Field calibration method of dosemeters for environmental monitoring with a collimated irradiation system

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Ionizing Radiation Group

The ionizing radiation standards group develops, maintains, and disseminates the measurement standards that contribute to the **radiotherapy** and the **radiation protection**.

Facilities Equipment	Sub-pA current measurement system
	Calorimetry
	Medical Liniac
	Gamma-ray irradiation facilities
	X-ray irradiation facilities
	beta-particle irradiation facility






Dosimetry standards for radiation protection

Primary standard

Graphite wall cavity Ionization chamber

Parallel plate Free Ionization chamber

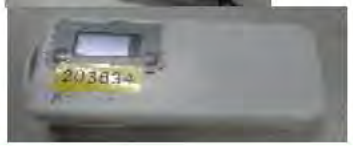
Extrapolation chamber

JCSS accredited laboratory

Secondary standards

Users

・Survey meters
・monitoring posts
・personal dosemeters



Dosimetry standards and the protection quantities

(From ICRU report 95)

Physical quantities
- Fluence, Φ
- Kerma, K
- Absorbed dose, D

ICRP Publication 103

Comparison and estimation

ICRU report 39/51

Protection quantities
- Organ absorbed dose, D_T
- Organ equivalent dose, H_T
- Effective dose, E

Operational quantities

Area monitoring
- Ambient dose equivalent, $H^*(d)$
- Directional dose equivalent, $H'(d,\Omega)$

Individual monitoring
- Personal dose equivalent, $H_p(d)$

Related by calculation and calibration

Monitored quantities
Instrument responses

Air kerma rate in the gamma-ray fields

Primary standard

Graphite-walled cavity chamber

Cylindrical shape
6 ml, 60 ml

irradiation facilities

Co-60: 3.5×10^{-6} Gy/h - 2.4×10^{2} Gy/h
(**148 TBq***, 185 GBq, 18.5 GBq, 3.7 GBq)

Cs-137: 1.0×10^{-6} Gy/h - 1.1 Gy/h
(**34 TBq**, 222 GBq, 18.5 GBq, 1.85 GBq)

(*Purchased in 2018)

Users/ Clients

secondary calibration laboratory

Monitoring service provider

Manufacturer
University

Low level Air kerma rate in gamma-ray fields

Secondary standard

Large volume spherical ionization chamber calibrated in the reference gamma-ray fields

irradiation system

Shielding box
Inside the box BG dose rate is lower than 0.01 μSv/h.

Users/ Clients

Survey meters

Air kerma rate in the X-ray fields

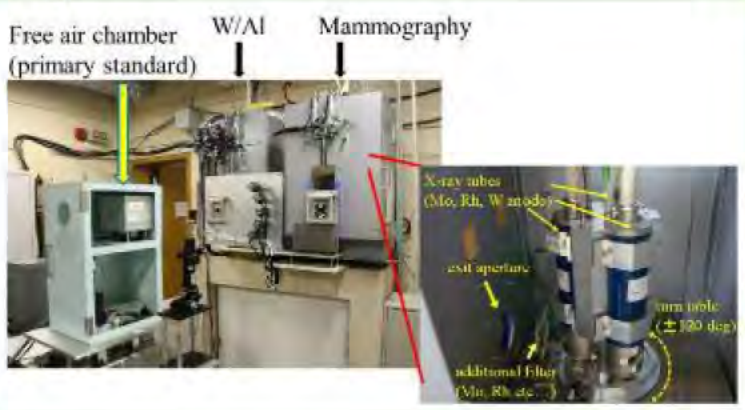
Primary standard

Free air ionization chambers and graphite wall cavity chamber

irradiation facilities

Medium-Hard x-ray
40kV-450kV

Low energy x-ray
10kV-50kV



Users/ Clients

secondary calibration laboratory

Monitoring service provider

Manufacturer

Dosimetry standards for beta-particles

Primary standard

Extrapolation chamber

irradiation system

Sr-90/Y-90 460 MBq
Kr-85 3.7 GBq
Pm-147 3.7 GBq (Purchased in 2016)
Ru-106/Rh-106 74 MBq (Purchased in 2019)

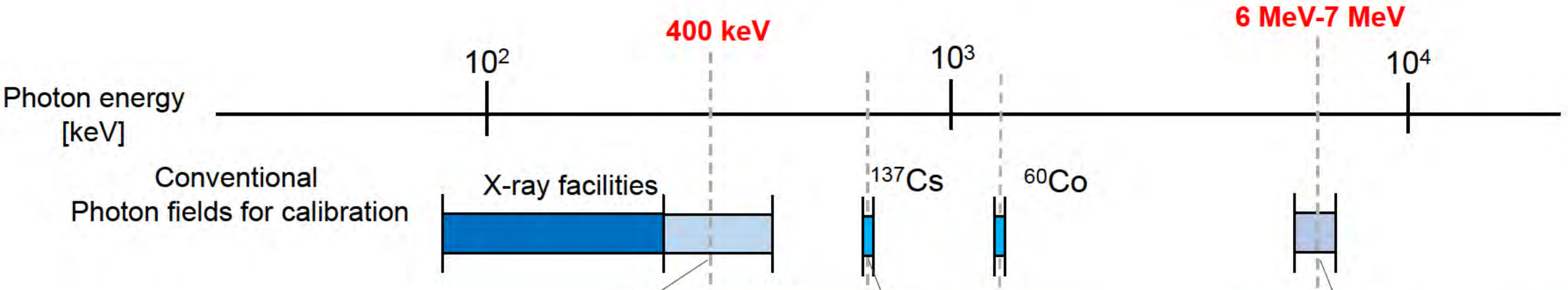
Users/ Clients

secondary calibration laboratory

Monitoring service provider

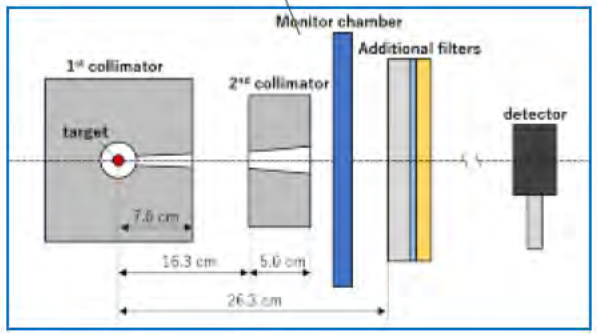
$H_p(0.07)$
$H_p(3)$

Photon fields under development



X-ray fields with the tube voltage up to 450 kV

J. Ishii *et al.*, *Biomed. Phys. Eng. Express* **8** 015021.(2022)



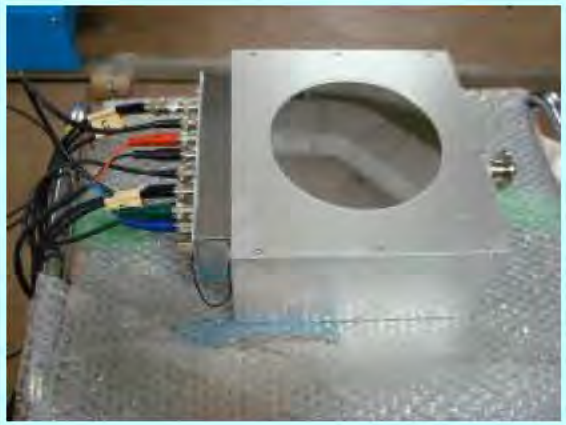
Accelerator-driven photon reference field for replacement of Cs-137 γ-ray
J. Ishii *et al.*, *Metrologia*, 60 042101

Photon fields with 6 MeV-7MeV using a medical LINAC

Dosimetry standards for radiotherapy

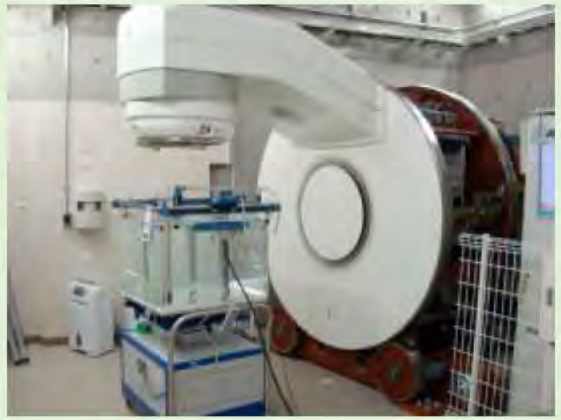
Absorbed dose rate to water

Primary standard



Graphite calorimeter

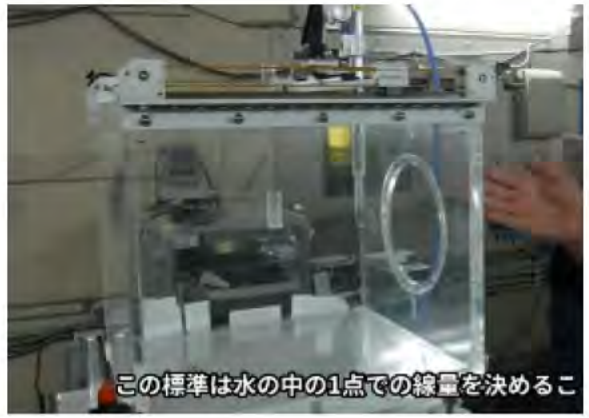
irradiation facilities



Co-60 146TBq
Linac photons 6MV, 10MV, 15MV
Linac electrons 9MV 12MV 15MV 18MV

Users/ Clients

secondary calibration laboratory



Manufacturer
University

Air kerma rate for Ir-192 Brachytherapy source

Primary standard

Graphite-walled cavity chamber

Cylindrical shape
60 ml

irradiation system

Ir-192 Remote After Loading System

Place the Ir-192 source and the cavity chamber at a calibration distance of 1m

Users/ Clients

secondary calibration laboratory

Well-type ionization chamber

Field calibration method of dosemeters for environmental monitoring with a collimated irradiation system

Introduction

Several thousand environmental radiation monitoring devices, so-called monitoring posts, have been installed all over Japan.

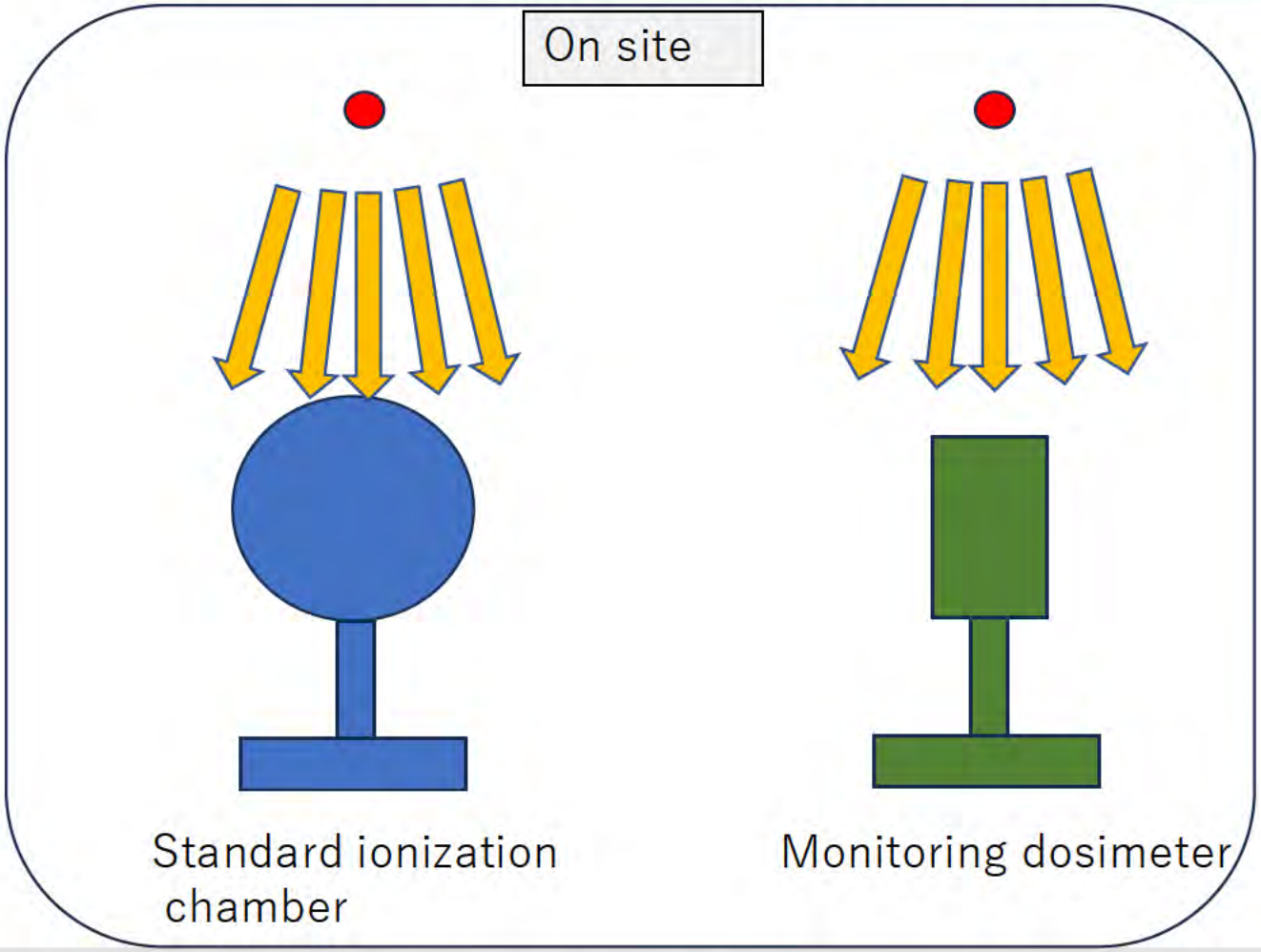
Most of the monitoring devices are strongly fixed on site, besides they are large and heavy.

Calibration in a laboratory is difficult.

The collimated irradiation system for field calibration have been developed.

Conventional method

Irradiate Cs-137 gamma-ray to standard ionization chamber and the calibration item under the same conditions and compare the respective measurement values.

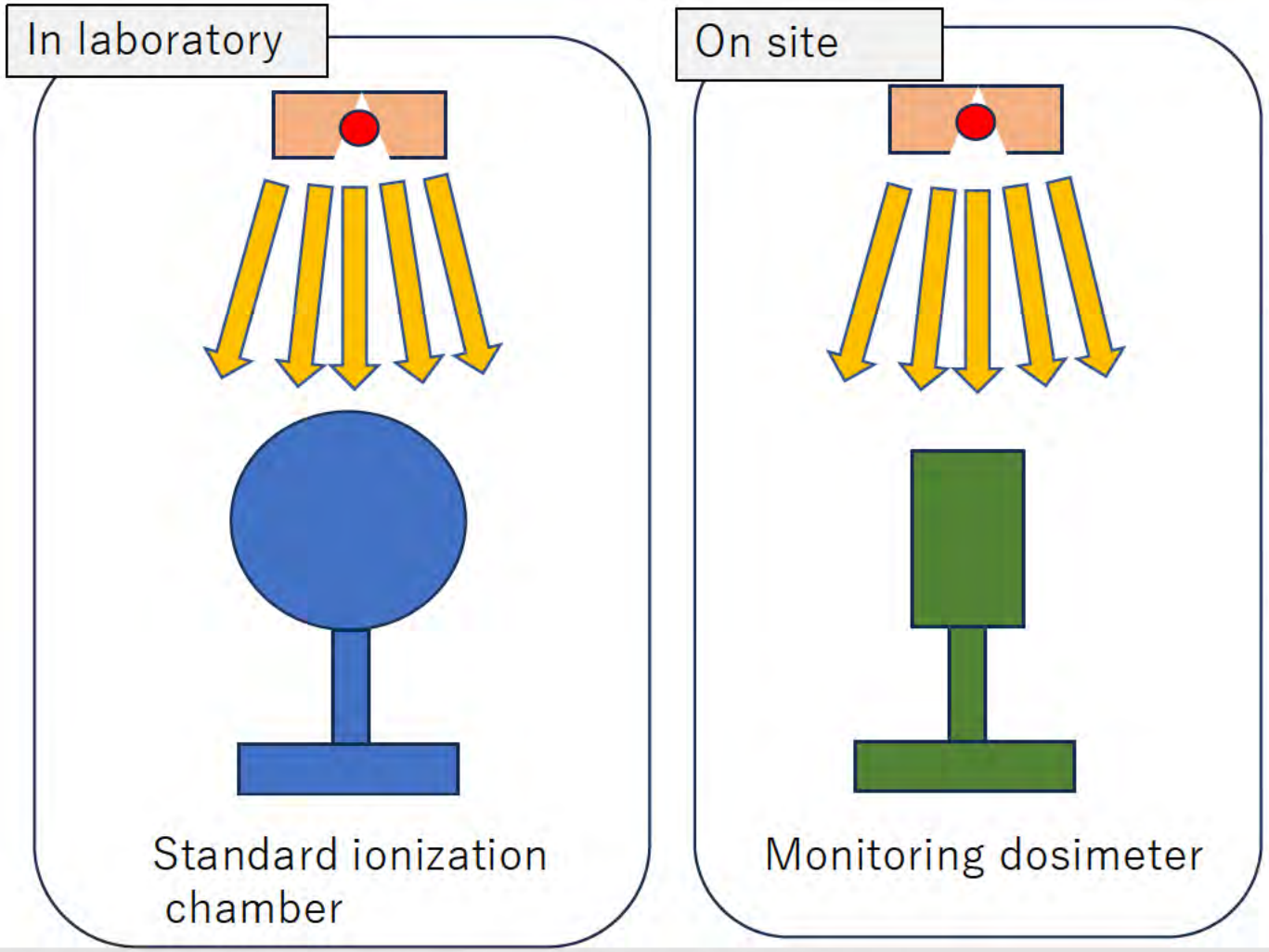


- Need to bring the standard ionization chamber to the site.
- The standard ionization chamber need several hours for warm-up.
- Affected by scattering from surrounding objects.

5 hour for on-site measurement

Collimated irradiation system

Calibrate the Cs-137 RI source in the laboratory and use the source for the calibration of monitoring dosimeters



- No need to bring the standard ionization chamber to the site.
- No need for standard ionization chamber measurements on site.
- Not affected by scattering from surrounding objects.

1 hour for on-site measurement

Extension to other RI sources

- Extend the method to other gamma-ray sources and perform the test for the energy dependence.

Primary standards

①calibration of the standard ionization chamber in x-rays and gamma rays

Standard ionization chamber

②Determination of the air kerma rate for each RI source

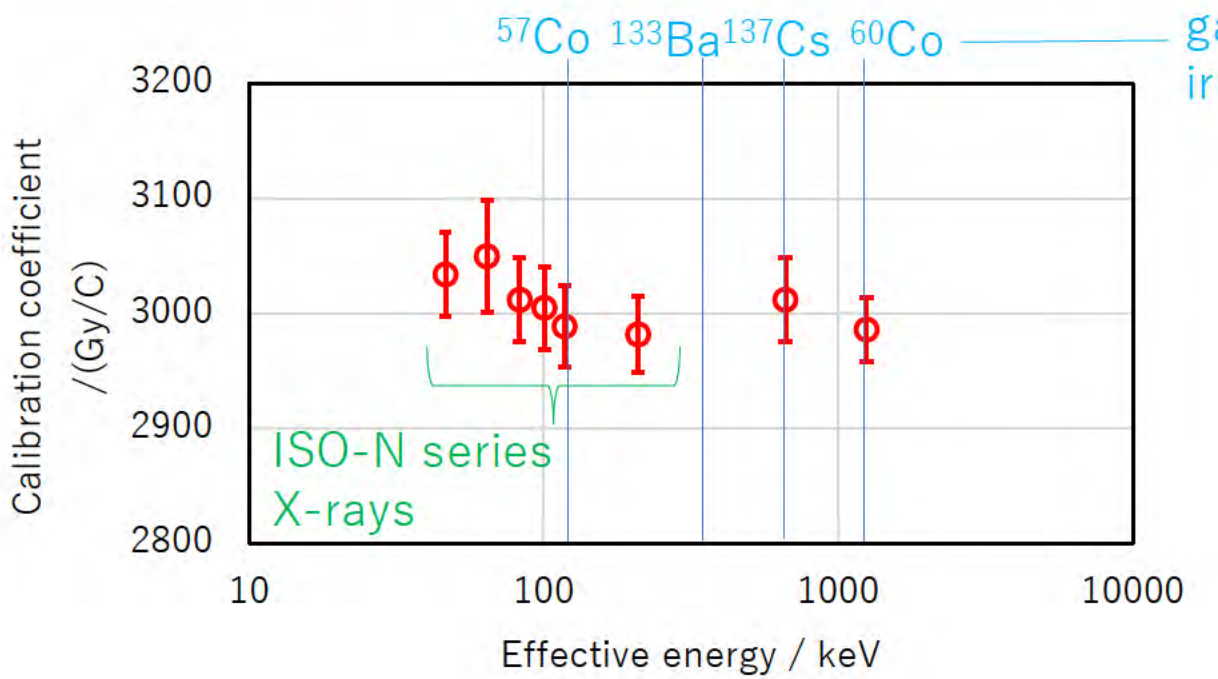
Collimated Irradiation system
+
3.7 MBq/10 MBq RI gamma-sources
(Co-57、Ba-133、Cs-137、Co-60)

③Calibration of the monitoring devices on site

Monitoring devices

①Calibration of the WS ionization chamber

Calibration coefficients for ISO-N series X-rays and Cs-137 and Co-60 gamma-rays



WS ionization chamber : PTW 32003 (10L)
Air kerma rate: 1.4 μGy/h ～ 13 μGy/h

②Determination of the air kerma rate

	Nominal Activity	distance	Air kerma rate	Relative uncertainty (k=2)
Co-57	10 MBq	70 cm	0.165 μGy/h	10 %
Ba-133	10 MBq	70 cm	0.737 μGy/h	4 %
Cs-137	3.7 MBq	50 cm	0.608 μGy/h	5 %
Cs-137	3.7 MBq	70 cm	0.303 μGy/h	6 %
Co-60	10 MBq	70 cm	4.71 μGy/h	2 %

Uncertainty budget for the calibration with the system

	Relative standard uncertainty (%)
Calibration coefficient of the standard ionization chamber	1.4
Dose rate determination with interpolation	1.6
Source to detector distance	1.9
Correction the difference in irradiation geometry	0.6
Measurement of monitoring dosimeter	0.4
Combined standard uncertainty	2.9
Expanded uncertainty (k=2)	5.9

Uncertainty evaluation is easier than the conventional method.
No need to consider the effects of the scattering from the surrounding objects.

Summary

- The ionizing radiation standards group develops, maintains, and disseminates the measurement standards that contribute to the radiotherapy and the radiation protection.
- The field calibration method for environmental monitoring with a collimated irradiation system can shorten the calibration time on site.
- Applying the other RI sources to the irradiation system, the energy dependence test can be performed for the monitoring devices on site.

Thank you for your attention