Detailed measurement of indoor $\gamma$ ray dose rate distribution and directional radiation in detached house in Fukushima

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Introduction

• Artificial radionuclides widely dispersed into the environment from the Fukushima nuclear power plant hit by the 2011 Great East Japan Earthquake tsunami.

• The outdoor gamma ray air dose rate right after the disaster was significantly high within the affected area of Fukushima.

• Decontamination work has considerably reduced gamma ray air dose rate, gradually lifting the government’s evacuation orders and allowing residents to return home.

• Housing reconstruction is underway, but the radiation dose rate of some sites is still over 0.23 µSv/h, the Japanese government's decontamination target value.
• To keep occupants‘ dose rate at a lower level, it is important to clarify the mechanism of formation of gamma ray distribution inside the wooden building.

• The measurement results of gamma ray dose rate distribution inside and outside wooden buildings in Fukushima are reported in this research.

• Radiation incidence passing through the outer wall is also reported.
Monitoring air dose rates from aircraft surveys

May 2011: 2nd month after the accident

September 2017: 6th year after the accident

Air dose rates at 1m from ground (µSv/h)

Nuclear Regulation Authority, Japan
http://radioactivity.nsr.go.jp/ja/list/191/list-1.html
Research purpose:

To clarify the relationship between the direction of radiation entering the building and the $\gamma$ ray field formed in the room. This relationship has not so far been measured.

Research process:

1. Development of a directional radiation dose rate measurement method, and verification of accuracy.

Principle of directional radiation dose rate measurement

Directional measurement is realized by subtracting the shielding measurement result from the ordinal measurement result.
A conventional measurement method uses a cylindrical lead collimator. This requires a long collimator for a small viewing angle, and the mass becomes very large. Impractical for field measurement.

50 mm thick lead is required to shield 662 keV gamma ray of 137 Cs. The weight of the collimator can be more than 40 kg.
Design of shielding instrument for suitable viewing angle

The viewing angle of the measuring instrument is determined by the diameter of the shielding plate and the distance between the plate and the scintillator. Analysis was made with radiation analysis code PHITS* to determine the diameter and the distance so that the viewing angle is approximately +/- 15°.

\[
\text{Relative Response } R(\theta) \text{ (sensitivity)} = \frac{\text{Directional value}(\theta)[Sv/h]}{\text{Scalar value}[Sv/h]}
\]

*PHITS: Particle and Heavy Ion Transport Code System, JAEA
Outline of the wooden buildings to be measured

Wooden flat buildings A and B located in the evacuation order lifted area in Tomioka, Fukushima

Building A: The groove beside the building was not decontaminated enough.

Building B: The neighboring forest was not decontaminated enough.

Total measurement points:
- **Scalar:** 111, **Directional:** 7(x12) for Building A.
- **Scalar:** 85, **Directional:** 5(x12) for Building B.
Outline of the wooden buildings to be measured

Directional radiation measurement

Total of 12 directions were measured for each position.
Measurement of height direction air dose rate using survey meter
Result of Building A

East

Asphalt Pavement
Decontamination is not sufficient

Building A

Groove not decontaminated

West

Gamma ray air dose rate on section
(Normal scalar value)

Directional radiation dose within viewing angle ± 15 degrees

East

2m
1m
0m
0m 5m 10m 15m 20m 25m 30m

West

Asphalt Pavement
Decontamination is not sufficient

Building A

Groove not decontaminated

0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1 µSv/h

0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1 µSv/h

East 0m 5m 10m 15m 20m 25m 30m

West

Asphalt Pavement
Decontamination is not sufficient

Building A

Groove not decontaminated

0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1 µSv/h
Result of Building B

Gamma ray air dose rate on section (Normal scalar value)

Directional radiation dose within viewing angle ± 15 degrees
For the building A, the convex distribution of the indoor radiation dose rate is considered to be the influence of gamma ray sources near the building.

For the building B, the horizontal layered distribution of indoor radiation dose rate is considered to be the influence of the neighboring strong gamma ray source.
In case of low-rise residential building, it is thought that it is possible to design a garden with radiation shielding effect based on investigation of radiation dose rate and directional radiation as well as renovation of the building.
Conclusion

• Detailed measurement of indoor/outdoor gamma ray dose rate and directional gamma ray dose rate of wooden buildings in Fukushima was conducted.

• This measurement made it possible to consider the mechanism of forming the gamma ray distribution inside the wooden building.

• The research results also suggest the possibility of various countermeasures to reduce indoor gamma ray.