ELSEVIER
Available online at www.sciencedirect.com
ScienceDirect
Energy Procedia 5 (2011) 2421–2425
Energy Procedia

IACEED2010

Study of ratio of tritium concentration in plants water to tritium concentration in air moisture for chronic atmospheric release of tritium

SHEN Hui-fang[a,b*], YAO Ren-tai[b]

[a]College of Arts and Science, Shanxi Agricultural University, Taigu , 030801, China
[b]China Institute for Radiation Protection, Taiyuan, 030006, China (yaorentai001@vip.sina.com)

Abstract

Specific activity models (SA) are often used to estimate tritium concentration in the plants for chronic-release of atmospheric HTO in some regulatory models by some countries and commissions. In such models, a major assumption is that the value of specific activity of tritium of tritium oxide in vegetation to the specific activity of tritium of tritium oxide in air moisture is maintained at a constant ratio (R). The value of R is an important factor in determining tritium concentration and dose from chronic atmospheric release. But the value of R recommended is different from different models. Concentrations of tritium in plants will be have huge difference in plants because of the difference of the value of R, and this in turn would result in difference of ingestion dose via food chain. Some studies suggested that a site-specific distribution of R should be developed in suing a specific activity model. In this study, distribution of R is established for the Qinshan NPP Base. The environmental monitoring data of tritium concentration in five type plants (rapeseed, tea, cabbage, radish and rice) and air at three sampling points (Xiajiawan, Qinlian and Ganpu) around Qinshan NPP Base(QNNP) over a 4 years period as the basis for analysis, and the tritium ratio(R) between plant water and air moisture were determined. The results showed the average value of R of five plants were 0.103, 0.687, 1.055, 0.695 and 0.183 respectively. These values of R are mostly consistent with the law presented by foreign literature, only the value of R for cabbage is greater than the value of R for foliage vegetation presented by foreign reports. This is partly attributable to the difference of experimental conditions. The concentration of HTO of vegetations around QNNP could be assessed using the values of R recommended by this report for chronic release of atmospheric HTO.

Selection and peer-review under responsibility of RIUDS

Keywords: tritium; ratio; concentration; plant water; air moisture

* Corresponding author. Tel.: 86-351-2202043;
E-mail address: shfgf@126.com.

doi:10.1016/j.egypro.2011.03.416

1. Introduction

^3H(tritium, T), a beta-emitting radionuclide, is one of the major radionuclides released routinely in the form of tritiated water vapor (HTO) from nuclear installations such as nuclear power plants, reprocessing plants during normal operation. Atmospheric HTO easily passes through the stomata of growing plants to enter into their water pools. Tritium atoms in the plant water pool are generally called tissue free water tritium (TFWT). Some amount of HTO entering plant is incorporated into organically bound tritium (OBT) mainly by photosynthesis and partly by a metabolic process involved in respiration, while the rest escapes back to the atmosphere or remains in plant tissues as tissue free water tritium (TFWT). The plant also obtains some tritium from soil water [1][2].

It is commonly done with a specific activity model (SA) to estimate tritium concentration in the plants for chronic-release of atmospheric HTO [3][4][5][6]. A major assumption of this model is that the specific activities of tritium oxide (HTO: H_2O) in vegetation and in atmospheric moisture are maintained at a constant ratio. For dose assessments of atmospheric tritium released by chronic, the plant-to-atmospheric tritium ratio(R) is used to estimate the concentration of tritium, then is used to estimate tritium concentration in meat, milk and vegetables consumed by the receptor. The value of R is an important factor in determining tritium dose for chronic atmospheric release of tritium.

The value of R is different by recommended from different countries, and the range of R is from 0.17 to 0.80[7][8]. The value of R recommended by different organizations is distinct even in the same country such as the Nuclear Regulatory Commission (NRC) recommends a value of 0.5 for R while the Environment Protection agency(EPA) assumes equal specific activities (R=1). Environmental data from the Savannah River Site suggest that the annual average value of R lies between 0.3 and 0.8.The ratio of absorption moisture is different for different type vegetables from air moisture and soil water, so the value of R is distinct for different type vegetations. Concentrations of tritium in plants will be huge difference because of the difference of the value of R, and this in turn would result in difference of ingestion dose via food chain. Some studies indicated that it should recommend a site-specific distribution of R in using a specific activity model. Some studies also show that the values of R vary greatly in different site, and the R is very sensitive for relative humidity and solar radiation [7][8]. At the same time, Site-specific values of R account for tritium in plant tissues by both uptake mechanisms, thus emphasizing the use of site-specific data.

In order to development environmental migration model and dose assessment model which applied to environmental characteristics of Chinese nuclear site for chronic atmospheric release of tritium, the monitoring data of tritium concentration in five type plants (rapeseed, tea, cabbage, radish and rice) and air at three sampling points (Xiajiawan, Qinlian and Ganpu) of Qinshan NPP Base were studied, and the tritium ratio(R) between plant water and air moisture were determined.

2. Materials and method

2.1 Data collection and analysis

The concentration data of tritium in vegetation and air collected at the QNPP Bsae from 2005 to 2008 were analyzed to determine the value of R. The data were extracted from QNPP Bsae environmental monitoring records for 3 sampling location around the site boundary.

The meteorological data required came from the information provided by weather station of QNPP.

2.2 Data treatment

Because of the rapid turnover rate of tritium by vegetation, tritium concentration measured in different type plants will reflect the atmospheric and HTO release conditions present just prior to sample collection. So in this report, the concentration of air moisture in sampling points is the average concentration of tritium in air moisture prior to one month in sampling time.

The concentration of tritium in air moisture is calculated based on:

$$C_a = \frac{C}{H_a} \tag{1}$$

where C_a=the concentration of tritium in air moisture(Bq kg^{-1}), C= the concentration of tritium(Bq m^{-3}), H_a= the absolute humidity of air (kg m^{-3}).

The absolute humidity in air is calculated using the equation (2).

$$H_a = \frac{289 \times e}{T} \tag{2}$$

where T=temperature (K), e = vapor pressure(mm).

The equation to calculate vapor pressure (e) is :

$$e = 6.11 \times 10^{\left(\frac{a \times t}{b+t}\right)} \tag{3}$$

where a=7.5, b=237.3, t=temperature(℃).

The value of R is determined by the ratio between tritium concentration in plant sample and the concentration in air moisture.

3.Results and discussion

Concentration ratios of free-water tritium in five plants to atmospheric moisture by year are showed in table 1.

The law of the value of R is similar with the law got by the foreign studies for the data of environmental monitoring in four years for five plants at three sampling points.

The average value of R got by four years monitoring data is 0.23 for rapeseed, but in 2006 the value of R is significantly greater than that of the other three years. This is attribute to the concentration of HTO monitored in rapeseed was higher (4.8Bq/kg). This may arise when plant water concentration at the time of sample do not represent the concentrations tritium in air moisture, or may be caused by measure errors. Eliminating this value, the average value of R is 0.103 (table 2) for rapeseed.

The average value of R of four years for tea is 2.51, but the value of R in 2008 was obviously higher than that of the other three years, and the concentration of HTO in tea was 53.6Bq/kg. The higher value obtained in this study could be attributable to the measurement errors or may be an artifact of the analytical method used to determine the concentration of tritium in tea. Excluding the value of 7.98, the average value of R for the rest three years remained 0.687(table 2).

The mean value of R over 4 years determined from the QNPP data was 1.055 for cabbage (table 2), and the value of R was greater than one. This is because the cabbage obtains the more HTO from the air moisture than that of soil water.

The mean value of R was 0.695 for radish (table 2), which the consistent with the value determined in potato [8] that are root crops.

The four years mean value of R was 0.398 for rice, but the value of R (1.04) in 2007 is obviously greater than that of the rest value of R, which is higher than the other R by a factor 8 and it should be exclude. This is because the concentration of tritium in air monitored lower significantly than that of other years, the reason may be caused by measure errors. The average value of R obtained is 0.183 for the rest three years (table 2). The value of R less than that of determined in grain vegetation by the foreign studies. In the case of rice, less tritium is contributed from the atmosphere and more is contributed from the paddies, and the paddy are normally flooded to a greater or less extent, so the tritium deposited into paddy water may be greatly diluted over the tritium concentration in air moisture, perhaps even more so than in soil water. Therefore the value of R should be smaller for rice [9].

Table 1 Ratio of HTO concentration in five plants water to HTO concentration in air moisture by year

Plant type	year	Ratio
rapeseed	2005	0.07
	2006	0.61
	2007	0.19
	2008	0.05
tea	2005	1.03
	2006	0.24
	2007	0.79
	2008	7.98
cabbage	2005	0.94（range 0.18-1.56）
	2006	1.13（range 0.21-1.62）
	2007	1.07（range 0.16-1.62）
	2008	1.08（range 0.17-1.62）
radish	2005	1.08（range 0.50-1.48）
	2006	0.62（range 0.41-0.84）
	2007	0.53（range 0.11-0.94）
	2008	0.55
rice	2005	0.28（range 0.195-0. 377）
	2006	0.14(range 0.11-0.19)
	2007	1.04（range 0.22-1.86）
	2008	0.13

Table 2 The average value of R of four years in plants

Plant type	The average value of R
Rapeseed	0.103
Tea	0.687
Cabbage	1.055
Radish	0.695
Rice	0.183

4. Discussion and conclusions

The NRC and EPA recommend the use of a specific activity model for estimating tritium concentration in foodstuffs. However both agencies suggest default values that differ by a factor 2 for the concentration ratio (R) of tritium in vegetation to tritium in atmospheric moisture [3][4][5].

Vegetation-to-atmospheric tritium ratios varied dependent on plant species [7][8], and this report is consistent with the viewpoint. The value of R for grain vegetation (rapeseed and rice) is less (0.103 for rapeseed and 0.183 for rice), because the dominant mechanism for tritium uptake by grain vegetation is the soil-root uptake route and less tritium is contributed from the atmosphere. For an atmospheric source, soil water concentration of tritium trend to be lower than air moisture concentration, so the concentration of tritium in the plant will be reduced compared with air moisture. Furthermore the water content of grain vegetation is lower.

The value of R for radish and tea (0.687 for tea and 0.695 for radish) are identical with the foreign literature [7][8][9], and the value of R is less than that of cabbage (1.055)which belong to leafy vegetation.

For chronic release of HTO to the atmosphere, the radish and tea obtain the tritium not only from air moisture but from soil water, but the dominant mechanism for tritium uptake by foliage is air-leaf uptake route and the concentration of tritium of soil water is lower than that of air moisture. Thus, plant water/air moisture ratio for radish and tea should lower than the ratios of foliage (cabbage).

As leafy vegetation, the value of R for cabbage is greater than one, and this value is greater than the value of R for foliage vegetation presented by foreign reports [8][9]. Because the ratios of HTO concentration in plant water to HTO concentration in air moisture in field plants grown in the vicinity of sources of tritium may be higher than the value of R which are taken from controlled experiments or from environmental samples from background areas.

The assumption is made in the dose model of EPA's CAP88 code, that the specific activity of tritium in atmospheric water vapor is equal to the specific activity of tritium in vegetation[4][5]. The assumption in CAP88 model is overly conservative. Use of the CAP88 assumption at Qinshan potentially results in overestimates of tritium dose via food pathways by a factor of 2-6. So, site-specific parameters values of R are essential for accurate environmental modeling.

Examination of the specific activity model shows that the concentrations of HTO of vegetation estimates are linearly proportional to R. The concentrations of tritium in plant products and animal products, and hence dose, are also linearly proportional to this ratios. Therefore, underestimation or overestimation of the concentration of tritium would affect the ingestion dose.

The concentrations of HTO of vegetations around QNNP could be assessed using the values of R recommended by this report for chronic release of atmospheric HTO.

Acknowledgement

We would like to acknowledge the National Natural Science foundation of China (No. 10875108) supported by the National Science Foundation Commission.

References

[1] Yong Ho Choi, Kwang Muk Lim, Won Yun Lee, et al. Tritium levels in Chinese cabbage and radish plants acutely exposed to HTO vapor at different growth stages.J. Enviro. Radioactivity 2005; (84): 79-94.

[2] L. Vichot, C. Boyer, T. Boissieux, et ai. Organically bound tritium (OBT) for various plants in the vicinity of a continuous atmospheric tritium releases. J. Enviro. Radioactivity 2008; (99): 1535-1643.

[3] N.S. Nuclear Regulatory Commission: Regulatory guide 1.109: Calculation of annual doses to man from routine release of radioactive effluents for the purpose of evaluating compliance with 10CTR Part 50, Appendix Ⅰ, Washington, DC: Government Printing Office, Revision 1, 1977.

[4] Beres, D.A: The clean air act assessment package-1988 (CAP88): A dose and risk assessment methodology for radionuclide emissions to air, Vol.1, 1990.

[5] Barry Parks: Mathematical models in CAP88-PC, U.S. Department of Energy, June1997

[6] U.S. Environmental Protection Agency: User's guide for the COMPLY code, Washington, DC: EPA, 520/1-89-003,1989c

[7] D.M.Hamby and L.R.Bauer: The vegetation-to-air concentration ratio in a specific activity atmospheric tritium model. Health Phys 1994; 66(3):339-42.

[8] S-P.Peterson and P.A. Davis. Tritium doses from chronic atmospheric releases: A new approach proposed for regulatory compliance. HEALTH PHYS 2002; 82(2):213-25.

[9] S-P. Peterson and P. A. Davis Modeled concentrations in rice and ingestion doses from chronic atmospheric releases of tritium, Health Phys 2000; 78(5):533-41.