

Survey of Environmental Radiation Dose Rates in Kyoto and Shiga Prefectures, Japan

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Abstract. We have measured environmental radiation dose rates in several Prefectures, such as Aichi Prefecture, Gifu Prefecture, and Mie Prefecture, in central Japan. Recently, we measured the environmental radiation dose rates in Kyoto and Shiga Prefectures that are also located in central Japan with a car-borne survey system. At the time of measurement, Kyoto Prefecture (area: 4,613 km²) had a total of 36 districts, and Shiga Prefecture (area: 3,387 km²) a total of 26. Terrestrial gamma ray dose rates and secondary cosmic ray dose rates were measured by a 2" × 2" NaI(Tl) scintillation counter and a handy-type altimeter (GPS eTrex Legend by GARMIN), respectively. The following factors were taken into consideration the shielding effect of the car body, the effect of the road pavement, radon progeny borne by precipitation, and increases in tunnels and near the walls. Terrestrial gamma ray dose rates in Kyoto and Shiga Prefectures were estimated to be 51.7 ± 6.0 nGy/h (district average: 52.4 ± 4.7 nGy/h), 52.2 ± 10.5 nGy/h (district average: 51.9 ± 8.1 nGy/h), respectively. Secondary cosmic ray dose rates in Kyoto and Shiga Prefectures were 30.0 ± 0.6 nGy/h (district average: 29.9 ± 0.3 nGy/h), 30.1 ± 0.3 nGy/h (district average: 30.0 ± 0.2 nGy/h), respectively. The environmental radiation dose rates due to the sum dose rates of terrestrial gamma ray and secondary cosmic ray in Kyoto and Shiga Prefectures were 81.7 ± 6.2 nGy/h (district average: 82.3 ± 4.8 nGy/h), 82.3 ± 10.6 nGy/h (district average: 82.0 ± 8.1 nGy/h), respectively. We confirmed that the environmental radiation dose rates in Kyoto and Shiga Prefectures mainly depended on the change of the terrestrial gamma ray dose rates, since the secondary cosmic ray dose rates had little change. Therefore, radiation dose-rate maps of the terrestrial gamma rays as well as maps of the environmental radiation dose-rate were drawn.

KEYWORDS: *environmental radiation, terrestrial gamma ray, secondary cosmic ray, dose rate, car-borne survey*

1. Introduction

To date, we have measured environmental radiation with a car-borne survey system in Japanese prefectures including Aichi, Gifu, Mie, Gunma, Nagano, Toyama, Wakayama, and Tokushima [1-3]. The car-borne survey method is an effective measuring procedure that involves mounting a measuring device on a car and taking measurements while driving, permitting measurement over a wide area in a short period of time. The objective of our study is to measure environmental radiation at the municipal level in prefectures throughout Japan, to accumulate useful data from the standpoints of both health physics and geoinformatics. In this study, we measured environmental radiation in Kyoto and Shiga prefectures, and investigated the adequacy of the data by means of a geological comparison.

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2. Materials and Methods

2.1 Objects

Figure 1 shows the locations within Japan of Kyoto and Shiga prefectures. These two adjoining prefectures are located almost at the center of the Japanese archipelago. Kyoto Prefecture houses numerous World Heritage Sites, while Shiga Prefecture is famous for the home of Lake Biwa, the largest lake in Japan.

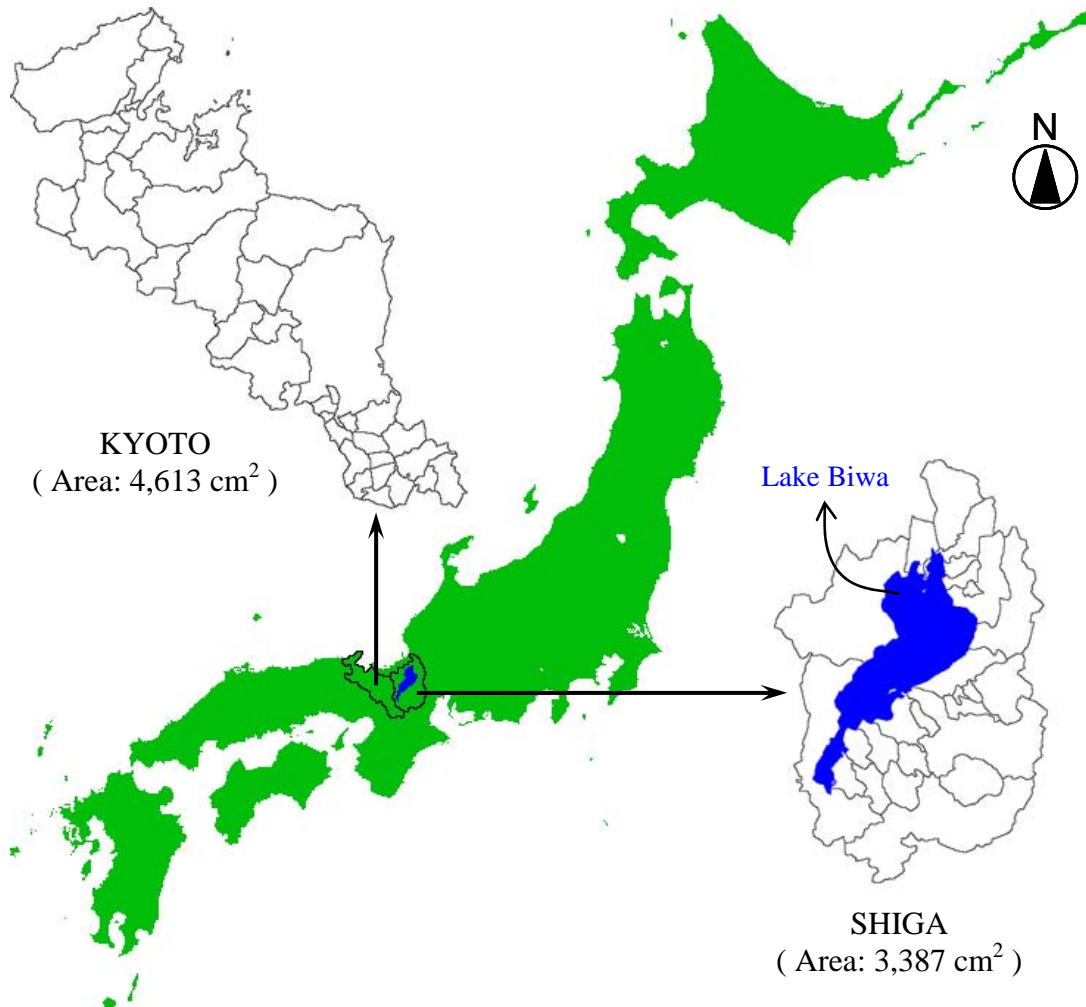


Figure 1: Location of Kyoto and Shiga prefectures in Japan

We carried out measurements in Kyoto and Shiga prefectures in August 6–9, 2005, and August 9–11, 2007, respectively. At the time of measurement, Kyoto Prefecture contained a total of 36 districts, and Shiga Prefecture a total of 26.

2.2 Methods

The method of measurement used was a car-borne survey along the driving route shown in Fig. 2, in which measurements were made in a continuous two-minute cycle consisting of measurements of one minute's duration taken at intervals of one minute. Terrestrial gamma ray dose rates and levels were measured by a 2" × 2" NaI(Tl) scintillation counter and an eTrex Legend global positioning system (GPS) (Garmin, USA), respectively. Terrestrial gamma ray dose rate measurements were corrected for the shielding effect of the vehicle body, the paving effect of the road, and the influence of cliffs and tunnels at the time of measurement. The shielding effect of the vehicle body was corrected by

measuring terrestrial gamma ray dose rates both inside and outside the car at 21 points along the driving route in Kyoto Prefecture and 14 points in Shiga Prefecture, and using the average of these values as a conversion coefficient to obtain values outside the car. The paving effect of the road was corrected by measuring terrestrial gamma ray dose rates both on the surface of the paved road and on nearby bare ground at 21 points along the driving route in Kyoto Prefecture and 14 points in Shiga Prefecture. The influence of gamma radiation from cliffs or tunnels at the time of measurement was corrected by linearly interpolating between the values taken at the nearest points outside the region occupied by the cliff or tunnel. Levels were converted from the secondary cosmic ray dose rate, using Minato's report as a reference [4]. The environmental radiation dose rate was calculated as the sum of the corrected terrestrial gamma ray dose rate and the secondary cosmic ray dose rate.

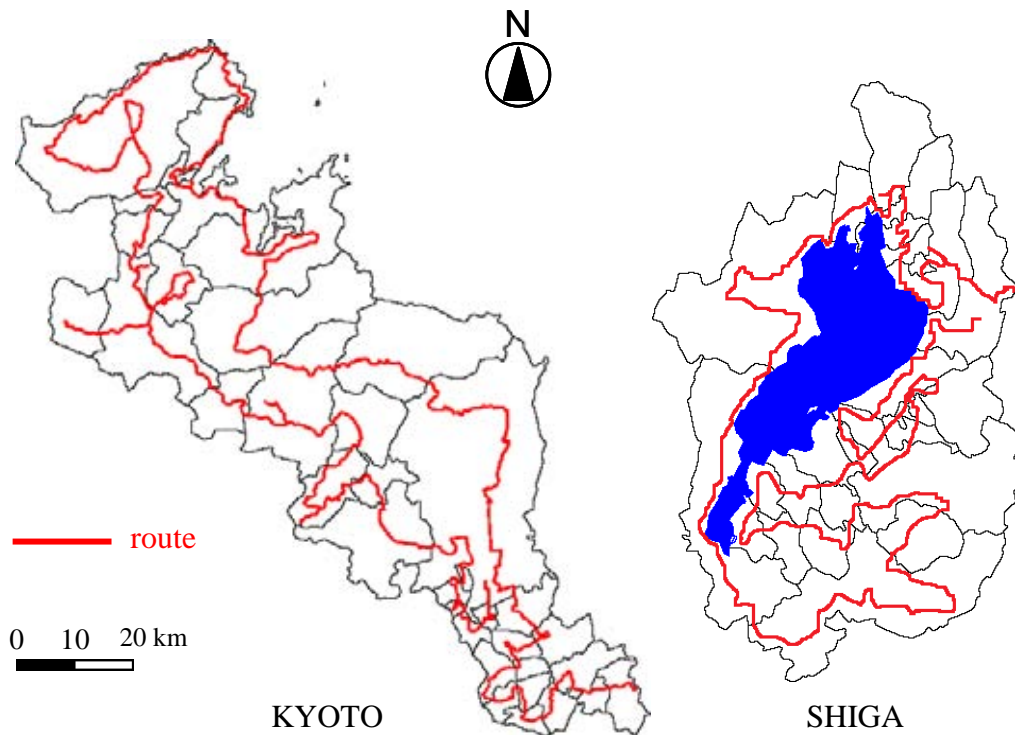


Figure 2: Measurement route for the car-borne survey

3. Results

3.1 Kyoto Prefecture

A regression formula of $y = 1.6x$ was used to convert the values inside the car (x) into the outside values (y). Terrestrial gamma ray dose rates were converted from paved roads (x) to bare ground (y) by using the formula $y = x + 7.1$. Terrestrial gamma ray dose rates in Kyoto Prefecture ranged from 32.2 to 65.5 nGy/h, with an average value of 51.7 ± 6.0 nGy/h (district average: 51.9 ± 8.1 nGy/h). Secondary cosmic ray dose rates in Kyoto Prefecture ranged from 29.4 to 33.7 nGy/h, with an average value of 30.0 ± 0.6 nGy/h (district average: 29.9 ± 0.3 nGy/h). As shown in Fig. 3, environmental radiation dose rates in Kyoto Prefecture ranged from 61.8 to 96.2 nGy/h, with an average value of 81.7 ± 6.2 nGy/h (district average: 82.3 ± 4.8 nGy/h).

3.2 Shiga Prefecture

A formula of $y = 1.7x$ was used to the values inside the car (x) into the outside values (y). The conversion coefficient for converting terrestrial gamma ray dose rates from paved road to bare ground was 1.07. The terrestrial gamma ray dose rate in Shiga Prefecture ranged from 22.3 to 82.6 nGy/h,

with an average value of 52.2 ± 10.5 nGy/h (district average: 51.9 ± 8.1 nGy/h). Secondary cosmic ray dose rates in Shiga Prefecture ranged from 29.4 to 31.3 nGy/h, with an average value of 30.1 ± 0.3 nGy/h (district average: 30.0 ± 0.2 nGy/h). As shown in Fig. 3, environmental radiation dose rates in Shiga Prefecture ranged from 52.2 to 112.6 nGy/h, with an average value of 82.3 ± 10.6 nGy/h (district average: 82.0 ± 8.1 nGy/h).

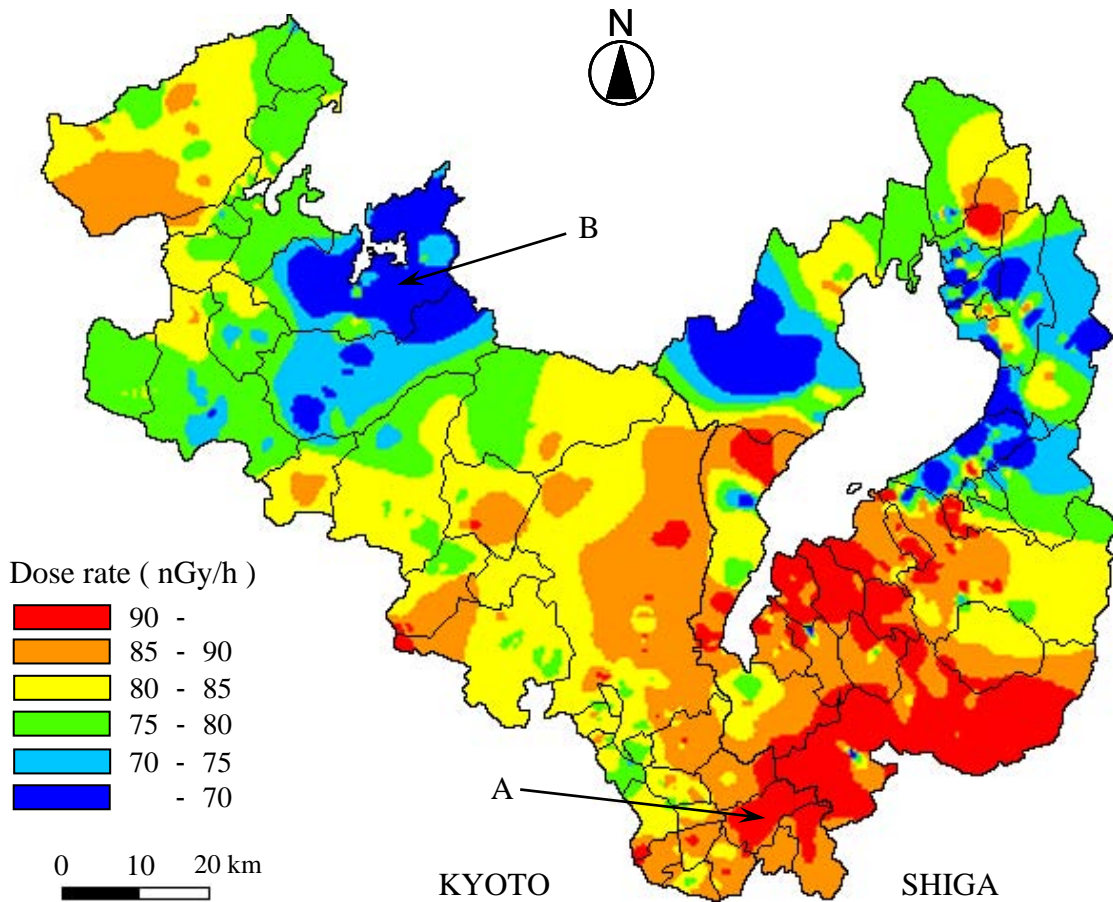


Figure 3: Environmental radiation dose rates in Kyoto and Shiga prefectures

4. Discussion

Secondary cosmic ray dose rates in Kyoto and Shiga prefectures were about 30 nGy/h, and showed little variation in both prefectures. For this reason, environmental radiation dose rates in Kyoto and Shiga prefectures may be regarded as dependent on changes in terrestrial gamma ray dose rates.

4.1 Terrestrial gamma ray dose rates in Kyoto Prefecture

The geology around point A, where we measured the highest terrestrial gamma ray dose rate in Kyoto Prefecture, consists mainly of granite, an acidic rock, which may be regarded as the reason for the high dose rate value. The geology around point B, where we measured the lowest terrestrial gamma ray dose rate, is mainly composed of basic and ultrabasic rock, which may be regarded as the reason for the low value. Most of the geology of Kyoto Prefecture consists of sedimentary rock, and the overall high value of the terrestrial gamma ray dose rate is regarded as due to the influence of clastic rock [5–7].

4.2 Terrestrial gamma ray dose rates in Shiga Prefecture

The terrestrial gamma ray dose rate in Shiga Prefecture tended to be higher in the southern part than in the north. The higher dose rate in the south is regarded as being due to the fact that granite and rhyolite, which generally tend to have high dose rates, are more widely distributed in the geology of the southern part of the prefecture in comparison with the north. The lower dose rate in the north is regarded as being due to the fact that sedimentary rocks from the Paleozoic and Mesozoic eras, which in general tend to have lower dose rates than the acidic rocks, are widely distributed in the northern part in comparison with the south [5–7].

5. Conclusion

Environmental radiation dose rates in Kyoto and Shiga prefectures averaged 81.7 ± 6.2 nGy/h (district average: 82.3 ± 4.8 nGy/h) and 82.3 ± 10.6 nGy/h (district average: 82.0 ± 8.1 nGy/h) respectively. Changes in environmental radiation dose rates in both prefectures were dependent on terrestrial gamma ray dose rates and were highly consistent with geological distribution.

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