University of Belgrade, Technical Faculty in Bor

29th International Conference Ecological Truth & Environmental Research

EcoTER'22

Proceedings

Editor
Prof. Dr Snežana Šerbula

21-24 June 2022, Hotel Sunce, Sokobanja, Serbia

University of Belgrade, Technical Faculty in Bor

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PREFACE

In today's world, the environment has been endangered by the use of outdated technology, fossil fuels and environmental law violations. Therefore, environmental and many other scientists all over the world have been concerned about finding sustainable technology in resolving these issues. That is why environmental research and ecological truth are at the focus of the 29th International Conference Ecological Truth & Environmental Research 2022 (EcoTER'22), which will be held in Sokobanja, Serbia, 21–24 June 2022. On behalf of the Organizing Committee, it is a great honor and pleasure to wish all the participants a warm welcome to the Conference.

We hope to convey the message of the conference, which is that a transformation of attitudes and behavior would bring the necessary changes. This is also an opportunity for the participants who are experts in this field to exchange their experiences, expertise and ideas, and also to consider the possibilities for their collaborative research.

The 29th International Conference Ecological Truth & Environmental Research 2022 is organized by the University of Belgrade, Technical Faculty in Bor, and co-organized by the University of Banja Luka, Faculty of Technology, the University of Montenegro, Faculty of Metallurgy and Technology – Podgorica, the University of Zagreb, Faculty of Metallurgy – Sisak, the University of Pristina, Faculty of Technical Sciences – Kosovska Mitrovica and the Association of Young Researchers, Bor.

These proceedings include 85 papers from the authors coming from the universities, research institutes and industries in 6 countries: Bulgaria, Italia, Albania, Bosnia and Herzegovina, Montenegro and Serbia.

As a part of this year's conference, the 4th Student section – EcoTERS'22 is being held. We appreciate the contribution of the students and their mentors who have also participated in the Conference.

Financial assistance provided by the Ministry of Education, Science and Technological Development of the Republic of Serbia is gratefully acknowledged by the Organizing Committee of the EcoTER'22 conference.

The support of the Platinum donor and their willingness and ability to cooperate have been of great importance for the success of EcoTER'22. The Organizing Committee would like to extend their appreciation and gratitude to the Platinum donor of the Conference for their donation and support.

We appreciate the effort of all the authors who have contributed to these Proceedings. We would also like to express our gratitude to the members of the scientific and organizing committees, reviewers, speakers, chairpersons and all the Conference participants for their support to EcoTER'22. Sincere thanks go to all the people who have contributed to the successful organization of EcoTER'22.

Prof. Snežana Šerbula,

President of the Organizing Committee

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RADIONUCLIDE CONTENT IN SAMPLES OF BERRIES

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Abstract

After the Chernobyl accident, the presence of artificial radionuclides in foodstuff, especially in berries (blueberries, cranberries etc.), was heightened. Legislative, presented in Rulebook on Radioactivity Control of Goods During the Import, Export and Transit (Official Gazette RS, 86/19 and 90/19), establishes the mandatory gamma spectrometry measurement of berries, while the limits of radionuclide content in these products is defined in the Rulebook on Limits of radionuclide content in drinking water, foodstuff, feedstuff, medicines, items of general use, building materials and other goods placed on the market (Official Gazette RS, 36/18). At the Radiation and Environment Protection Department of the Vinča Institute of Nuclear Sciences, measurements of the radionuclide activity in foodstuff are readily performed. In this paper, the results of the investigation of berries in the period of 2014 to 2021 are presented along with the amount of this produce that can be ingested by the various age groups without exceeding the annual effective dose limit of 0.1 mSv.

Keywords: radioactivity, gamma spectrometry, berries

INTRODUCTION

One of the most significant pathways of atmosphere contamination are nuclear tests, which were dominant in the period of 1945–2009 as well as the nuclear accidents, especially the one on the nuclear reactor in Chernobyl. Due to relatively long half–life of about 30 years, radionuclides ^{137}Cs and ^{90}Sr released in that period are still detectable in the environment. These radionuclides belong to a group of so called biologically significant radionuclides because they migrate and are easily incorporated in the food chain, thus representing the potential danger to all living beings.

Berries, the group of fruit such as blueberries, cranberries, currants and other, is also called forest fruit because it often grows in forests of different origin (for instance, blueberries grow mostly in the zone of deciduous, especially beech forests). It is known that this kind of fruit accumulates radionuclides, and in this way can cause the contamination of people through the food chain: air−earth−plant−animal–man [1].

Values of the ^{137}Cs activity reported in the literature vary significantly. In blueberries, during 2014 values of this radionuclide measured in Checz Republic were 16−87 Bq/kg [2]. That same year, in Switzerland, the range of measured values was 30−40 Bq/kg [3], while in Italy, during 2021, measured values reached as high as 234 Bq/kg [4].

During 1986, after the Chernobyl accident, on the teritory of former Yugoslavia, measured value of ^{137}Cs in blueberries was 240 Bq/kg (location of Kupinečki Kraljevac) [5], while during 1987, in the city of Zadar, the measured value was 58 Bq/kg [6].

Today in the Republic of Serbia, there are two Rulebooks which refer to the radioactivity control of berries. The first Rulebook [7], defines the method of the control at the border crossing, while the allowed values of the radionuclide activity are stated in the Rulebook [8]. Radiation and Environment Protection Department of the Vinča Institute of Nuclear Sciences has been measuring radioactivity in the environmental samples such as air, precipitation, water, soil, food etc, for years.

In this paper, radioactivity measurement results of berries in the period of 2014 to 2021 are presented, along with the amount of this produce that can be ingested by the various age groups without exceeding the annual effective dose limit of 0.1 mSv.

MATERIALS AND METHODS

Measurement of the fruit samples was conducted in accordance with international recommendations [9]. Preparation of the samples of berries consisted of weighing and placing the sample into the appropriate measurement geometry (Marinelli beakers). The samples were measured in native state.

The analysis was performed by gamma spectrometry, using three High Purity Germanium (HPGe) detectors, with the relative efficiency of 18 %, 20 % and 50 % respectively, produced by CANBERRA company. The resolution of the detectors is 1.8 keV on the energy of 1332 keV.

The calibration of the detection system was performed using a certified radioactive standard in Marinelli beaker, filled with the silica resin matrix produced by Czech Metrology Institute, Praha, certificate number 9031−OL−420/12, total activity 71.48 kBq on the day of August 31, 2012 (containing ^{241}Am, ^{109}Cd, ^{139}Ce, ^{57}Co, ^{60}Co, ^{137}Cs, ^{113}Sn, ^{85}Sr, ^{88}Y and ^{203}Hg) and Czech Metrology Institute, Praha, certificate number 1035−SE−40845−17 total activity 80.64 kBq on the day of December 22, 2017 (containing ^{241}Am, ^{109}Cd, ^{139}Ce, ^{57}Co, ^{60}Co, ^{137}Cs, ^{113}Sn, ^{85}Sr, ^{88}Y, ^{51}Cr and ^{210}Pb).

Measurement results are given with the measurement uncertainty expressed as the expanded measurement uncertainty with a coverage factor k=2, which corresponds to a 95 % level of confidence for the normal distribution.

RESULTS AND DISCUSSION

A total of 1038 samples of berries were analyzed in the period from 2014 to 2021. Specification of the samples along with measurement results and estimated annual effective dose are presented in the Table 1.

In 1.2 % of the total number of analyzed samples of berries, a certain activity of the artificial radionuclide ^{137}Cs has been detected, as was expected due to its half life of 30 years corresponding to the time that has passed since the Chernobyl accident of 1986. In the samples of certain species (currants, strawberries, raspberries and goji berries) the detected activities of ^{137}Cs did not exceed the minimal detectable activity (MDA). Minimal measured values for all species is equal to the MDA. It can be seen, based on the values presented in the Table 1, that the maximal value was measured in blueberries and was (330 ± 20) Bq/kg. The maximal average value was also obtained for blueberries and was equal to 70.8 Bq/kg. Due to the wide range of the results, spanning from 2.1 Bq/kg to 330 Bq/kg, standard deviation of the detected activity was close to 82 Bq/kg. For other species of berries, average value of ^{137}Cs activity does not vary significantly and is within the range from 11.7 Bq/kg for blackberries to 18 Bq/kg for chokeberry. Measured activities of ^{137}Cs are similar to those found in the literature [2−4].

Table 1 *Activity of* ^{137}Cs *in berries samples (A) and effective annual dose* (H_E)

Type of berry	Number of samples	Number of samples with A > MDA	A_{max} [Bq/kg]	A_{min} [Bq/kg]	A_{avr} ± St. Dev [Bq/kg]	H_E [mSv]
Blueberry	836	174	330 ± 20	<10	70.8 ± 81.7	0.007−0.220
Cranberry	76	8	50 ± 5	< 8	13 ± 16	0.005−0.033
Blackberry	32	8	33 ± 6	< 5	11.7 ± 9.8	0.003−0.022
Currants	27	0	/	< 4	/	/
Red mix	27	5	22 ± 3	< 6	11.8 ± 8.9	0.004−0.015
Strawberry	14	0	/	< 4	/	/
Raspberry	14	0	/	< 3	/	/
Chokeberry	11	2	24 ± 4	< 6	18.0 ± 8.5	0.004−0.016
Goji berries	1	0	/	< 2	/	/

According to the legislative enforced in the Republic of Serbia [8], allowed value of the ^{137}Cs content in berries (150 Bq/kg) is exceeded in 1.2 % of tested samples. Measured activities in these samples ranged from 150 to 330 Bq/kg and were all detected in the samples of blueberries.

The limits of activity of detected radionuclides is obtained in such a way that ensures that the annual effective dose by ingestion for the public does not exceed 0.1 mSv. The annual effective dose (H_E) is determined according to the following equation:

$$H_E = M \cdot A \cdot F \tag{1}$$

where M represents the average annual consumption of the investigated produce in kg, A – value of the ^{137}Cs activity in the investigated produce in Bq/kg, and F is a dose conversion factor for the given radionuclide (Sv/Bq). The values of dose conversion factors depend on the age group for which the annual effective dose is calculated and can be found in the Annex of the Rulebook on Limits of Radioactive Contamination of People, Working and Living Environment and Ways of Performing Decontamination [10].

Since there are no data regarding the annual consumption of berries in the Republic of Serbia, based on the allowed activity of ^{137}Cs in berries [8] and dose conversion factor for different age groups [10], the quantity of berries consumed, which would not lead to the exceeding the 0.1 mSv annual effective dose, are calculated. Thus calculated maximal allowed consumption for different age groups are presented in the Table 2.

Using this information, the intervals of the annual effective dose received by each age group by consuming the investigated samples in the amounts defined in the Table 2, are presented in the last column of the Table 1.

Table 2 *The quantity of annual consumption of berries with respect to the population age group*

Age of the population	**< 1**	**1−2**	**2−7**	**7−12**	**12−17**	**> 17**
Dose conversion factor for ^{137}Cs, F (10^{-8} Sv/Bq)	2.1	1.2	0.96	1	1.3	1.3
Annual intake [kg]	31.7	55.6	69.4	66.7	51.3	51.3
Daily intake [g]	87.0	152.2	190.3	182.6	140.5	140.5

It can be seen from the Table 2, that the estimated intake of berries for the population over 17 years of age is 51 kg (about 140 g/day), while for babies up to 1 year of age it is close to 32 kg (about 87 g/day). It is also assumed that the largest amount of berries is consumed by the children aged 2–7 years, about 70 kg per year.

Table 3 presents the activity concentration of ^{137}Cs for different age groups, with respect to the estimated annual consumption, that would lead to the exceeding of the 0.1 mSv annual effective dose limit.

Table 3 *Activity concentration of* ^{137}Cs *in berries samples which leads to the exceeding of the annual effective dose limit of 0.1 mSv, with respect to the different amounts of annual consumption and population age group*

Annual intake [kg]	**36**	**18**
Age of the population	A(^{137}Cs) [Bq/kg]	
< 1	132	265
1−2	231	463
2−7	289	579
7−12	278	556
12−17	214	427
> 17	214	427

From this estimation it can be concluded that with a smaller intake of 36 kg (about 100 g/day) or 18 kg (about 50 g/day) persons of 12 years of age and above can safely consume even berries that have ^{137}Cs activity of 210 Bq/kg and 420 Bq/kg, respectively.

Using the same amounts, the population of 2−7 years of age can safely consume berries that have 290 Bq/kg and 580 Bq/kg of ^{137}Cs, respectively.

Taking into account that the maximal detected activity of ^{137}Cs was 330 Bq/kg, all investigated samples may be considered safe for consumption for the population above 1 year of age in the amount that does not exceed 18 kg per year. Only 2 of all 1038 investigated samples (blueberries) were not safe for consumption for age groups below 2 and above 12 years of age, in the amounts larger than 36 kg per year. The sample with the maximum detected ^{137}Cs activity, could be safely consumed by the population of 2–7 years of age, in the amounts no larger than 31 kg per year, while for all other age groups, the safe amount would be up to 14 kg per year.

CONCLUSION

In the Radiation and Environment Protection Department of the Vinča Institute of Nuclear Sciences, 1038 samples of berries, of which 80 % were blueberries, were analyzed in the period from 2014 to 2021. All measured activities of ^{137}Cs are similar to those found in the literature [2−4].

Activities of ^{137}Cs that exceed the values allowed by the Rulebook [8] were in the range of 150−330 Bq/kg and were detected only in the samples of blueberries (total of 12 samples). Minimum and maximum average ^{137}Cs activity were 11.7 Bq/kg for blackberries and 70.8 Bq/kg in blueberries, respectively. Due to wide range of detected activities (2.1–330 Bq/kg), standard deviation of ^{137}Cs activity in blueberries was close to 82 Bq/kg. In all other species of berries, except blueberries, the measured activity was below or equal 18 Bq/kg.

It is estimated that by consuming majority of tested samples in the quantities provided for certain age groups of the population, the received effective dose would not contribute to the increase of the total received annual dose by more than 0.1 mSv. Thus, depending on the age and living habits (consumption of certain species of berries), it is safe to consume even those berries in which the ^{137}Cs activity exceeds the limit of 150 Bq/kg.

Taking into account that, at the moment of investigation, the information about the geographical origin of samples was not available, it is not possible to establish a connection between the origin of the sample and the measured ^{137}Cs activity.

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