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Temperature performance of portable radiation survey instruments used for environmental monitoring and clean-up activities in Fukushima

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HIGHLIGHTS

- Temperature performance of Japanese radiation survey instruments was investigated.
- Experimental results showed diverse characteristics among the different instrument models.
- Instruments' performance practically conforms to the requirement in IEC 60846-1 standard.

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ABSTRACT

Following the Fukushima Dai-ichi Nuclear Power Plant accident in March 2011, extensive radiation monitoring and environmental clean-up activities have been conducted throughout the Fukushima region. Outside air temperatures there reach 40 °C in summer and −20 °C in winter, which are beyond the quoted operational range of many radiation survey instruments. Herein, temperature performance of four types of portable Japanese radiation survey instruments widely used in Fukushima was experimentally investigated using a temperature-controlled chamber. They included two ionization chamber type instruments, Fuji NHA1 and Aloka ICS-323C, and two NaI(Tl) scintillation type ones, Fuji NHC7 and Aloka TCS-172B. Experimental results showed significantly diverse characteristics on the temperature dependences from one type of instrument to another. For example, NHA1 overestimated the ambient dose-equivalent rate by as much as 17% at −30 °C and 10% at 40 °C, whereas the TCS-172B readings underestimated the rate by 30% at −30 °C and 7% at 40 °C.

1. Introduction

As a result of the Fukushima Daiichi Nuclear Power Plant (NPP) accident in March 2011, ambient dose-equivalent rates in the outdoor environments of Fukushima Prefecture vary from the background level to as much as 40 μSv per hour as of November 2013 (Japan Atomic Energy Agency, 2015). Radiation monitoring and clean-up activities have been conducted widely and continuously across Fukushima to address the situation (IAEA, 2011; Baba, 2013). For such activities, numerous portable radiation survey instruments of either the scintillation type for dose rates below several tens of μSv h^{-1}, or the ionization chamber type for over that dose rate, are used (Tanigaki et al., 2013; Nuclear Regulation Authority of Japan, 2015). A vast majority of these instruments fall into four models that are all commercially available and manufactured in Japan.

While the outside air temperature in Fukushima approaches 40 °C in summer and −20 °C in winter, radiation measurements must be continued across all four seasons to ensure radiation safety and achieve early decontaminations in the region (Fig. 1). Most radiation survey instruments are not supposed to be used in such harsh conditions.

It is generally known that a radiation detector, including its associated equipment such as a photomultiplier tube, has temperature dependency as to its sensitivity. There are many reports on the temperature performance of radiation detectors, mainly for NaI(Tl) detectors (Sabharwal et al., 1982; Zucker, 1986; Yamada et al., 2009), and some of them refer to the dependency mechanism of an individual detector model (Reeder and Stromswold, 2004; Johnson, 2009).

Temperature performances of the aforementioned four models have only been obtained by their manufacturers. However, the number of the tested temperature points is very limited and does not include data below −10 °C. Thus, to enhance the reliability of measured results and assure radiation safety in the

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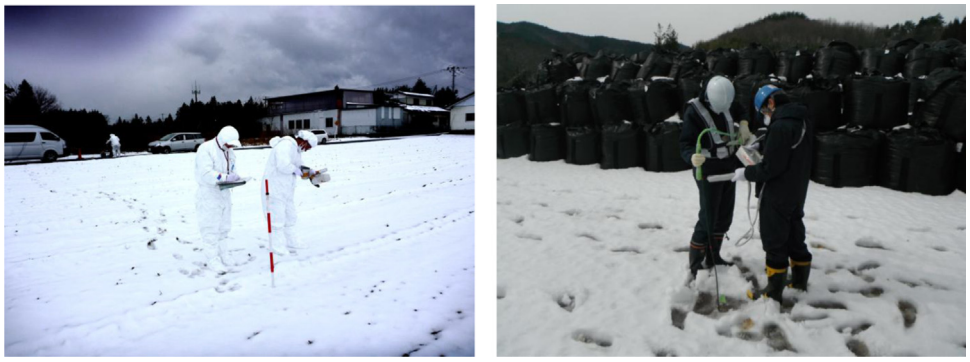

Fig. 1. Radiation measurements during severe winter in Fukushima.

decontamination sites, temperature performances for radiation survey instruments widely used in Fukushima were experimentally investigated in this study.

2. Survey instruments

The performances of the four types of portable survey instruments were determined as a function of temperature. The instruments included two ionization chamber type instruments, model NHA1 manufactured by Fuji electric Co. Ltd. (Fuji) and model ICS-323C by Hitachi Aloka Medical Co. Ltd. (Aloka), and two NaI(Tl) type instruments, models NHC7 from Fuji and TCS-172B from Aloka. Principal characteristics of these instruments are summarized in Table 1. All the models are powered by alkaline dry cells. The nominal operational temperature range for all these instruments is specified to be from 0 °C to 40 °C in each of their respective manufacturer's instruction manual, i.e., they are designed for indoor use (International Electrotechnical Commission, 2009; Japanese Industrial Standard, 2014).

3. Experiments

The performance was investigated using two bench-top-type temperature-controlled chambers (SH-661 and SH-642 by Espec Co. Ltd.) in which each type of radiation survey meter was set-up. A reference point source (^{137}Cs: 8.5 kBq or ^{60}Co: 84 kBq) was placed in the chamber so that each instrument was irradiated with an appropriate ambient dose-equivalent rate, i.e., 0.5–15 μSv h^{-1}. Fig. 2 shows an example of the experimental set-up inside the chamber.

For model NHA1, dose-rate readings from three instruments were periodically recorded by visual observations through the chamber window. For model NHC7, dose rates from three instruments were independently recorded in the internal memory of each instrument. Models ICS-323C (4 instruments) and TCS-172B (4 instruments) both have output terminals that enabled dose-rate signals (DC 0–100 mV for ICS-323C and 0–10 mV for TCS-172B) to be picked up outside the chamber, where the data were continuously recorded by a 16-channel electronic recorder (TR-V550 by Keyence Co. Ltd.) together with temperature and humidity data provided by the chamber's built-in thermoelectric couple and psychrometer.

The temperature was changed by either a 5.0 °C or 10 °C step in the range between −30 °C and 40 °C. Preliminary experiments were conducted to determine the minimum cooling time required to obtain stable readings after changing the temperature setting. For all instruments, 10–30 min was typically required for the stabilization of readings when the temperature step was 5 °C. Thus, the

Table 1
Characteristics of Japanese radiation survey instruments studied in this work (Fuji, 2015a, 2015b; Aloka, 2015a, 2015b).

Detector type	Ionization chamber		NaI(Tl) scintillation	
Model	NHA1	ICS-323C	NHC7	TCS-172B
Photo				
Manufacturer	Fuji electric Co. Ltd. (Fuji)	Hitachi Aloka Medical Co. Ltd. (Aloka)	Fuji	Aloka
Sensitivity	γ(X), β (without cover)	γ(X), β (without cover)	γ(X)	γ
Measurement range	1 μSv h^{-1}–30 mSv h^{-1} 0.1–10 μSv	1 μSv h^{-1}–300 mSv h^{-1} 0.3–10 μSv	BKG-75 μSv h^{-1} 0–99.999 μSv	BKG-30 μSv h^{-1} 0–30 k s^{-1}
Weight	1 kg	0.6 kg	1.3 kg	1.5 kg
Number of tested instruments	3	4	3	4

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