Overview of the Radioecological Research at KAERI

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1. Introduction

Radioecology is a scientific discipline for studying the movement and accumulation of radionuclides within ecosystems composed of air, soil, water and living organisms including humans [1]. It started in the late 1940s in the USSR and the early 1950s in the USA for the purpose of assessing the environmental impact of the radionuclides released by military uses of fissile material [1]. With an increase in the peaceful use of nuclear energy, radioecologists took a great interest in the environmental impact assessment of nuclear power plants and other nuclear fuel cycle facilities. Radiation doses to the public by the planned and ongoing operations of such nuclear installations should be estimated for both normal operation and an accident. These estimations are made using assessment models which require parameter values to quantify various transfer processes of radionuclides in the ecosystem. In KAERI, radioecological research has been conducted for the past 30 years with an emphasis put on the production of data on the transfer of radionuclides to major food crops [2]. This paper presents a brief history of the research and a summary of the data production.

2. Brief History of the Radioecology at KAERI

The radioecological research for food crops in KAERI started in 1981 by greenhouse experiments performed to investigate ^{90}Sr and ^{137}Cs transfer to soybean plants using pot cultures. Shortly after this, other pot experiments were conducted to obtain the soil-to-plant transfer data of ^{90}Sr and ^{137}Cs for paddy rice in different soils. For three years from 1987, soil-to-plant transfer factors (TF_m, dimensionless) of ^{54}Mn, ^{60}Co, ^{90}Sr and ^{137}Cs were measured in a greenhouse for rice, barley, soybean, radish and Chinese cabbage in relation to the environmental assessment of Kori Unit No. 5 and 6 (currently No. 3 and 4). In the late 1980s and the early 1990s, TF_m values of ^{54}Mn, ^{60}Co, ^{65}Zn and ^{137}Cs for rice, soybean and vegetables such as lettuce, carrot and squash in 2-4 different soils were measured through pot experiments in a greenhouse for a governmental R&D project. Through the support from this project, a greenhouse for RI experiments in current use was built at Daeduck campus of KAERI in 1992.

In 1992, a national long-term nuclear R&D program was launched. Within the framework of this program, lysimeter experiments were performed for five years to investigate the root uptake of ^{54}Mn, ^{60}Co, ^{90}Sr (^{85}Sr), ^{137}Cs and HTO by major Korean food crops following their depositions onto the water (rice) or soil (upland crops) surface at different times during the vegetation periods. As a result of these greenhouse experiments, a set of deposition time-dependent aggregated TF values (TF_{ag}, $m^2\ kg^{-1}$) were produced for use in estimating the root-uptake concentrations after an acute deposition during the plant growth. In addition, iodine TF_{ag} values were produced for potted Chinese cabbage. In 1994 and 1995, field studies on the root uptake of fallout ^{137}Cs were conducted for rice and Chinese cabbage.

From 1997 to 2006, experiments on the direct plant contamination were performed. Several plant species were exposed to the sprays of mixed RI solutions, HTO vapor, I_2 vapor and/or $^{14}CO_2$ gas in exposure chambers at different growth stages. Interception fractions (IF), translocation factors (TLF) and weathering half-lives (Wt) of some important radionuclides were measured. Transfer data on the foliar uptake of those vapors or gases were produced. During the earlier years of the decade, lysimeter experiments using undisturbed soil blocks collected in rice fields around NPPs were conducted to investigate the rice uptake (TF_{ag}) of ^{90}Sr and ^{137}Cs deposited at different times of the year. For five years since 2007, the uptake of ^{99}Tc and ^{129}I by rice and upland crops were investigated for pre- and post-planting depositions onto different paddy or upland soils collected around the Wolsung nuclear site. For rice, an experiment on the uptake of ^{85}Sr and ^{137}Cs were also made using some paddy soils.

3. Summary of the Data Production by KAERI

3.1 TF_m values

Table I shows the amount of TF_m data produced by KAERI. A total of 147 values were reported for the edible parts of various food crops. The highest number was recorded by Cs, followed by Mn. A very small number of values were produced for Sr, two RIs of which, ^{89}Sr and ^{90}Sr are radioecologically very important. Among the plant species, the rice has the largest number of TF_m values. This crop has 10 values for freshly deposited Cs and 12 for fallout Cs. With these numbers of Cs values, a reliable representative value for domestic uses can be determined.

3.2 TF_{ag} values

Table II is a summary of the TF_{ag} data production. Post-planting depositions very often led to higher uptake than pre-planting depositions, indicating the

Table I: Production of TF_m data by KAERI

Radio-nuclide	No. of crops	No. of soils	No. of TF_m values
Mn	9	6	23
Co	9	6	21
Zn	6	4	18
Sr	7	5	10
Cs	9	11	28
Cs-fallout	2	24	24
Tc	4	8	12
I	4	7	11
Total	-	-	147

activity distribution in soil and the plant conditions at the time of deposition played an important role. This trend is inconsistent with a general assumption for using TF_m values in estimating the root uptake after a post-planting deposition. These empirical data may be useful for a realistic estimation of such root uptake.

Table II: Production of TF_{ag} data by KAERI

Radio-nuclide	No. of crops	No. of soils	No. of deposition times	No. of TF_{ag} values
Mn	7	1	4-6	51
Co	7	1	4-6	51
Sr	7	16	4-8	74
Cs	7	22	4-8	86
Tc	2	6	2	12
I	3	6	2-5	15
HTO	2	1	5-6	16
Total	-	-	-	305

3.3 Parameter values for direct plant contamination

A total of 110 IF values, 85 TLF values and 110 Wt values were obtained for rice, radish, soybean and Chinese cabbage plants exposed to mixed RI sprays (Mn, Co, Sr, Ru and Cs) at 5-6 growth stages (Fig. 1). The IF values increased with increases in the plant ages. The TLF values were mostly highest for Cs and lowest for Ru. The Wt values for the earlier-growth-stage depositions were generally longer than a generic value of 14 d. Several TLF values of elemental I_2 were also produced for the rice and radish.

For the rice, soybean, Chinese cabbage and radish, a considerable amount of transfer data on the foliar uptake of HTO vapor was produced. Particularly for rice, some data on the foliar uptake of CO_2 gas were also produced. These data on the direct plant contamination can be used for establishing and validating dynamic food-chain models

Fig. 1. Exposure of rice plants to the sprays of a mixed RI solution.

4. Ongoing Activity for Radioecological Research

The protection of non-human biota from ionizing radiations has become an important issue world-wide. Accordingly, it is necessary to have a relevant tool for a dose assessment. The concentration ratio (CR) between an organism and an environmental medium is a key parameter in evaluating the radiation doses to wild lives. Since 2012, a 5-year project has been carried out at KAERI to establish a database of CR values for various Korean wild lives through field studies.

5. Conclusions

During the past 30 years, a comparatively large amount of radioecological data for food crops was produced at KAERI. Some of the data have been used for the off-site dose calculation or dynamic food-chain model validation in one way or another. A considerable amount of KAERI data was included in an IAEA's handbook and underlying TECDOC [3]. Further studies should be conducted to have sufficient numbers of parameter values to realistically cover various environmental and agricultural conditions. It is desirable for as many of the produced data as possible to be used by the dose assessor. Not only the data producer but also the dose assessor needs to make an effort for a greater amount of the domestic data to be used in estimating the public dose for Koreans.

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