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Radionuclides in fruit systems: Model prediction-experimental data intercomparison study

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Abstract

This paper presents results from an international exercise undertaken to test model predictions against an independent data set for the transfer of radioactivity to fruit. Six models with various structures and complexity participated in this exercise. Predictions from these models were compared against independent experimental measurements on the transfer of ^{134}Cs and ^{85}Sr via leaf-to-fruit and soil-to-fruit in strawberry plants after an acute release. Foliar contamination was carried out through wet deposition on the plant at two different growing stages, anthesis and ripening, while soil contamination was effected at anthesis only. In the case of foliar contamination, predicted values are within the same order of magnitude as the measured values for both radionuclides, while in the case of soil contamination models tend to under-predict by up to three orders of magnitude for ^{134}Cs, while differences for ^{85}Sr are lower. Performance of models against experimental data is discussed together with the lessons learned from this exercise.

Keywords: Radionuclides; Model-testing; Biomass; Fruit; ^{134}Cs; ^{85}Sr

1. Introduction

One of the objectives of the programme of the Fruits Working Group (preface of Carini et al., this issue), was to undertake testing and validation of existing or new models against independent data sets. The objectives of

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the exercise were to intercompare the predictions generated by the models and to compare predictions with the observed data.

This paper presents the results of the model-testing exercise that was undertaken by the participants of the Group. The exercise involved comparison of outputs from six different models with a data set for which modellers had no prior information. Various experimental data sets were offered by participants of the Group, but it was difficult to find a complete series of data describing the fluxes of radionuclides, from deposition to distribution with time within the compartments of fruit ecosystems, with supporting yield data. After discussion of possible scenarios, a data set on the transfer of ^{134}Cs and ^{85}Sr via leaf-to-fruit and soil-to-fruit in strawberry plants after an acute release was chosen and finalised for the validation exercise. This was the first model validation exercise for fruit crops. It offered the opportunity to test whether models concerned with the assessment of the transfer of radionuclides to fruits adequately describe the system modelled.

2. Description of the test scenarios

The model scenarios are based on experimental work carried out at Università Cattolica del Sacro Cuore of Piacenza (Italy) to investigate the short-term transfer of ^{134}Cs and ^{85}Sr via leaf-to-fruit and soil-to-fruit in strawberry plants after an acute release. Strawberry plants were grown in pots filled with peat substrate and placed beneath a ventilated tunnel in a field representative of horticultural growing conditions in Italy. Three groups of plants were contaminated by application of ^{134}Cs and ^{85}Sr in the form of chlorides (^{134}CsCl and $^{85}SrCl_2$) in aqueous solution, either to the above-ground part of the plant (foliar contamination) or to the soil surface (soil contamination). A synopsis of the scenario is presented below. A full description of the experimental design is given in IAEA (2003). Details and results of foliar contamination are described in Carini et al. (2003).

3. Foliar contamination scenarios

Foliar contamination was carried out on two groups of plants (9 replicates for each group) at two phenological stages, anthesis and ripening. The two treatments were named: “first foliar contamination” and “second foliar contamination”. Plants were flowering (anthesis) at the first contamination, had well-developed leaves and a few small immature green fruits. Only ^{134}Cs was included in this scenario. Plants had aged by a further 26 days by the time of the second foliar treatment, the crop was ripening, although bearing green and red fruits, and very few flowers remained. Contamination was effected with both ^{134}Cs and ^{85}Sr.

Radionuclides were applied to plants as small droplets using an aspirated spray to simulate wet deposition, while the soil surface of each pot was protected. The radioactivity sprayed over plants at each phenological stage, expressed as kBq m^{-2}, is reported in Table 1. In order to determine the activity intercepted by plant components, the above-ground parts of four plants were harvested as soon as dry after spraying, and separated into leaves and fruits. The activity intercepted by leaves and fruits, expressed as percentage of that applied, is reported in Table 1.

4. Soil contamination scenario

Soil contamination was carried out only at the anthesis stage, on 12 replicates. The soil of each pot was moistened over the entire surface with 150 ml of an

Table 1
Radioactivity sprayed over plants (kBq m^{-2} or kBq plant^{-1}) and intercepted (% of the sprayed) in the case of foliar contamination, or deposited onto the soil (kBq m^{-2} or kBq plant^{-1}) in the case of soil contamination

Contaminated compartments		Above-ground plant part	Above-ground plant part		Soil	
Treatment code		First foliar	Second foliar		Soil	
Phenological stage at time of contamination		Anthesis	Ripening		Anthesis	
Date of contamination		22 April 1998	18 May 1998		27 April 1998	
Radionuclide		^{134}Cs	^{134}Cs	^{85}Sr	^{134}Cs	^{85}Sr
Sprayed activity	kBq m^{-2}	805.1	890.8	776.6	–	–
Intercepted activity (% of the sprayed)	Leaves	36.7±0.9	29.2±1.7	30.3±1.5	–	–
	Fruits	0.23±0.07	1.16±0.22	1.20±0.24		
	Whole above-ground part	36.9±1.0	30.3±1.8	31.5±1.6		
Deposited activity	kBq m^{-2}	–	–	–	765.5	1698.2
	kBq plant^{-1}	–	–	–	147.5	327.2