Internal dosimetry for continuous chronic intake of caesium-137 in cedar pollen after the Fukushima Daiichi nuclear power plant accident

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Internal exposures of members of the public were assessed for chronic intake of caesium-137 in cedar pollen after the Fukushima Daiichi nuclear power plant accident. Committed effective doses were evaluated using the DSYS-chronic code, which was developed at the Japan Atomic Energy Agency (JAEA). The Activity Median Aerodynamic Diameter (AMAD) and particle density for cedar pollen were assumed to be 32 μm and 0.7 $g \cdot cm^{-3}$, respectively. The observation period was from early February to the end of May, 2012. It was found that the committed effective doses for adults in Fukushima, Ibaraki, and Tokyo were 1.6-1.8×10^{-3} μSv, 4.5×10^{-4}μSv, and 3.0×10^{-4}μSv, respectively. Hence, it can be stated that internal doses from chronic intake of caesium-137 in cedar pollen were insignificant in 2012. In addition, retention and excretion functions for caesium-137 in the whole body were found to be dependent on the times of intake and the fractional activity related to chronic intake.

Key Words : *chronic, internal dose, Cs, cedar pollen, DSYS-chronic*

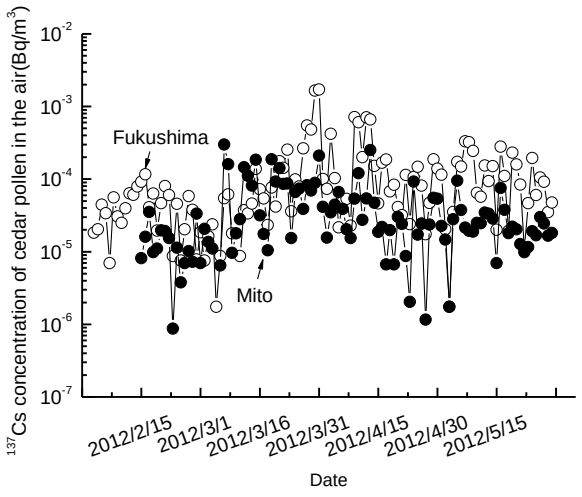
1. Introduction

The Fukushima Daiichi nuclear power plant accident that occurred in March of 2011 resulted in widespread caesium contamination in the eastern region of Japan. It is predicted that caesium deposited in cedar forests would be released as cedar pollen after caesium uptake by cedar trees. Caesium in cedar pollen would be one of sources of chronic exposure. Internal exposure from the chronic intake of caesium in cedar pollen is of considerable concern from the standpoint of public exposure. However, very little work is currently available in the published literatures on the chronic intake of caesium-137 in cedar pollen. In the present study, internal dose assessments for the chronic intake of caesium-137 in cedar pollen were carried out for members of the public —adult residents in Fukushima, Ibaraki, and Tokyo— on the basis of data on cedar pollen from a pollen observation system in the Ministry of the Environment (MOE) of Japan[1)]. Committed effective and equivalent doses, and retention and excretion functions for caesium-137 in the whole body were evaluated using the DSYS-chronic code, which was developed at the Japan Atomic Energy Agency (JAEA) [2)].

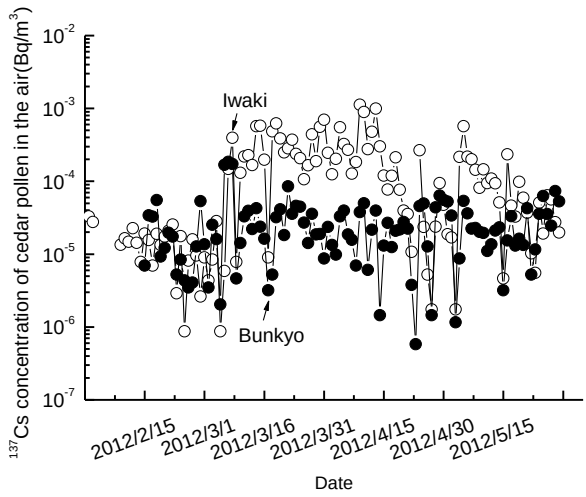
2. Materials and Methods

(1) DSYS-chronic code

The DSYS-chronic code was used to evaluate internal



(a) Fukusima (Fukushima) and Mito (Ibaraki)



(b) Iwaki (Fukushima) and Bunkyo (Tokyo)

Fig. 1 Caesium-137 concentration of cedar pollen in the air in Fukushima, Ibaraki, and Tokyo.

doses to members of the public for the chronic intake of caesium-137 in cedar pollen. The DSYS-chronic code can treat internal dosimetry for chronic intake using the International Commission on Radiological Protection's (ICRP's) respiratory tract[3], gastrointestinal tract[4], and biokinetic and bioassay models for ICRP Publication 71[5]. It enables the users to specify their own parameter values to their customized internal dose evaluations. Retention and excretion functions for caesium-137 in the whole body can be evaluated using the DSYS-chronic code.

(2) Cedar pollen

Caesium-137 concentration of cedar pollen in the air in Fukushima, Ibaraki, and Tokyo was calculated conservatively on the basis of data on cedar pollen from a pollen observation system in the Ministry of the Environment (MOE) of Japan. It was assumed that the concentration of caesium-137 in cedar pollen was 14.5×10^{1} Bq·g^{-1} (the weight of a particle of cedar pollen was 12×10^{-9} g) in accordance with a report from the forestry agency of Japan[6]. In the present study, the observation period was from early February to the end of May, 2012.

(3) Internal dose assessments

Internal doses to adult residents in Fukushima, Ibaraki, and Tokyo for the chronic intake of caesium-137 in cedar pollen were evaluated. In addition, retention and excretion functions for caesium-137 in the whole body were evaluated to refine dose assessments. The periods of intake by inhalation of caesium-137 in cedar pollen were determined to be the periods of cedar pollen observations in each area. The breathing rate of the adult was assumed to be 22.2m^3·d^{-1} to estimate caesium-137 intake[5]. According to the report from the forestry agency of Japan, the Activity Median Aerodynamic Diameter (AMAD) and particle density for cedar pollen were to be 32 μm and 0.7 g·cm^{-3}, respectively[6]. They were considerably different from the ICRP defaults —1 or 5 μm AMAD and 3 g·cm^{-3} particle density. The processes of cedar pollen deposition, transport, absorption, and formation of a fixed deposit in the respiratory tract were formulated in the ICRP's respiratory tract model[3].

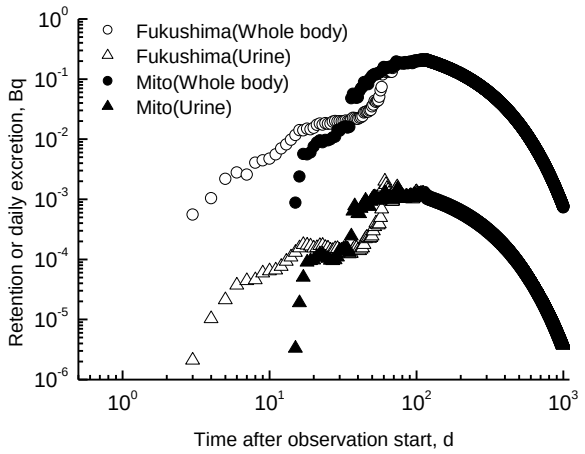
3. Results and Discussion

(1) Caesium-137 concentration of cedar pollen in the air

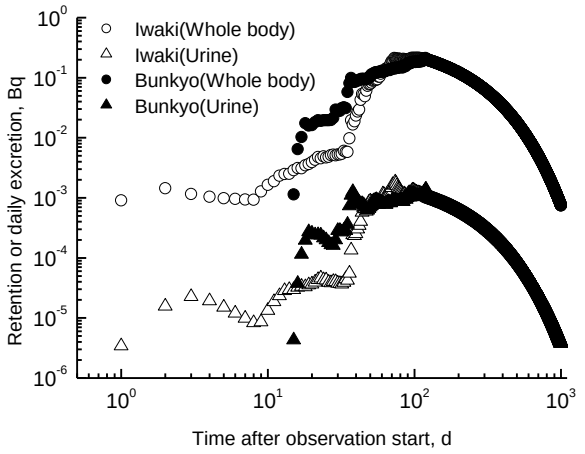
Figures 1 (a) and (b) show the caesium-137 concentration of cedar pollen in the air at Fukushima and Iwaki (Fukushima), Mito (Ibaraki), and Bunkyo (Tokyo). There are fluctuations that occur during each day. From the figure, it can be stated that the caesium-137 concentration by region decreases in the order of Fukushima, Ibaraki, and Tokyo.

(2) Internal doses

Table 1 lists the committed effective doses to adult residents at Fukushima and Iwaki (Fukushima), Mito (Ibaraki), and Bunkyo (Tokyo) for chronic intake of



(a) Fukusima (Fukushima) and Mito (Ibaraki)



(b) Iwaki (Fukushima) and Bunkyo (Tokyo)

Fig. 2 Caesium-137 inhalation: predicted values (Bq per Bq intake) following chronic intake in Fukushima, Ibaraki, and Tokyo.

caesium-137 in cedar pollen. The larger the distance from the Fukushima Daiichi nuclear power plant, the lower are the doses. It was found that committed effective doses from chronic intake of caesium-137 in cedar pollen were small and insignificant in 2012. Table 2 lists the committed equivalent doses to adult residents at Iwaki (Fukushima) for chronic intake of caesium-137 in cedar pollen. There is no great difference among the committed equivalent doses since the systemic caesium in the biokinetic model is taken to be distributed uniformly throughout all body tissues.

Retention and excretion functions for the chronic intake of caesium-137 are shown in Fig. 2. Data are given for time periods up to 10^3 days from the observation start date, which was in early February. Whole-body activity increases until the intake is stopped, after which it decreases. The retention and excretion functions for caesium-137 in the whole body were found to be dependent on the times of intake and the fractional activity related to the chronic intake. Retention and excretion functions for continuous chronic intake, which are evaluated using the DSYS-chronic code, may be useful since they may provide reassurance that intake is indeed low.

4. Conclusions

Committed effective and equivalent doses to adult residents in Fukushima, Ibaraki, and Tokyo for the chronic intake of caesium-137 in cedar pollen were evaluated using the DSYS-chronic code. Retention and excretion functions were also evaluated to refine the dose

Table 1 Committed effective doses to adult for chronic intake of caesium-137 in cedar pollen

City	Commited effective dose (μSv)
Fukushima	1.6×10^{-3}
Iwaki	1.8×10^{-3}
Mito	4.5×10^{-4}
Bunkyo	3.0×10^{-4}

Table 2 Committed equivalent doses to adult at Iwaki for chronic intake of caesium-137 in cedar pollen

Organ	Commited equivalent dose (μSv)
Adrenals	1.8×10^{-3}
Brain	1.5×10^{-3}
Breasts	1.4×10^{-3}
Colon	1.9×10^{-3}
ET region	3.9×10^{-3}
Kidneys	1.7×10^{-3}
Liver	1.7×10^{-3}
Lungs	1.6×10^{-3}
Muscle	1.6×10^{-3}
LLI_wall	2.1×10^{-3}
Oesophagus	1.7×10^{-3}
Ovaries	1.8×10^{-3}
Pancreas	1.8×10^{-3}
Small intestine wall	1.8×10^{-3}
Stomach wall	1.7×10^{-3}
Spleen	1.7×10^{-3}
Testes	1.6×10^{-3}
Thymus	1.7×10^{-3}
Thyroid	1.7×10^{-3}
ULI_wall	1.8×10^{-3}
Uterus	1.8×10^{-3}
Urinary bladder wall	1.8×10^{-3}
Skeleton	1.8×10^{-3}
Red bone marrow	1.7×10^{-3}

assessments. It was found that committed effective and equivalent doses from chronic intake of caesium-137 in cedar pollen were insignificant in 2012. In addition, retention and excretion functions for caesium-137 in the whole body were found to be dependent on the times of intake and the fractional activity related to the chronic intake.

References

1) The Ministry of the Environment of Japan, *Pollen observation system*, Online. Available: http://kafun.taiki.go.jp/index.aspx (2012, May 30).
2) Kimura, M., Kinase, S. and Hato, S., *Development of internal dosimetry evaluation code for chronic exposure*, JAEA-Data /Code, JAEA (in press).
3) ICRP, *Human respiratory tract model for radiological protection*, ICRP Publication 66, Ann. ICRP 24 (1-3), 1994.
4) ICRP, *Limits on intakes of radionuclides for workers*, ICRP Publication 30, Ann. ICRP 2 (3/4), 1979.
5) ICRP, *Age-dependent doses to members of the public from intake of radionuclides. Part 4. Inhalation dose coefficients*, ICRP Publication 71, Ann. ICRP 25 (3/4), 1995.
6) Forestry agency of Japan, *Investigation on the concentrations of radioactive cesium in male flowers of Sugi (an interim report)*, Online. Available: http://www.rinya.maff.go.jp/j/press/hozen/111227.html (2011, December 27).

Appendix

To validate internal dose assessments using the DSYS-chronic code, retention and excretion functions for acute intake of caesium-137 by inhalation (5 μm AMAD) were evaluated using the DSYS-chronic code and were compared with published data. Figure A1 shows the results in comparison with data from ICRP Publ.78[A1)] and MONDAL[A2)]. These results are in good agreement with the published data. Hence, the DSYS-chronic code would be useful for internal dosimetry.

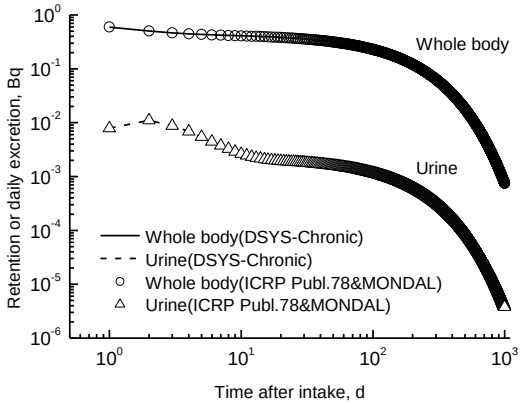


Fig. A1. Comparison of the retention and excretion functions for acute intake of caesium-137 by inhalation (5 μm AMAD).

References

A1) ICRP, *Individual monitoring for internal exposure of workers. Replacement of ICRP Publication 54*, ICRP Publication 78, Ann. ICRP 27 (3/4), 1997.
A2) Ishigure, N., Matsumoto, M., Nakano, T. and Enomoto, H., *Support system for internal dosimetry*, NIRS-M-142, NIRS, 2001.