Radiation measurement in East Japan using a GM-tube detector after the Fukushima nuclear accident

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A commercially available GM-tube detector calibrated with a Cs-137 standard source was used to determine the status of environmental radioactive contamination caused by the Fukushima nuclear accident. The calibration was achieved with a quadratic correction function for dose rates up to 4 μSv/h. The calibrated GM-tube detector was used for measuring air dose rates and ground surface contamination in East Japan. Measurements were taken inside a car and a bullet train as well as outdoors from March to August of 2011. The dose rates measured inside a vehicle along the Tohoku expressway (in May) and in the Tohoku Shinkansen (in August) were up to 1.0 and 0.25 μSv/h, respectively. However, the dose rates measured in Namie, Fukushima (in August), were still higher and approached a maximum of 4.0 μSv/h. The measurement results agreed well with the official data obtained using a NaI scintillation counter, demonstrating that a calibrated GM-tube detector can be an effective tool for measuring radioactivity.

Key Words: *mobile radiation survey, GM-tube detector, air dose rate, surface contamination*

1. Introduction

As a result of the Great East Japan Earthquake, a large amount of radioactive material was accidentally released from the Fukushima Daiichi Nuclear Power Plant (NPP). Many reports concerning radioactivity[1-3)], including surface contamination, radioactive concentration, and air dose rate, were published by researchers, mass media outlets, and the government. Additional information was obtained and published by some members of the general population who used commercially available detectors, mainly Geiger Mueller tube (GM-tube) detectors, without calibration. However, these detectors often exhibited considerable amount of inter-individual variability, and the measurement results sometimes caused unnecessary confusion.

In this study, a calibrated GM-tube detector was used for measuring radioactivity in East Japan, and the measurement results were compared with official data provided by the Japanese government.

2. Materials and Methods

The GM-tube detector used in this study is the “Radiation Alert Inspector+,” commercially available in Japan and manufactured by SE International, Inc., which is co-owned by International Medcom. The detector was calibrated using a standard Cs-137 radioactive source (#JDSR9518, 1.47×10^{-12} C kg/s at 1 m, 0.225 μSv/h at 1 m), which provided dose rates of 3.6, 0.9, and 0.4 μSv/h at distances of 0.25, 0.50, and 0.75 m from the source, respectively. During the calibration, the detector and the radioactive source were placed on a 1-m-high plastic table.

The calibrated GM-tube detector measured the dose rate (μSv/h) just above the ground surface and at a height of 1 m from the ground surfaces. The locations and dates of the radioactive measurements were as follows: Ueno Park in Tokyo on March 30, 2011; the Tohoku expressway from Tochigi to Miyagi on May 26, 2011; the Tohoku Shinkansen bullet train from Saitama to Koriyama, Fukushima in August 2011; and Namie and its surrounding area in Fukushima in August 2011.

3. Results and Discussion

(1) Calibration

The GM-tube detector measured the radiation fields regulated by the Cs-137 standard radioactive source. Measurements were taken ten times every minute. The background air dose rate measured using a NaI scintillation counter was 0.09 μSv/h; this value was added to the air dose regulated from the standard source. The temporal change in the measurement is presented in Table 1. The measurement values barely approached a certain value correlated with the actual air dose rate, unlike the values obtained using the scintillation counter, and their variation coefficient decreased with the air dose rate. The GM-tube detector used here showed an instrument reading with a maximum error of ±20%.

The GM-tube detector was calibrated with certified values from 0.09 to 3.69 μSv/h to obtain the following calibration equation:

$$Y = (-0.0409)\,X^2 + (0.9238)X + (-0.0264)$$

where Y and X represent the calibrated value and the instrument reading, respectively. Figure 1 clearly shows the calibration equation as a quadratic rather than a linear function. The fact that the function is convex upward suggests that the GM-tube detector would underestimate the radiation fields at higher air dose rate conditions.

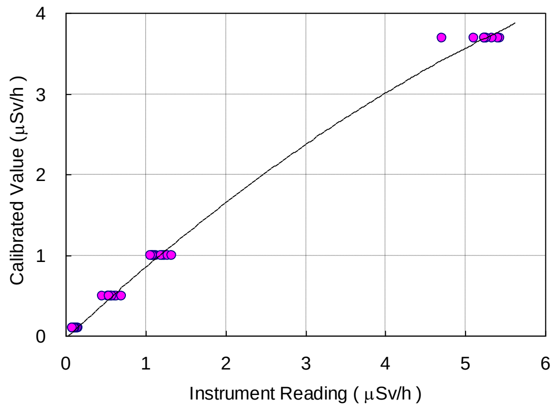

Fig. 1 Calibration of a GM-tube detector

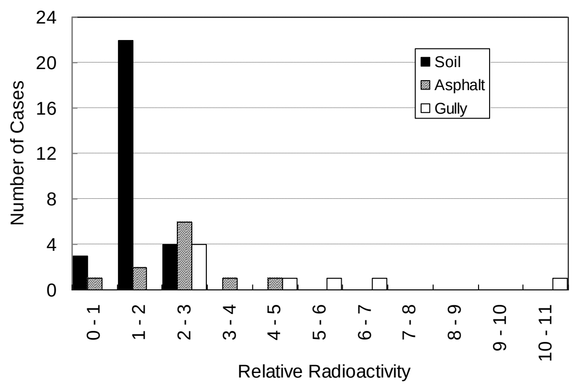

Fig. 2 Number of relative radioactivity (instrument reading indicated in μSv/h) obtained near the ground surface

Table 1 Temporal change in instrument reading.

Certified dose rate (μSv/h)	Instrument reading (μSv/h)										Ave.	SD	VC
	#1	#2	#3	#4	#5	#6	#7	#8	#9	#10			
0.09	0.149	0.161	0.125	0.089	0.143	0.113	0.119	0.119	0.107	0.089	0.121	0.024	0.20
0.49	0.527	0.539	0.569	0.581	0.461	0.611	0.640	0.575	0.706	0.539	0.575	0.067	0.12
0.99	1.132	1.220	1.114	1.246	1.084	1.192	1.090	1.060	1.282	1.330	1.175	0.093	0.08
3.69	5.431	5.250	5.238	5.413	5.335	5.262	5.262	4.708	5.244	5.112	5.226	0.204	0.04

Ave.: Average of Instrument reading, SD: Standard deviation,

VC: Variation coefficient evaluated from standard deviation divided by the average.

(2) Ueno Park

Figure 2 shows the number of the instrument reading (uncalibrated value) obtained near the surface ground in and around Ueno Park, two weeks after the nuclear accident. Some of the values obtained are beyond the calibration value, and hence, the original instrument reading is adopted.

The measurement values and the width of their distribution increased in the following order: park ground, road asphalt, and street gully. The removal of several millimeters of surface park ground provided a decrease in the measured dose rate by a factor of 2 to 4, which showed that radioactive material contaminated only the park ground surface and barely penetrated deeper. The nature of the ground surface affected the measurement values, although all the monitoring locations were very close to each other. Our observation discovered “hot spots” where radioactive material would accumulate with fine soil particle from its original deposit location owing to wind and rain.

In addition to the surface measurement, the air dose rate was measured at the same location. The values of the calibrated dose rates ranged from 0.12 to 0.17 μSv/h at almost all the locations; however, they ranged from 1.81 to 2.03 μSv/h at a subway exhaust port at the Nezu subway station near Ueno Park. This location can also be identified as a “hot spot,” although the radioactive accumulation path was unclear.

(3) Tohoku expressway

The calibrated dose rates obtained inside a car along the Tohoku expressway (Fig. 5) on May 26, 2011, are shown in Fig. 3. A peak dose rate of 0.94 μSv/h was recorded at Nihonmatsu city, which is 55 km from the Fukushima Daiichi NPP and is the nearest point to the plant on the Tohoku expressway.

A similar measurement was carried out using a NaI scintillation counter on May 22, 2011; this was part of the official data published by the Fukushima prefecture government [4]. The results of the long-distance mobile radiation survey, shown in Fig. 3, indicate that both measurements provide comparable results, except for three points in Fukushima and Koriyama city, and they validate the use of calibrated GM-tube counting.

A comparison of dose rate trends north and south of

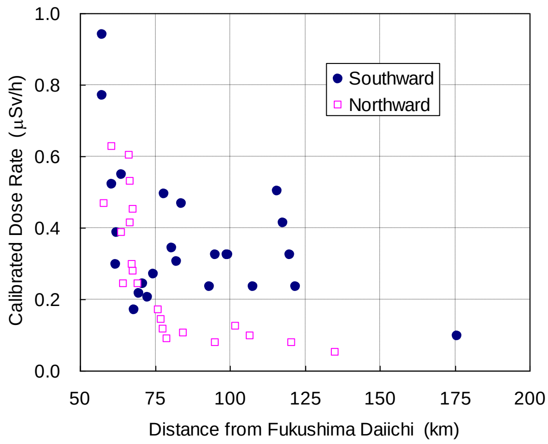

Fig. 4 Measure of contamination based on distance from Fukushima Daiichi NPP.

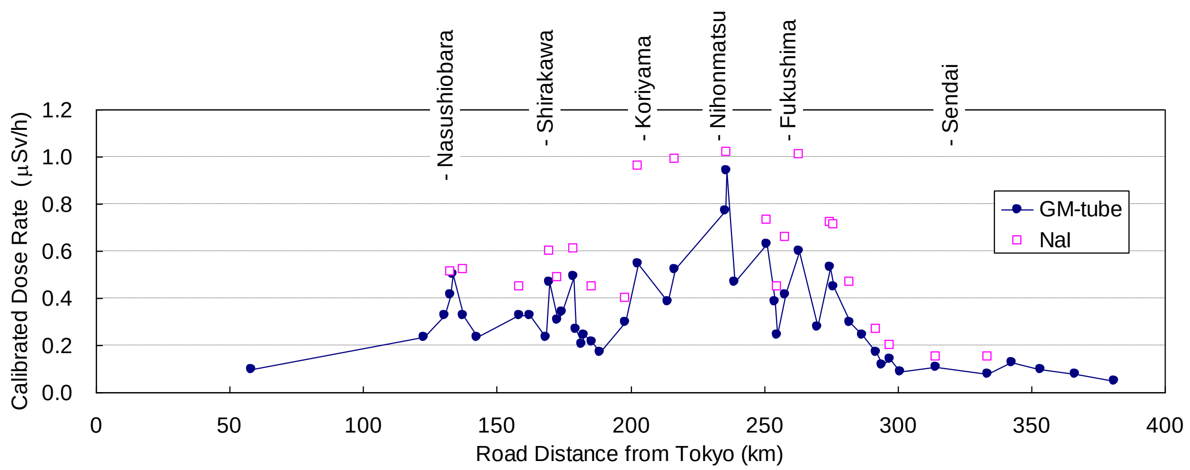

Fig. 3 Dose rate inside a car along the Tohoku expressway. Closed circles and open squares indicate data from the GM-tube measurements and official material, respectively.

Nihonmatsu city, shown in Fig. 4, provided the status of the radioactive contamination spread in the environment. Both trends show a similar decrease up to 75 km. Different trends, however, are shown from 75 to 125 km. The values obtained in the northern location decreased to a certain constant value, defined here as the background value. In contrast, the values obtained in the southern location are two to five times higher than the background value and exhibit some small peaks, which could be considered hot spots. These trends indicate that larger amounts of radioactive material were widespread in the southern location.

(4) Tohoku Shinkansen

The results of measurements carried out in August 2011 aboard the Tohoku Shinkansen (bullet train), which runs almost parallel to the Tohoku expressway, are shown in Fig. 5. The dose rates in the Shinkansen were lower than those obtained along the expressway in May 2011. However, in a trend that is similar to the results obtained along the expressway, the dose rates recorded at Shirakawa (0.16 μSv/h) and Nasushiobara (0.20 μSv/h) were higher than those from their surroundings. Therefore, the distribution trend of radioactive contamination was found to remain consistent.

Fig. 5 Dose rate in the Tohoku Shinkansen and in Namie, measured with a GM-tube. Yellow thick line indicates the pathway of the Tohoku expressway.

(5) Namie

The results obtained in August 2011 in and around Namie, which is located about 30 km northwest of the Fukushima Daiichi NPP, are shown in Fig. 5. The calibrated dose rates measured inside a car were quite higher than those measured in the Shinkansen and along the expressway. The locations exhibiting a high dose rate are within a highly contaminated area reported by the Ministry of Education, Culture, Sports, Science & Technology (MEXT) in Japan [5]. A measurement of surface ground, conducted at two points, provided values of 54 and 175 μSv/h (uncalibrated), which are 10 to 100 times higher than the results obtained at Ueno Park on March 30, 2011. In other words, serious contamination was observed.

4. Conclusion

A GM-tube detector was calibrated with a standard Cs-137 source and used for measuring radioactive contamination from the Fukushima Daiichi Nuclear Power Plant. The GM-tube detector used in this study was calibrated up to 4 μSv/h based on a quadratic equation. This GM-tube detector yielded the same result as a NaI scintillation counter, and its practical use was validated under calibration.

Acknowledgments

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