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Distribution and migration of ^{95}Zr in a tea plant/soil system

Jianjun Shi [a], Jiangfeng Guo [b,*]

[a] College of Science, Zhejiang Sci-Tech University, Hangzhou 310018, P.R. China
[b] Institute of Bioengineering, Zhejiang Sci-Tech University, Hangzhou 310018, P.R. China

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Abstract

^{95}Zr is a primary radionuclide in the radioactive liquid efflux from a pressurized water reactor and one of the main radionuclides released after nuclear accidents. The fission yield of ^{95}Zr is as high as 6.2%, however, its environmental behavior has not been well documented. An experiment was conducted to evaluate the accumulation and distribution of ^{95}Zr in a tea plant/soil system. ^{95}Zr was accumulated primarily in the trunk of tea plants after being taken up from the soil. The radioactivity concentration of ^{95}Zr in the trunk increased slowly with time, then it reached a dynamic equilibrium 14 days after application. The radioactivity concentration of ^{95}Zr in the other parts of the tea plant was very low; only slighter greater than the detection limit. The results indicated that ^{95}Zr was not readily translocated in the tea plant. About 98.9% of applied ^{95}Zr was found to concentrate in the upper 5 cm layer after being sprayed onto the soil surface. The results indicated that ^{95}Zr could not readily move downwards with percolating water due to strong adsorption to surface soil.

Keywords: ^{95}Zr; Tea plant; Soil; Migration; Distribution; Radioecology

1. Introduction

^{95}Zr is one of the primary fission products in a nuclear reactor. As a primary radionuclide in the radioactive liquid efflux from a pressurized water reactor, its half-life is 64.02 days, and its fission yield is as high as 6.2% (Whicker and Schultz 1982). The distribution of ^{95}Zr in the

* Corresponding author. Tel: +86 571 8684 3195; fax: +86 571 8684 3196.
E-mail address: jfguo@zist.edu.cn (J. Guo).

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vicinity of the Chernobyl Nuclear Power Plant and other places in the world has been investigated after the Chernobyl catastrophe (Yirchenko and Agapkina, 1993; Kruglov et al., 1996; Mosulishvili et al., 1994). In paddy soil, Shi et al. (2002) found that most of the ^{95}Zr was concentrated in the surface layer of soil and could not readily move downwards with percolating water. They also found that ^{95}Zr taken up from surface water and soil concentrated mainly in the roots and lower parts of stems of rice plants. Shi and Guo (2002) investigated the uptake of ^{95}Zr from soil and its distribution in Chinese cabbage. ^{95}Zr can be taken up by barley, corn and alfalfa (Sanzharova and Aleksakhin, 1982). However, in comparison with other fission products, such as ^{90}Sr, ^{137}Cs, ^{60}Co (Avila et al., 1999; Shenber and Johanson, 1992; Yasuda et al., 1995), the environmental behavior of ^{95}Zr has not been well documented.

Tea is a popular drink in many countries. At present more than forty countries in the world grow tea with Asian countries producing 90% of the world's total output. However, no data are available on the uptake of ^{95}Zr by the tea plant and the environmental fate of ^{95}Zr in a tea plantation. In this study, ^{95}Zr was administered to a tea plant/soil system to study its uptake from the soil by the tea plant and its distribution in the system. The objectives of this study were to evaluate the accumulation and distribution of ^{95}Zr in the tea plant and the distribution of ^{95}Zr in the soil profile of a tea plantation.

2. Materials and methods

2.1. Isotope

$^{95}ZrO_2$, in the form of a black powder, was supplied by the Academy of Atomic Energy of China. Its specific activity was 2.284×10^8 Bq g^{-1}, and its radiochemical purity was greater than 95%. Zirconium oxide, a chemically inert compound, is water insoluble. It has to be dissolved with strong acid to produce its aqueous solution. Prior to use, it was chemically transformed with HF into $^{95}ZrF_4$ with a concentration of 1.233×10^7 Bq ml^{-1} on June 20, 2000. $^{95}ZrF_4$ solution, in a volume of 2.0 ml, was diluted to 3200 ml with H_2O, and pH value of the diluted solution was 6.5. This diluted aqueous solution, with a concentration of 7.706×10^3 Bq ml^{-1}, was used for the experiment.

2.2. Soil

The soil sample was collected from the Experimental Tea Plantation of Zhejiang University. It was air-dried, pulverized, and sieved to remove stones and plant debris prior to use. The soil properties are summarized in Table 1.

2.3. Experimental

Two concrete tanks with dimensions of $1 \times 1 \times 0.3$ m were constructed outdoors. Three hundred kilograms of soil with a moisture content of 17.5% were filled into each tank. Tea plants, 25–30 cm in height and with a tree age of 3 years, were transplanted into each tank with a row spacing of 17 cm in November, 1999, and each row having 14 individual tea plants. The variety of tea plant is Zhenong 121, provided by the

Table 1
Physico-chemical properties of the soils studied

pH	Organic matter (%)	CEC cmol(+) kg^{-1}	Clay (0.001 mm) (%)
4.71	0.31	0.94	12.5