



## Soil-to-crop transfer factors of tellurium



Guosheng Yang, Jian Zheng, Keiko Tagami\*, Shigeo Uchida

Office of Biospheric Assessment for Waste Disposal, National Institute of Radiological Sciences, Japan

### HIGHLIGHTS

- Soil-to-crop transfer factors (TFs) of Te were obtained for various crop samples.
- TFs varied from  $1.3 \times 10^{-3}$  to  $2.3 \times 10^{-1}$  (GM =  $2.4 \times 10^{-2}$ ) for all crop samples.
- Water management practices were likely to affect the Te transfer from soil to crops.

### ARTICLE INFO

#### Article history:

Received 24 December 2013  
Received in revised form 9 April 2014  
Accepted 28 April 2014  
Available online 28 May 2014

Handling Editor: X. Cao

#### Keywords:

Radiotellurium  
Stable tellurium  
Soil  
Crop  
Transfer factor

### ABSTRACT

Stable tellurium (Te) concentrations in 148 sets of agricultural soil and associated crop samples were measured in this study to obtain soil-to-crop transfer factor (TF) of Te. We used a recently developed simple method that applies digestion of samples with *aqua regia* and sector field inductively coupled plasma mass spectrometry to measure low Te levels in these samples. Geometric mean (GM) concentrations of Te in soil and crops were  $75 \mu\text{g kg}^{-1}$ -dry (range:  $15$ – $850 \mu\text{g kg}^{-1}$ -dry) and  $1.8 \mu\text{g kg}^{-1}$ -dry (range:  $0.1$ – $120 \mu\text{g kg}^{-1}$ -dry), respectively; the Te concentration range was significantly wider in crops than in soil. Using these data, we calculated TFs and obtained their range from  $1.3 \times 10^{-3}$  to  $1.1 \times 10^{-1}$ . The GM of TF for upland field crops was calculated to be  $2.0 \times 10^{-2}$  and for brown rice was  $3.1 \times 10^{-2}$ ; all crop types had the similar GMs of their TF values. Data comparison for TF of Te was carried out with six elements, which are present in anionic forms in soil environment like Te is, i.e. P, Br, As, Se, Mo, and I. TFs of Te and I showed the highest correlation factor for upland field crops by *t*-test ( $r = 0.577$ ,  $p < 0.001$ ), but no correlation was found for brown rice. We considered it likely that different water management practices in upland fields and paddy fields affected the Te transfer from soil to crops.

© 2014 Elsevier Ltd. All rights reserved.

## 1. Introduction

Large amounts ( $\sim 10^{17}$  Bq) of tellurium (Te) isotopes, including  $^{127\text{m}}\text{Te}$  ( $T_{1/2} = 109$  d),  $^{129\text{m}}\text{Te}$  ( $T_{1/2} = 33.6$  d),  $^{131\text{m}}\text{Te}$  ( $T_{1/2} = 30$  h), and  $^{132}\text{Te}$  ( $T_{1/2} = 3.204$  d) were released into northeastern Japan by the Fukushima Daiichi Nuclear Power Plant (FDNPP) accident, mainly in March 2011 (METI, 2011). Estimation of the radiation dose from radiotellurium isotopes by ingestion before their decaying-out, that is, at an early stage after releases (ca. within one year from March 2011), is still important to know the potential contribution to the total dose to the residents by these radionuclides. For short-lived radionuclides, i.e.  $^{131\text{m}}\text{Te}$  and  $^{132}\text{Te}$ , only direct deposition on food should be taken into account, however, radiotellurium isotopes having longer half-lives, i.e.  $^{127\text{m}}\text{Te}$  and  $^{129\text{m}}\text{Te}$ , deposited on agricultural soil would be taken up by plants through roots to

an edible part before they decayed-out. Therefore,  $^{127\text{m}}\text{Te}$  and  $^{129\text{m}}\text{Te}$  might have been ingested by residents through contaminated crops by root uptake. In order to estimate what amount of radiotellurium was ingested through this pathway, the soil-to-plant transfer factor (TF) is a useful parameter. The TF is defined as the concentration of a radionuclide in a plant (in Bq  $\text{kg}^{-1}$ -dry or wet weight) divided by the concentration of the radionuclide in the soil (in Bq  $\text{kg}^{-1}$ -dry weight). There are only a few data on the TF of radiotellurium (IAEA, 2010, referred to as IAEA-TRS-472 in the following text), however, and they are all from crop samples collected in European countries.

Due to the scarceness of the Te TFs data, it is necessary to provide more data for crops native to Japan for reliable dose estimation from  $^{127\text{m}}\text{Te}$  and  $^{129\text{m}}\text{Te}$ . But, none of these radiotellurium isotopes released from the FDNPP accident can be measured in soil and crop samples now because these isotopes have already been decayed-out, so that a radiometric method is not suitable. Addition of  $^{127\text{m}}\text{Te}$  or  $^{129\text{m}}\text{Te}$  to soil to conduct radiotracer experiments can be applicable but these isotopes are not commercially available.

\* Corresponding author. Address: Anagawa 4-9-1, Inage-ku, Chiba 263-8555, Japan. Tel.: +81 43 2063265; fax: +81 43 2063267.

E-mail address: [k\\_tagami@nirs.go.jp](mailto:k_tagami@nirs.go.jp) (K. Tagami).

Therefore, instead, stable Te TF can be used as a surrogate for radiotellurium, and TF of the stable element can be calculated by applying elemental concentrations in plant and soil ( $\text{mg kg}^{-1}$ -dry plant divided by  $\text{mg kg}^{-1}$ -dry soil).

Generally, concentrations of stable Te in soil and plant samples are extremely low. For example, the following values have been reported for soil samples;  $<0.08$ – $0.12 \text{ mg kg}^{-1}$ -dry in Swedish arable topsoil (Eriksson, 2001),  $0.01$ – $0.16 \text{ mg kg}^{-1}$ -dry in Japanese soil (Sekine et al., 1991),  $0.01$ – $0.109 \text{ mg kg}^{-1}$ -dry (geometric mean:  $0.041 \text{ mg kg}^{-1}$ -dry) in non-contaminated Japanese soil (Asami et al., 1999), and  $0.007$ – $0.113 \text{ mg kg}^{-1}$ -dry in Chinese soil (Qi et al., 1992). The world average Te concentration in soil was estimated as  $0.006 \text{ mg kg}^{-1}$ -dry (Reimann and Caritat, 1998), and, recently, Ba et al. (2010) reported the world average Te concentration in soil was  $0.027 \text{ mg kg}^{-1}$ . For plant samples, the following values have been reported;  $<0.013$  to  $0.35 \text{ mg kg}^{-1}$ -dry (Kabata-Pendias and Mukherjee, 2007) and  $0.013$ – $6 \mu\text{g kg}^{-1}$  (D'Ulivo, 1997) for plants;  $<0.001 \text{ mg kg}^{-1}$ -dry in wheat and barley (Eriksson, 2001); and  $0.018$ – $0.033 \text{ mg kg}^{-1}$ -dry (geometric mean:  $0.023 \text{ mg kg}^{-1}$ -dry) in Japanese herbaceous plants (Asami et al., 1999). It has also been reported that seleniferous plant species contained elevated quantities of Te when they were grown on Te-enriched soil (Kabata-Pendias and Mukherjee, 2007). Since major Te chemical forms in soil are  $\text{TeO}_3^{2-}$  and  $\text{TeO}_4^{2-}$ , Te has high mobility in soil; however, at the same time, these chemical forms have affinities to Fe(III) (Harada and Takahashi, 2008). According to such chemical characteristics, Te in soil will not be highly bioavailable to plants and thus, generally, the concentration in plants will be low.

D'Ulivo (1997) summarized the methods to measure Te in environmental samples, and inductively coupled plasma mass spectrometry (ICP-MS) was mentioned as suitable for Te detection; polyatomic interferences are not a problem for measuring the most abundant natural isotopes of Te, but non-spectroscopic interferences may affect Te signals. Thus, previously, when low-levels of Te in soil and plant matrix samples were studied, a simple *aqua regia* digestion method followed by sector field ICP-MS (SF-ICP-MS) was applied (Yang et al., 2013). In this study, we applied this method to measure Te concentrations in agricultural soil and associated crop samples collected throughout Japan, and then, we calculated the TF values of stable Te. These TF data will also be useful for making radionuclide assessments in other Asian countries where rice is a staple food and many of the vegetables consumed differ from those eaten in European countries. The obtained Te data were compared with six elements already reported elsewhere (Uchida and Tagami, 2011; Uchida et al., 2007a,b), i.e. P, Br, As, Se, Mo and I, which are expected to be present in anionic forms ( $\text{HPO}_4^{2-}$  or  $\text{H}_2\text{PO}_4^-$ ,  $\text{Br}^-$ ,  $\text{H}_2\text{AsO}_4^-$  or  $\text{HPO}_4^{2-}$ ,  $\text{SeO}_3^{2-}$  or  $\text{SeO}_4^{2-}$ ,  $\text{MoO}_4^{2-}$ , and  $\text{I}^-$  or  $\text{IO}_3^-$ ) in the aerobic soil environment (Pourbaix, 1974; Kabata-Pendias and Mukherjee, 2007) because Te chemical forms in soil are expected to be in  $\text{TeO}_3^{2-}$  and  $\text{TeO}_4^{2-}$  as mentioned above.

## 2. Materials and methods

### 2.1. Soil and plant sample preparation

Details of the sampling and preparation can be found elsewhere (Uchida et al., 2007a,b). In brief, upland field and paddy field soil samples (plowed soil layer: up to ca. 20 cm in depth) and associated edible parts of crop samples were collected throughout Japan. Upland field crop and brown rice samples were collected from 79 and 63 sampling sites, respectively, in the harvesting seasons from 2002 to 2006. For leek samples, green and white parts were separated, and leaves of carrot and Japanese radish samples are also considered as edible so that their roots and leaves were separated

as well. Therefore, samples of 85 crop edible parts were obtained in total for upland field crops. TFs of about 40 elements in these soil-crop sample sets were measured (Uchida et al., 2007a,b) so that use of these samples to obtain TF of Te were of interesting to compare the data with that of other elements.

Soil samples were air-dried and passed through a 2-mm mesh sieve. The soil samples were classified into four categories, that is, fluvisol, cambisol, andosol and others, according to FAO/UNESCO classifications. Crop samples were categorized into leafy vegetable, tuber, allium (leek and onion), legume, fruit vegetable, root vegetable, wheat and barley, and brown rice. Allium species were separately considered because they can concentrate Se from soil (Kabata-Pendias and Mukherjee, 2007; Anan et al., 2013). Each crop sample was washed with deionized water to remove dust and soil particles before being freeze-dried. Each dried soil and crop sample was then thoroughly ground into fine powders, separately. Each powdered sample was transferred into a glass vial and stored at room temperature. Before digestion for Te measurement by SF-ICP-MS, these samples were dried in an electrical oven at  $80^\circ\text{C}$ . We also used other portion of the samples for the determination of P, Br, As, Se, Mo and I.

### 2.2. Te determination in soil and crop samples by SF-ICP-MS

The soil and crop samples were digested with *aqua regia* (a mixture of super-pure grade  $\text{HNO}_3$  and  $\text{HCl}$  from Tama Chemicals, AA-100). For each soil sample, a  $0.05$ -g amount was transferred into a PTFE vessel and  $12 \text{ mL}$  of *aqua regia* was added. The mixture was heated on a hot plate ( $140^\circ\text{C}$ ) for 48 h. For each crop sample,  $0.5 \text{ g}$  was used; after addition of  $12 \text{ mL}$  of *aqua regia*, the mixture was kept at room temperature overnight to avoid excessive reaction during the subsequent heating for 48 h. Then, Te was directly measured without any separation and pre-concentration steps, but a dilution factor of 1000 for soil samples and 100 for crop samples was applied. Before analysis, the solution was passed through a  $0.45$ - $\mu\text{m}$  filter (PTFE) to remove fine particles and avoid clogging of the sample in a nebulizer.

Measurements were performed using SF-ICP-MS (Thermo Fisher Scientific, Element 2) with a conical concentric nebulizer. External calibration was performed with Te standard solutions ( $0$ – $1 \text{ ng mL}^{-1}$ ) spiked with  $0.5 \text{ ng mL}^{-1}$  internal standard (rhodium). Then, the detection limits, defined as 3 times the standard deviation ( $3\sigma$ ) of the process blank sample, were calculated to be  $0.17 \mu\text{g kg}^{-1}$  for soil and  $0.02 \mu\text{g kg}^{-1}$  for plant crop samples. The accuracy of the analytical procedure for soil and plant samples was checked using reference materials such as JSO-1 (The Geological Survey of Japan (GSJ), Andosol) for soil and SRM-1573a (National Institute of Standards and Technology (NIST), Tomato leaves) for crop samples. Details of Te determination by SF-ICP-MS were described in our previous work (Yang et al., 2013).

### 2.3. Determination of P, Br, As, Se, Mo and I in soil and crop samples

In order to measure P, As, Se and Mo in the soil samples,  $100 \text{ mg}$  each were digested with mineral acids (a mixture of super-pure grade  $\text{HNO}_3$ ,  $\text{HF}$  and  $\text{HClO}_4$  from Tama Chemicals, AA-100) using a microwave digester (CEM, Mars 5). For the crop samples,  $500 \text{ mg}$  were used. As, Se and Mo were measured by ICP-MS (Agilent, 7500c) and P was measured by ICP-optical emission spectrometry (Perkin-Elmer, Optima 3300 DV). Details of the method were reported elsewhere (Uchida et al., 2007a, b). Standard reference materials such as SRM-1573a (NIST), GBW-07603 (Institute of Geophysical and Geochemical Exploration, bush twigs and leaves) and JB-3 (GSJ, igneous rock) were also analyzed to check the accuracy of the method.

Download English Version:

<https://daneshyari.com/en/article/6308726>

Download Persian Version:

<https://daneshyari.com/article/6308726>

[Daneshyari.com](https://daneshyari.com)