters are particularly suitable for high-dose measurements, from 1 kGy to over 100 kGy. Due to these properties, they are widely used in a variety of industrial applications including radiation sterilization, food irradiation, and material modification. The free radicals generated within alanine remain stable for a long period of time, so dosimetry can be performed even months after irradiation, allowing for accurate dose assessment [2,4].

Phantoms provided by the 13 laboratories participating in this experiment were irradiated at five dose levels (5, 10, 15, 30 kGy, and unknown). Five alanine units and phantoms per individual dose were distributed to the participating institutions. Irradiation of the alanine samples was performed with a high level gamma irradiator (made by Nordion, Canada) using ^{60}Co gamma rays at room temperature (approximately 22°C).

2.3. Phantom

A phantom is a device used to measure radiation in radiation therapy, radiation safety, medical imaging, and radiation physics research to safely and accurately assess how radiation is absorbed and distributed by mimicking properties similar to those of the object being irradiated, rather than directly irradiating the actual object [3]. The phantom measures 7 centimeters long by 7 centimeters wide by 10.5 centimeters high. It is designed to hold five alanine dosimeters, as shown in Fig. 2 [5,6,7].

Fig. 2. Alanine dosimeter and phantom (left), irradiating the dose values presented in the phantom (right)

3. Results and Discussion

Figure 3 shows the measured dose distribution as a function of distance from the irradiator plane. The dose flatness was calculated to be 16% on average. It can be seen that the dose distribution broadens as the distance from the radiation source increases.

Figure 4 shows the dose-response curve from an alanine dosimeter as a function of distance from the center of the irradiation table, based on dose values obtained from the dose distribution in the plane of the irradiation table.

The reason why the response curve is a polynomial trend line rather than a straight first-order logarithmic function is because when irradiation is performed using a planar source, the influence of radiation scattering lines is very large due to scattering by the peripherals of the irradiation table and the walls of the irradiation room.

To reduce the residual dose value as a function of distance, the dose-response function obtained from the measurement was calculated as $y = -0.1004x^3 - 0.0649x^2 + 0.052x + 1.37$, $R^2 = 0.9993$. This measurement was performed using an alanine dosimeter without a high-capacity ionization chamber, but it will be necessary to validate this dose value using a high-capacity ionization chamber in the future.

Figure 5 shows measurements for 5, 10, 15, 30 kGy and an unknown dose using the alinine dosimeter and phantom shown in Fig. 2. The phantom was built so that it could be mounted at the top, bottom, left, and right of the dosimeter with the dosimeter 1 cm off center. Results for 5, 10, 15, 30 kGy and unknown doses are shown for South Korea among the 13 labs. The reproducibility of the results from the dosimeter system in South Korea ranged from 1.4 to 4.2%, all within 5%.

Figure 6 shows the results of the ESR intercomparison evaluation submitted by 13 laboratories from 10 Asian countries. The intercomparison was performed for samples irradiated at five doses: 5, 10, 15, 30 kGy and an unknown dose. Only three lab-

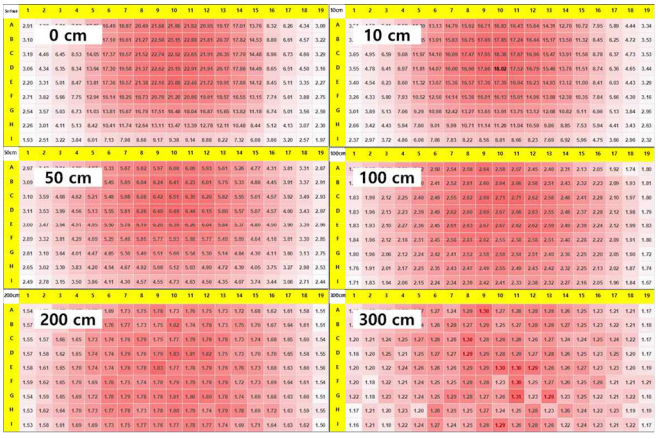


Fig. 3. Map of dose distribution by distance in the survey plane

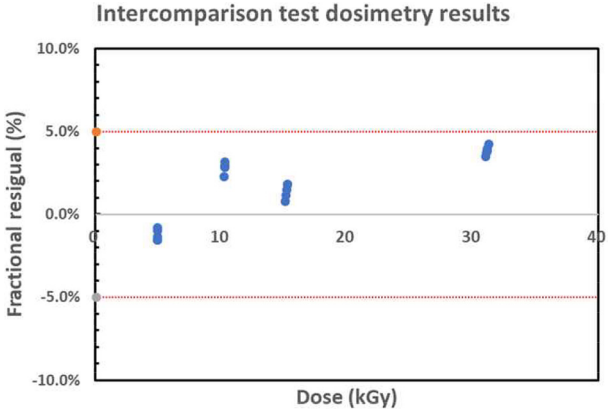
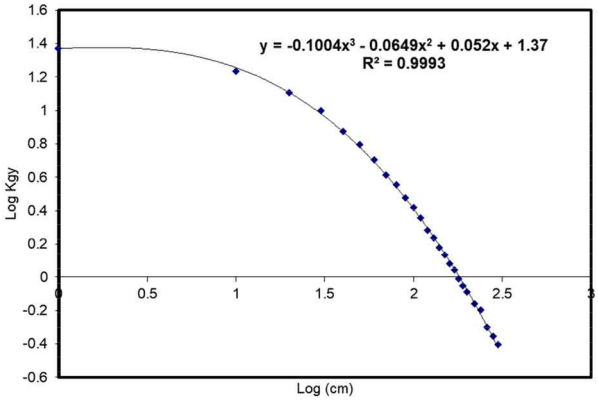


Fig. 5. Results of the irradiation dose values for the doses shown



Dosimeter ID	Dose (kGy)	Dose (kGy)	residual
1	23.53	23.44	0%
10	17.15	18.06	5%
20	12.72	12.78	1%
30	10.02	9.59	-4%
40	7.49	7.48	0%
50	6.25	6.01	-4%
60	5.08	4.93	-3%
70	4.11	4.11	0%
80	3.59	3.48	-3%
90	2.99	2.98	0%
100	2.62	2.58	-2%
110	2.27	2.25	-1%
120	1.91	1.97	3%
130	1.74	1.74	0%
140	1.51	1.55	3%
150	1.36	1.38	1%
160	1.21	1.24	3%
170	1.10	1.12	2%
180	0.98	1.01	4%
190	0.88	0.92	4%
200	0.82	0.84	2%
220	0.69	0.70	1%
240	0.64	0.59	-8%
260	0.50	0.50	0%
280	0.44	0.43	-2%
300	0.39	0.38	-4%

Fig. 4. Dose distribution curve as a function of distance from the center of the irradiation field

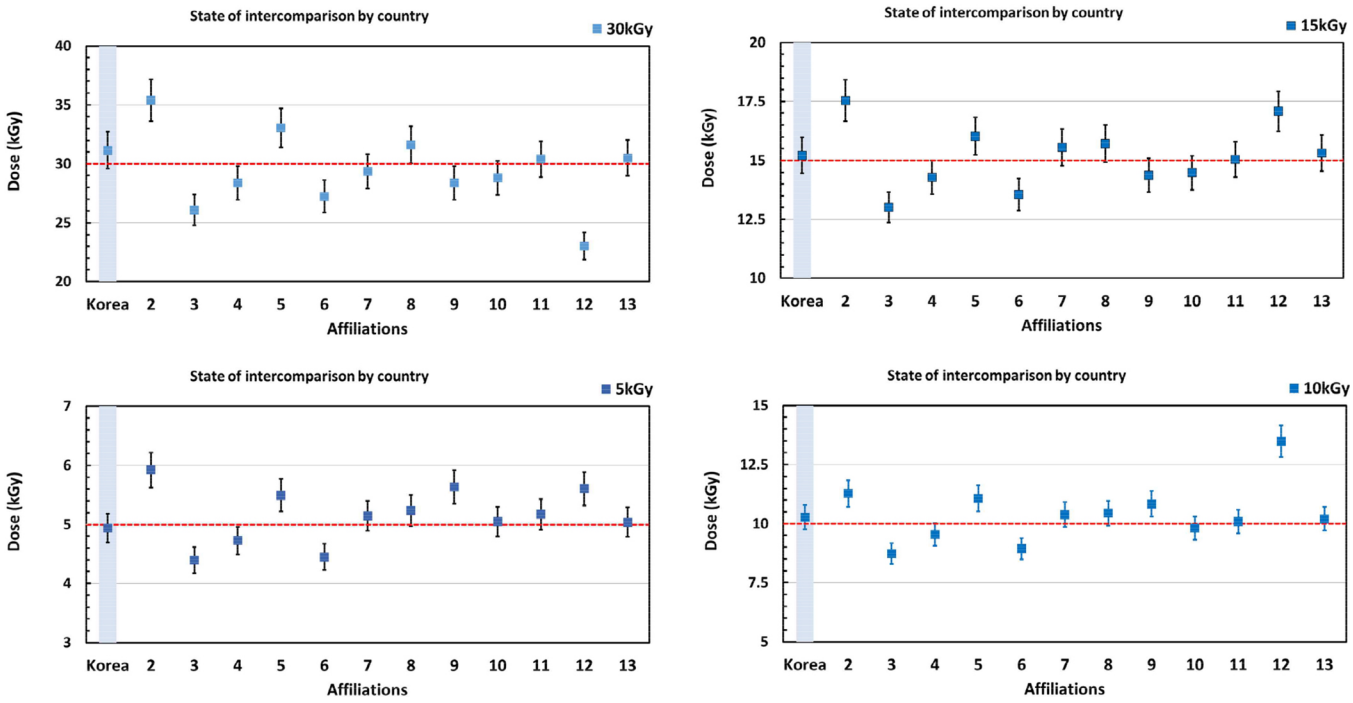


Fig. 6. 13 Interagency dose assessment results from 13 participating organization

oratories, including South Korea, achieved a reproducibility of dosimetry system results within 5%. Among the 13 laboratories, only three laboratories, including South Korea, achieved satisfactory results. This trial is significant in that it establishes a cooperative system for dose assessment between countries [6].

Conclusion

An ESR intercomparison evaluation was conducted using alanine dosimeters at 13 irradiation facilities in 10 Asian countries. The intercomparison was performed on samples irradiated at five doses: 5, 10, 15, 30 kGy and unknown. Korea achieved a reproducibility of dosimetry system results within 5%. Overall, the results of the 13 laboratories compared were generally satisfactory, with a few exceptions. This intercomparison was particularly significant because it was the first attempt to establish a cooperative system among laboratories using ESR dosimeters in Asian countries. It also provided an opportunity to improve the reliability of each laboratory's ESR measurement system. Since the first intercomparison, the participating laboratories have continued to meet to discuss various aspects of the national collaborative response, including standardizing EPR measurement uncertainties, sharing measurement results from different dosimetry samples, and training for the next intercomparison. The second intercomparison is scheduled for some time in 2025, and each laboratory is currently working to establish measurement procedures for their samples. The group is also looking for other laboratories to participate in the second intercomparison.

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