28th International Conference on Nuclear Engineering
(ICONE28), 4-6 August, 2021, Virtual Conference

Paper No. ICONE28-65725

Estimation of the Amount of I-129 in the Environment Generated due to the Decay of Te-129m Discharged by the Fukushima NPS Accident

Haruo SATO [1]

1 Graduate School of Natural Science & Technology, Okayama University

Okayama City, Okayama 700-8530, JAPAN

Email : sato.haruo@cc.okayama-u.ac.jp

Outline

- Introduction
- Analysis of the Amount of I-129 Generated by the Decay of Te-129m
  - Generation of I-129 from Te-129m by 2 decay processes
  - Equations of radioactive decay
  - Analytical solution for radioactivity of each radionuclide
  - Analytical condition
- Results and Discussion
  - Time variation of the amount of each radionuclide (Te-129m, Te-129, I-129)
  - Comparison with the amount of I-129 in the environment
- Conclusion

Introduction

- The accident at the TEPCO Fukushima Daiichi NPS (1F-NPS) occurred following the Great East Japan Earthquake in March 2011, and led to the release of volatile radionuclides such as I-131, Cs-134, Cs-137, Te-129m and Ag-110m, which were deposited on the environment in the Fukushima and the neighbouring prefectures.
- Te-129m (half-life 33.6d) is one of the radionuclides discharged from 1F-NPS, and it is worried that long-lived I-129 (half-life 1.57×10^7y) is generated and accumulated in the environment by the decay of Te-129m, because iodine tends to collect in the thyroid grand.
- In this study, we estimated the amount of I-129 in the environment generated due to the decay of Te-129m discharged by the 1F-NPS accident, based on the analysed data of Te-129m in soil and compared to the radioactivity concentrations of I-129 in the environment.

Generation of I-129 from Te-129m by 2 Decay Processes

Te-129m decays to I-129 by 2 decay processes

$$^{129m}\mathrm{Te}\ (64\%) \xrightarrow{\mathrm{IT},\ 33.6\mathrm{d}} {}^{129}\mathrm{Te} \xrightarrow{\beta^-,\ 69.6\mathrm{m}} {}^{129}\mathrm{I} \xrightarrow{\beta^-,\ 1.57\times10^7\mathrm{y}} {}^{129}\mathrm{Xe} \qquad (1)$$

$$^{129m}\mathrm{Te}\ (36\%) \xrightarrow{\mathrm{IT},\ 33.6\mathrm{d}} {}^{129}\mathrm{I} \xrightarrow{\beta^-,\ 1.57\times10^7\mathrm{y}} {}^{129}\mathrm{Xe} \qquad (2)$$

Number of nuclei

$$\mathrm{X}_1 \xrightarrow{\lambda_1} \mathrm{X}_2 \xrightarrow{\lambda_2} \mathrm{X}_3 \xrightarrow{\lambda_3} \qquad (3)$$

$$\mathrm{X}_1 \xrightarrow{\lambda_1} \mathrm{X'}_3 \xrightarrow{\lambda_3} \qquad (4)$$

X_1, X_2, X_3 in Eq. (3) : numbers of nuclei of ^{129m}Te, ^{129}Te and ^{129}I in decay process (1), respectively

X_1, X'_3 in Eq. (4) : numbers of nuclei of ^{129m}Te and ^{129}I in decay process (2), respectively

Equations of Radioactive Decay

$$\frac{dX_1}{dt} = -\lambda_1 X_1 \qquad (5)$$

$$\frac{dX_2}{dt} = -\lambda_2 X_2 + \lambda_1 X_1 \qquad (6)$$

$$\frac{dX_3}{dt} = -\lambda_3 X_3 + \lambda_2 X_2 \qquad (7)$$

$$\frac{dX'_3}{dt} = -\lambda_3 X'_3 + \lambda_1 X_1 \qquad (8)$$

λ_1, λ_2, λ_3 : decay constants of ^{129m}Te, ^{129}Te and ^{129}I, respectively

Analytical Solution

Radioactivity (concentration) of each radionuclide

$$A_1 = \lambda_1 X_0 e^{-\lambda_1 t} \quad (9)$$

$$A_2 = \frac{a X_0 \lambda_1 \lambda_2}{\lambda_2 - \lambda_1}\left(e^{-\lambda_1 t} - e^{-\lambda_2 t}\right) \quad (10)$$

$$A_3 = a X_0 \lambda_1 \lambda_2 \lambda_3 \left\{\frac{e^{-\lambda_1 t}}{(\lambda_2 - \lambda_1)(\lambda_3 - \lambda_1)} + \frac{e^{-\lambda_2 t}}{(\lambda_1 - \lambda_2)(\lambda_3 - \lambda_2)}\right.$$

$$A'_3 = \frac{b X_0 \lambda_1 \lambda_3}{\lambda_3 - \lambda_1}\left(e^{-\lambda_1 t} - e^{-\lambda_3 t}\right) \quad (12)$$

A_1, A_2, A_3 : radioactivities of ^{129m}Te, ^{129}Te & ^{129}I in decay process (1), respectively

A'_3 : radioactivity of ^{129}I in decay process (2)

X_0 : initial number of nuclei of ^{129m}Te

a & b : proportion of decay to decay series (1) & (2), respectively (a=64% & b=36%)

Analytical Condition

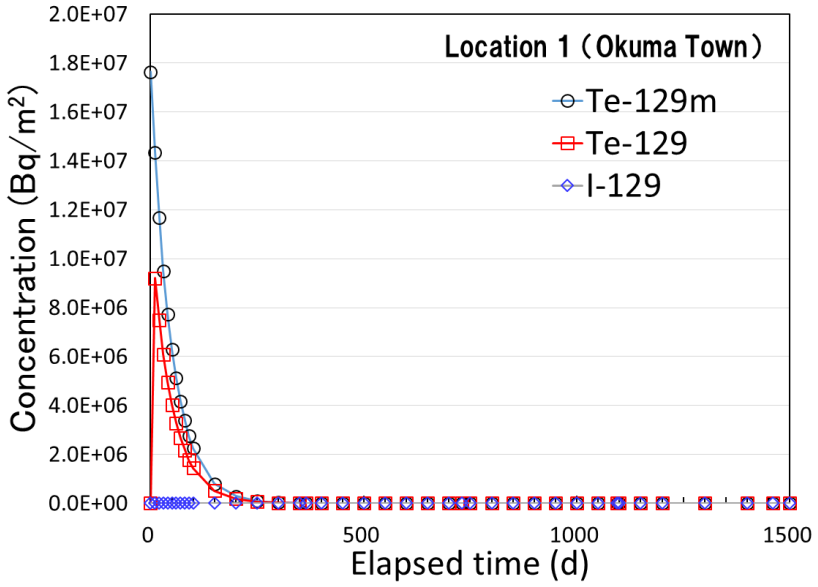
Input data of Te-129m at 3 investigation locations selected for analysis

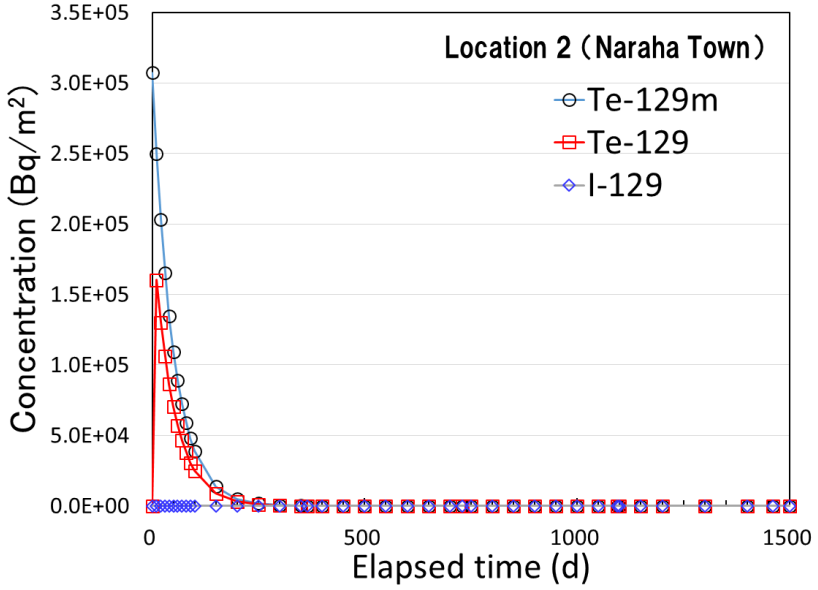
Location	WGS84 coordinate system	Deposition amount (as of 14 June 2011) (Bq/m^2)	Deposition amount (converted to as of 15 Mar. 2011) (Bq/m^2)	Remarks
Okuma Town	N37, 25, 30.9 E140, 00, 18.7	2.70×10^6	1.76×10^7	ca. 2.7km from 1F-NPS
Naraha Town	N37, 15, 29.4 E140, 58, 09.0	4.70×10^4	3.07×10^5	ca. 19km from 1F-NPS
Fukushima City	N37, 46, 21.0 E140, 30, 54.0	6.40×10^4	4.18×10^5	ca. 60km from 1F-NPS

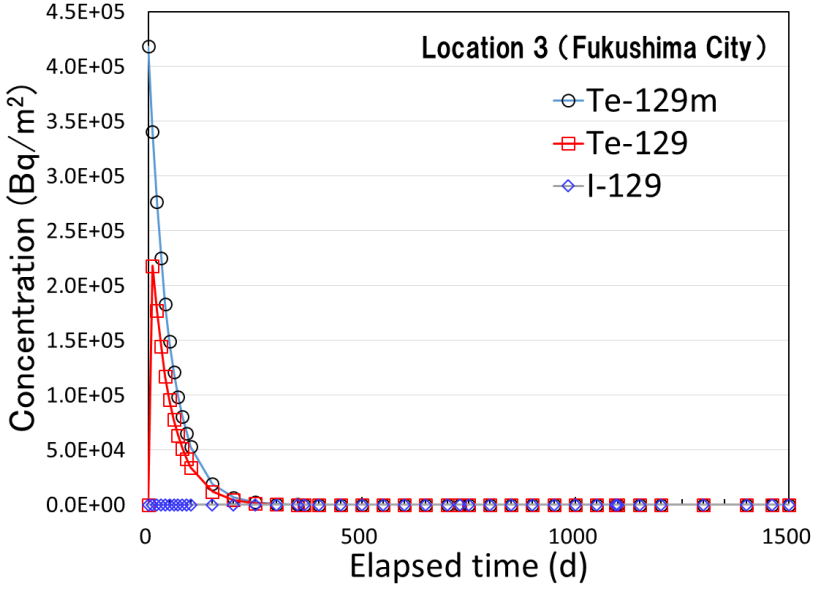
- Selected 3 locations (Okuma Town, Naraha Town, Fukushima City) as high, moderate and low contaminated areas among the analysed data of Te-129m in soil samples obtained at about 2,200 investigation locations in the Fukushima prefecture and the neighbouring prefectures.

Results and Discussion (1/3)

Time variation of the amounts of Te-129m, Te-129 and I-129



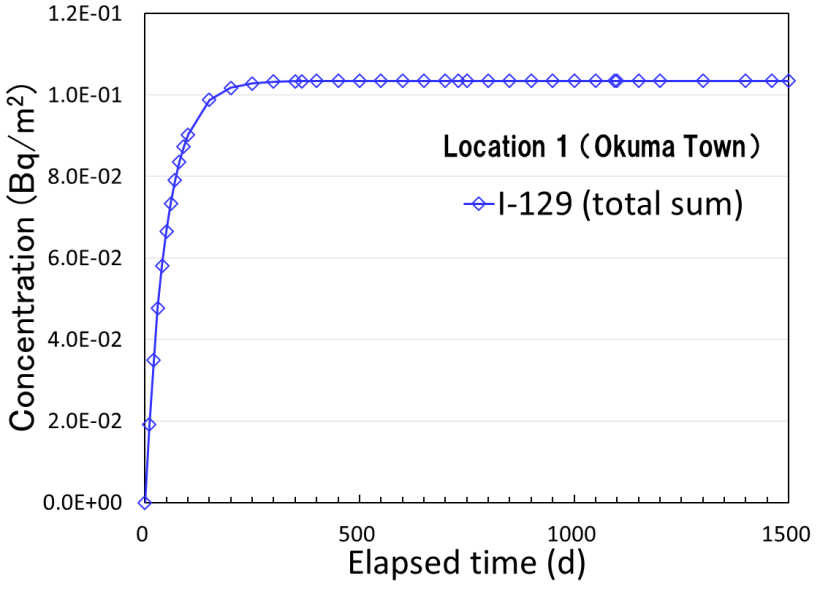


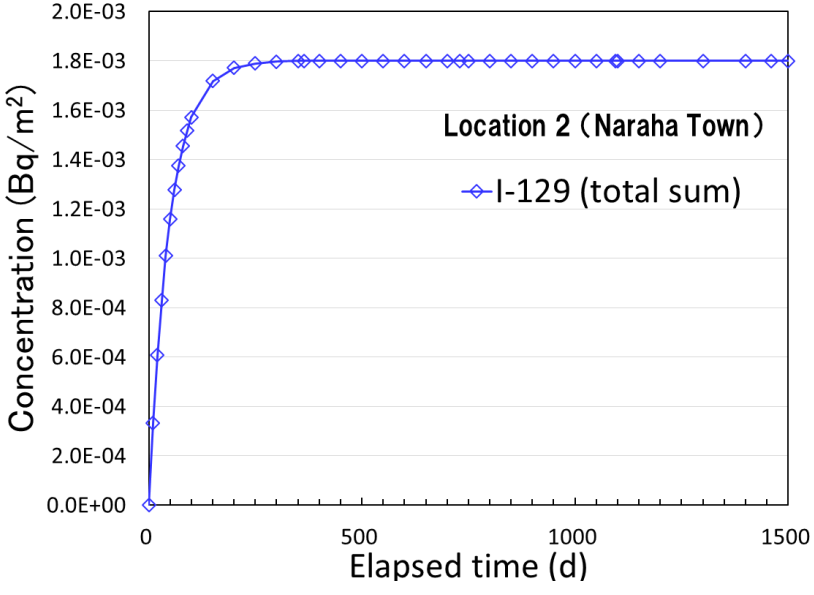


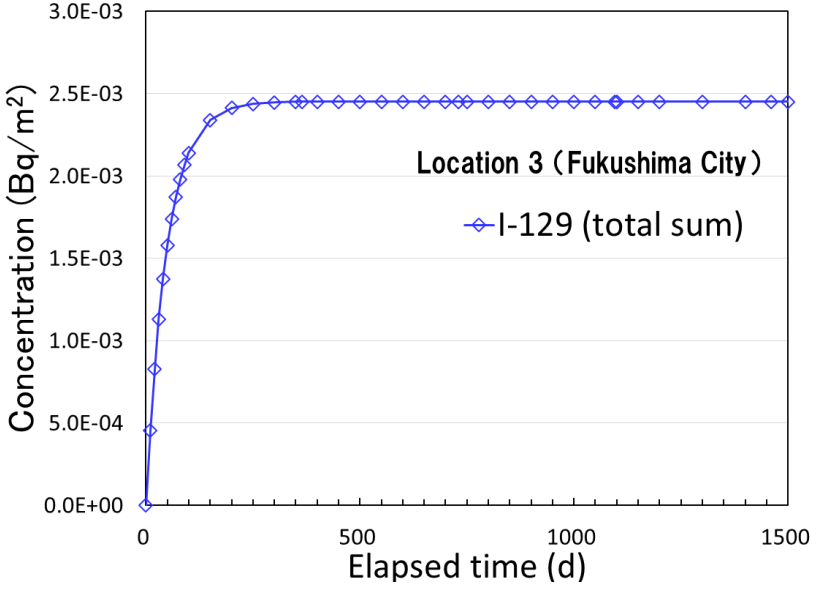
- Te-129m and Te-129 drastically decreased with an increase of time.
- On the other hand, the amount of I-129 was very low, which was nearly equal to zero.

Results and Discussion (2/3)

Graphs enlarged only time variation of the amounts of I-129







- The total amount of I-129 increased up to after about 1,000d from the 1F-NPS accident and gradually began to decrease after that.
- Maximum amount of I-129 was estimated 1.03×10^{-1} (Bq/m^2) after 1,000d.

Results and Discussion (3/3)

Amounts of I-129 in the environment (in soil) (all over Japan)

Location	I-129 (Bq/m^2)	Location	I-129 (Bq/m^2)
Shintoku, Hokkaido	1.46×10^{-1}	Higashi-Osaka, Osaka	7.05×10^{-3}
Nishiki, Akita	4.81×10^{-2}	Ningyotoge, Okayama	1.56×10^{-2}
Mito, Ibaraki Iwama, Ibaraki	1.24×10^{-1} 2.96×10^{-1}	Uwajima, Ehime	5.75×10^{-3}
Isesaki, Gunma	1.78×10^{-2}	Nishiyama, Nagasaki	1.61×10^{-2}
Kanazawa, Ishikawa	5.90×10^{-2}	Jonan, Kumamoto	1.85×10^{-2}
Kanmuriyama, Fukui Okuetsukogen, Fukui	1.48×10^{-1} 8.50×10^{-2}		

- The background of I-129 in the environment (in soil) is ranging $5.75\text{x}10^{-3}$～$2.96\text{x}10^{-1}$ (Bq/m^2), which is approximately the same level as the maximum amount of I-129 ($=1.03\text{x}10^{-1}$ (Bq/m^2)) in the environment generated by the decay of Te-129m.

Conclusion

- The maximum amount of I-129 in the environment generated by the decay of Te-129m was estimated 1.03×10^{-1} (Bq/m^2) after about 1,000d, based on the deposition data of Te-129m in soil obtained at about 2,200 locations in the Fukushima prefecture and the neighbouring prefectures, and compared to the radioactivity concentrations of I-129 in the environment all over Japan.
- The radioactivity concentrations of I-129 in the environment were in the range $5.75 \times 10^{-3} \sim 2.96 \times 10^{-1}$ (Bq/m^2), which was approximately the same level as the maximum amount of I-129 in the environment generated by the decay of Te-129m.
- The maximum amount of I-129 is estimated approximately one of the 2×10^8 of the initial deposition amount of Te-129m.

Thank you for your attention !