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04-06. oктобар 2023. године

Будва, Црна Гора

ДРУШТВО ЗА ЗАШТИТУ ОД ЗРАЧЕЊА СРБИЈЕ И ЦРНЕ ГОРЕ

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XXXII СИМПОЗИЈУМ ДЗЗСЦГ

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**XXXII СИМПОЗИЈУМ ДРУШТВА
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Овај Зборник је збирка радова саопштених на XXXII Симпозијуму Друштва за заштиту од зрачења Србије и Црне Горе који је одржан у Будви, Црна Гора, 04-06.10.2023. године. Радови су према обрађеној проблематици груписани у једанаест секција. Сви радови у Зборнику су рецензирани од стране Научног одбора, а за све приказане резултате и тврдње одговорни су сами аутори.

*Југословенско друштво за заштиту од зрачења основано је 1963. године у Порторожу, а од 2005. носи име "Друштво за заштиту од зрачења Србије и Црне Горе". На XXXII Симпозијуму, ове године обележавамо веома значајан јубилеј - **60 година организоване заштите од зрачења на нашим просторима**.*

Од оснивања, Симпозијуми Друштва за заштиту од зрачења представљају прилику да се кроз стручни програм прикажу резултати истраживања у области заштите од зрачења, представе различите области примене извора и генератора зрачења, анализирају актуелна дешавања, размене искуства са колегама из региона, дефинишу проблеми и правци даљег унапређивања наше професионалне заједнице.

Поред тога, Симпозијуми друштва представљају и прилику да у мање формалном маниру сретнемо старе и упознамо нове пријатеље и колеге, обновимо старе и започнемо нове професионалне сарадње.

Ауторима и коауторима научних и стручних радова саопштеним на XXXII Симпозијуму се захваљујемо на уложеном труду и настојању да квалитетним радовима заједно допринесемо остваривању циљева и задатака Друштва и наставимо традицију дугу импозантних 60 година.

Посебно се захваљујемо свима који су подржали одржавање овог Симпозијума.

Свим члановима Друштва, сарадницима и колегама честитамо овај значајан јубилеј!

Организациони одбор XXXII Симпозијума ДЗЗСЦГ

SOIL TO PLANT TRANSFER OF Cs-137, Sr-90, Ra-226, Pb-210 AND K-40 IN DIFFERENT AGRICULTURAL PRODUCTS IN CROATIA

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ABSTRACT

In this study, we investigated the soil-to-plant transfer of Cs-137, Sr-90, Ra-226, Pb-210 and K-40 in different types of vegetables and fruits collected on family farms in Croatia. The difference in radionuclide distribution between different plant compartments was also investigated. Our results suggest that, in general, the transfer of selected radionuclides within studied soil/plant agricultural ecosystems is on the lower part of ranges reported by IAEA for the temperate environments. Nevertheless, for all studied radionuclides, the transfer to the fruits and vegetables peels was higher than to the pulp. Overall, observed differences in the transfer of radionuclides indicate other additional exposure pathways and mechanisms that affect radionuclide content in plants besides soil activity concentrations.

Introduction

The deposition of radionuclides on vegetation and soil represents the starting point of their transfer into the terrestrial environment and consequently food chains. For many radionuclides with medium and long half-lives, this initial deposition is the beginning of the long-term management and monitoring in the decades following nuclear and radiological accidents and incidents. Knowledge of radionuclide transfer pathways, their distribution in the environment and uptake by different plants and animals enable us to predict radionuclide fate, estimate potential exposure to humans and apply appropriate protective measures within the radiation protection system.

This study aimed to investigate differences in the soil-to-plant transfer of Cs-137, Sr-90, Ra-226, Pb-210 and K-40, as one of the key anthropogenic and naturally occurring radionuclides, to different crops (vegetables and fruits) collected on family farms located in different geographic Croatian regions. This research is conducted as a part of the Croatian Science Foundation project RiChFALL (Radioactivity in children food and novel methods for low-level activity determination, 2020. – 2024.).

Materials and Methods

Samples

In Table 1 are presented the types of fruits and vegetables analyzed in the study and their categorization according to the plant groups and plant compartment division used by IAEA [1]. When appropriate, fruits and vegetables pulp and peel were analyzed separately.

Table 1: Type of fruits and vegetables analyzed in this study

Plant group	Plant type	Plant compartment studied	Plant group	Plant type	Plant compartment studied
Leafy vegetables	Chard Spinach Kale Cabbage	Leaves	Tubers	Potato Sweet potato	Tuber, tuber peel
Non-leafy vegetables	Zucchini Paprika Cauliflower	Fruit without peel Fruit with peel Flowers, leaves	Fruits	Apple Mandarin orange Hazelnut	Fruit, fruit peel Fruit, fruit peel Seed
Root crops	Carrot	Root, root peel	Herbs	Rosemary Immortelle	Leaves and stems Leaves and stems

Sampling and sample preparation

Soil samples were taken by auger at the same agricultural fields from which the crops were collected. Each soil sample consisted of 3-5 subsamples. The weight of collected crops ranged from several up to 10 kg (fresh mass). Crop samples were washed and where appropriate (e.g.fruit and tubers) were peeled off and cut into smaller pieces. Peeled material was kept for separate analysis. All samples were oven-dried at 80°C, milled, sieved and homogenized.

For gamma spectrometry samples were packed into cylindrical beakers (125 cm^3), sealed with PVC tape and left for 3 weeks to achieve radiochemical equilibrium between ^{226}Ra and its progenies. For the ^{90}Sr determination, approximately 50 g of soil and 1 kg (fresh weight) of crop samples were dried. Dried crop samples were ashed at 600°C to remove the organic matter.

Measurements

Activity concentrations of gamma emitters in soils were determined by gamma spectrometry, using the High Purity Germanium (HPGe) detector systems within a low background lead shield. For the measurements of activity concentrations in crops, the system was upgraded with active shielding (cosmic veto) to reach lower detection limits. Broad energy Germanium detector (BEGe) with a resolution of 1.95 keV at 1332 keV, and relative efficiency of 48% was used for the crop measurements. The spectra were analyzed using Genie 2000 software. Concentration activities were calculated from the 661.6 keV line for Cs-137, 1460.6 keV line for K-40, 46.5 keV for Pb-210 while Ra-226 is calculated from the lines of its progenies (Bi-214 and Pb-214). The counting time ranged from 80,000 s for soils, up to 250,000 s for crops. Efficiency calibrations were performed mathematically using Canberra's LabSOCS tool, and they were checked using gamma mix standards.

For the Sr-90 determination, Sr from soil samples was isolated by an ion exchanger, eluted with nitric acid and evaporated to dryness. The ashed residues of crops were dissolved in nitric acid, filtered and then evaporated to dryness. For both sample types, the precipitate was dissolved in 5M HNO_3 followed by strontium separation on Sr resin. After reaching radiochemical equilibrium with Y-90, Sr-90 was determined by Cherenkov counting on Quantulus GCT 6220 liquid scintillation counter (LSC) [2].

Transfer factor calculations

Transfer factors (TF) were calculated using the approach described in IAEA [1] for soil-to-plant transfer of radionuclides in temperate environments. Soil activity concentrations used for TF calculations were averages of the results for the first three upper soil layers (0-5 cm, 5-10 cm, 10-20 cm).

Results

Activity concentration was above the detection limits in 53 %, 32 %, 21 % and 100 % analysed vegetable and fruit samples, for Cs-137, Ra-226, Pb-210 and K-40, respectively. Sr-90 was above the limits of detection in all analysed samples. Differences in the transfer of radionuclides between pulp and peel fractions are shown in Figure 1 and Figure 2. In Table 2 are presented transfer factors calculated for 23 radionuclide/plant group (pulp fractions only) combinations. Where possible, calculated TF values were compared to those from different literature sources on radionuclide transfer to plants in temperate environments compiled by IAEA [1].

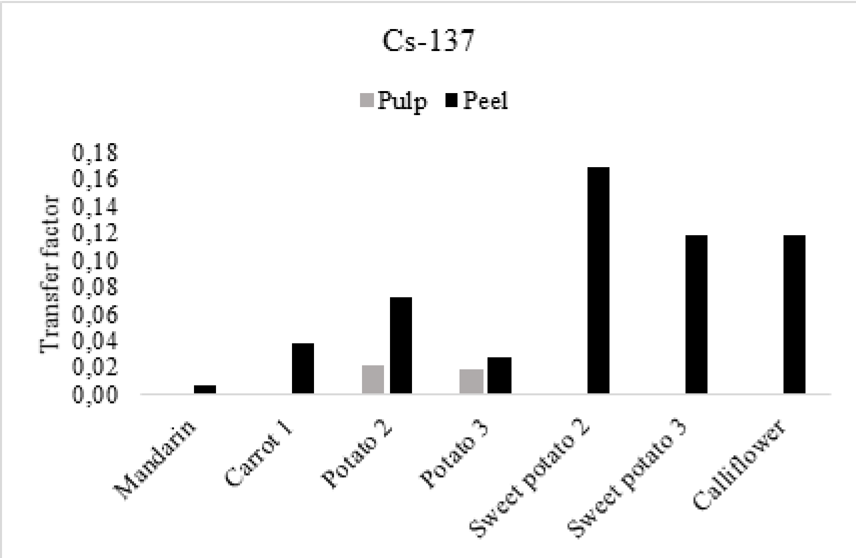

Figure 1: Comparison of Cs-137 transfer factors for pulp and peel parts of fruits and vegetables

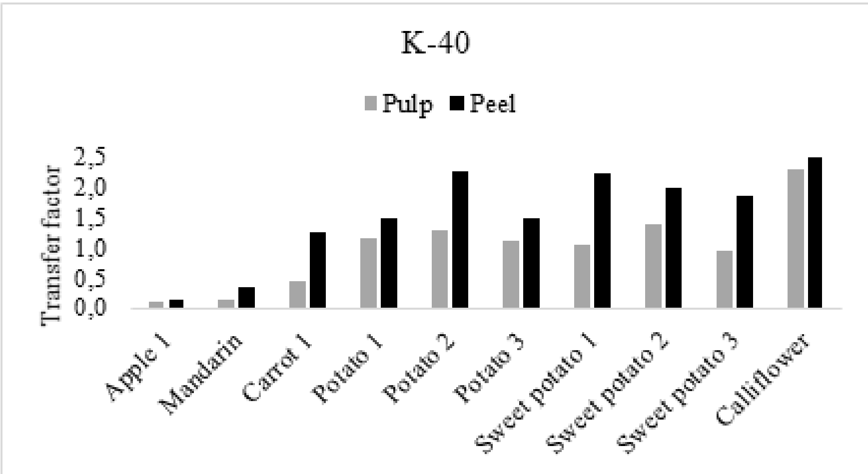

Figure 2: Comparison of K-40 transfer factors for pulp and peel parts of fruits and vegetables

Table 2: Transfer factors (TFs) of the fruits and vegetables (pulp fractions only) analysed in this study. TF values with a number of data (N) > 1 are presented by mean, minimum (Min) and maximum (Max) values. For comparison purposes mean values of TFs compiled by IAEA [1] for the radionuclide transfer to plants in temperate environments are also presentedb (soil type: all soils)

		Our study				IAEA TRS 472	
Element	Plant group	N	Mean	Min	Max	N	Mean
Cs	Leafy vegetables	2	1.09E-01	1.00E-01	1.18E-01	290	6.00E-02
	Non-leafy vegetables	2	1.75E-01	5.36E-02	2.96E-01	38	2.10E-02
	Root crops	1	5.11E-02			81	4.20E-02
	Tubers	4	1.78E-02	1.35E-02	2.17E-02	138	5.60E-02
	Fruit	1	4.26E-03			6	5.80E-03
Ra	Leafy vegetables	3	2.30E-02	9.45E-03	4.58E-02	77	9.10E-02
	Root crops	3	8.85E-02	1.99E-02	9.77E-01	60	7.00E-02
	Tubers	5	1.34E-02	7.92E-03	2.48E-02	45	1.10E-02
	Herbs	1	1.56E-02				n.d.
	Fruit	3	2.02E-03	8.38E-04	6.32E-03		n.d.
Pb	Leafy vegetables	3	1.47E-01	3.46E-02	4.16E-01	31	8.00E-02
	Herbs	2	2.17E-01	5.65E-02	3.78E-01		n.d.
K	Leafy vegetables	5	3.36E+00	1.76E+00	8.89E+00	2	1.30E+00
	Non-leafy vegetables	3	2.06E+00	1.94E+00	2.30E+00		n.d.
	Root crops	3	1.43E+00	4.52E-01	3.43E+00		n.d.
	Tubers	8	9.75E-01	4.27E-01	1.37E+00		n.d.
	Herbs	2	9.57E-01	8.78E-01	1.03E+00		n.d.
	Fruit	4	1.46E-01	7.76E-02	4.02E-01		n.d.
Sr	Leafy vegetables	3	8.44E-01	3.05E-01	1.77E+00	217	7.60E-01
	Non-leafy vegetables	3	1.46E-01	1.77E-02	5.02E-01	19	3.60E-01
	Root crops	2	6.86E-01	6.52E-01	7.20E-01	56	7.20E-01
	Tubers	4	7.10E-02	4.00E-02	1.93E-01	106	1.60E-01
	Fruit	2	1.23E-02	1.02E-02	1.49E-02	18	1.70E-02

n.d. no data

Discussion and conclusions

K-40 was the only radionuclide detected in all measured samples and also the radionuclide with the highest TFs, some of them being higher than unity. However, considering that potassium is a biogenic element, high TFs of K-40 are most likely a reflection of plant homeostasis and not bioaccumulation [3]. On the other hand, Pb-210 was below the limits of detection in the majority of samples. Therefore, for this radionuclide, it was possible to calculate TFs for only seven samples: three of them being characterized by larger surface leaves (chard, spinach and kale), two with "waxy" type of leaves (rosemary and immortelle), mandarin orange peel and sweet potato peel. These results are in line with the previous studies that indicated atmospheric deposition as the primary source of Pb-210 in plants which is usually the most pronounced in plants with significant aboveground green biomass [4,5]. However, this exposure pathway might not be significant only for Pb-210, but also for Cs-137 and Ra-226. In the cauliflower sample, these two radionuclides were below the limit of detection in its flowers, but not in cauliflower leaves that were shadowing flowers. Another exposure pathway that might have been a cause of differences in radionuclide content in cauliflower leaves and fruits is the resuspension of soil particles.

Comparison of TF values between pulp and peels of fruits and vegetables indicated uneven radionuclide distribution between these plant compartments. These differences were observed for all studied radionuclides, except for Pb-210 due to the above-mentioned low number of available data. TF values of Cs-137, Ra-226, K-40 and Sr-90 for peels were up to 12 times higher than those for the pulp fraction (on average three times). Moreover, while the activity of Cs-137 and Ra-226 was detected in approximately 20 and 50 % of pulp samples, in peel samples they were detected in 60 and 80 % of samples, respectively (Figure 1). Discrepancies in the number of data between peel and pulp TFs were not observed for K-40 and Sr-90 (Figure 2). Causes of these differences in the radionuclide content of different plant compartments might be due to the different metabolism of these radionuclides (e.g. root epidermis might serve as a barrier for some radionuclides [6] or residual soil trapped in the peel pores which usually remains even in the case of vigorous washing after sampling (and can be also related to the size and type of soil particles) [7].

The majority of TF values obtained by our study were in the same order of magnitude as mean values reported by IAEA (Table 2). On the other hand, calculated TFs for Cs in leafy and non-leafy vegetables and Pb in leafy vegetables were approximately an order of magnitude higher than the related IAEA's mean values while TF for Sr in tubers was approximately an order of magnitude lower. Overall, calculated TF values were on the lower edge of ranges reported by IAEA [1] for studied radionuclide/plant group combinations.

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PRIJENOS Cs-137, Sr-90, Ra-226, Pb-210 I K-40 IZ TLA U BILJKU U RAZLIČITIM POLJOPRIVREDNIM KULTURAMA U HRVATSKOJ

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SAŽETAK

U ovom smo radu istražili prijenos Cs-137, Sr-90, Ra-226, Pb-210 te K-40 iz tla u različite vrste povrća i voća sakupljenih na obiteljskim poljoprivrednim imanjima u Hrvatskoj. Istovremeno su istražene i razlike u prijenosu radionuklida u različite dijelove plodova. Rezultati ovog istraživanja ukazuju da je generalno prijenos radionuklida obuhvaćenih ovom studijom unutar raspona transfer faktora sugeriranih od strane IAEA za umjerena područja, ali na njihovom nižem dijelu. Unatoč nižem transferu, uočen je povišeni prijenos svih istraživanih radionuklida u kore plodova u odnosu na pulpu. Sveukupno, primjećene razlike u prijenosu radionuklida sugeriraju, osim sadržaja radionuklida u tlu, i druge mehanizme i puteve izlaganja radionuklidima, a koje utječu na njihove količine u biljkama.

САДРЖАЈ