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Prof. Dr Snežana Šerbula

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ACTIVTY CONCENTRATIONS OF ^{210}Pb, ^{137}Cs, AND ^{40}K IN WILD MUSHROOMS FROM SERBIA AND THEIR EFFECTIVE DOSE TO INGESTION

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Abstract

Fourteen samples of nine different species were collected in the region of Fruška gora, the suburban areas of Belgrade, and the vicinity of Vlasina Lake (Serbia) have been analyzed from the radiological point of view. Specific activities of radionuclides ^{210}Pb, ^{137}Cs, and ^{40}K were measured using a semiconductor HPGe spectrometer system in these wild mushroom samples. The activity concentrations of all measured dried wild mushrooms are for ^{210}Pb: between 2.05 Bq/kg and 9.74 Bq/kg; for ^{137}Cs: between < 0.2 Bq/kg and 19.3 Bq/kg; for ^{40}K between 704 Bq/kg and 2530 Bq/kg. The total individual annual effective doses due to ingestion of ^{210}Pb, ^{137}Cs, and ^{40}K radionuclides within a 0.5 kg dry mass of the wild mushrooms is between 3.99 µSv and 10.81 µSv, and are much lower than the recommended level for the public (1 mSv/y).

Keywords: wild mushrooms, radioactivity, annual effective dose.

INTRODUCTION

The environmental contamination caused by global fallout due to atmospheric nuclear weapons testing, which peaked in 1963, as well as various nuclear accidents such as Chernobyl and Fukushima, has contributed to the presence of anthropogenic radionuclides in the environment [1]. Furthermore, the use of radionuclides in everyday life has also led to contamination with anthropogenic radionuclides. On the other hand, it is important to pay attention to the presence of naturally occurring radionuclides, particularly in regions with high levels of radioactivity and near uranium mines.

Mushrooms have the ability to accumulate both anthropogenic and naturally occurring radionuclides, particularly in areas with high levels of radioactive fallout. This is due to the fact that certain species of mushrooms absorb and concentrate radionuclides from the substrate in which they grow. As a result, they are considered excellent bioindicators of environmental pollution within their ecosystem. Studies have found that wild mushrooms typically have higher levels of radioactivity than cultivated mushrooms. However, it is important to note that the accumulation of radionuclides in mushrooms can pose a radiological hazard [2–5].

Measuring the levels of radioactivity in mushrooms allows us to assess the degree of radioactive contamination in the nearby soil and air. The amount of radionuclides found in wild mushrooms can be influenced by several factors, including the composition and moisture of the soil, climate, radioactive fallout, and natural radionuclides present in the environment. Additionally, the radioactivity levels found in mushroom fruit bodies are dependent on various factors such as the mushroom species, its nutrition and ecology (whether it's saprophytic or mycorrhizal), the depth of the mycelium in the substrate from which the mushroom obtains nutrients and radionuclides, and the vertical distribution of radionuclides in the soil [2,3,6]. In spite of that, it has been observed that even for the same mushroom species in the same location and at the same time, there can be significant variation in the radioactivity concentration recorded [1].

Although various radionuclides have been investigated in mushrooms in different countries worldwide [2,4–10], most attention is given to ^{137}Cs because it is a long-lived radionuclide and chemically similar to potassium. The analysis of the radioactive content of mushrooms reported in the literature was also focused on ^{40}K, as mushrooms contain between 1.5 g and 117 g of potassium per kg of dry matter (d.m.) [2]. On the other, ^{210}Pb has a significantly higher effective dose coefficient (52 times higher than for ^{137}Cs and 91 times higher than for ^{40}K). Therefore, it was the subject of our research.

Guillén and Baeza [5] gave an exhaustive review of the radioactivity levels of mushrooms. According to their findings, the range of radiocesium content in mushrooms worldwide since 1986 varies greatly, spanning nine orders of magnitude from 0.4 Bq/kg d.m. to 50.7 MBq/kg d.m. As potassium is an essential nutrient, its range of variation is limited, spanning only three orders of magnitude, with the most commonly reported values for ^{40}K falling between 1000 Bq/kg d.m. and 2000 Bq/kg d.m., depending on the mushroom species (ranging from 70 Bq/kg d.m. to 3.52 kBq/kg d.m.). Besides, their paper reports that the range for ^{210}Pb falls between 0.75 Bq/kg d.m. and 289 Bq/kg d.m. [5].

The objective of this study is to analyze the content of radionuclides ^{210}Pb, ^{137}Cs, and ^{40}K in fourteen samples of nine different wild mushroom species from three regions of Serbia (Fruška gora, suburban areas of Belgrade, and vicinity of Vlasina Lake). Additionally, the study aims to estimate the individual annual effective dose resulting from ingestion of these mushrooms.

MATERIALS AND METHODS

Fourteen samples of nine different wild mushroom species were collected from three regions in Serbia: Fruška gora, suburban areas of Belgrade, and the vicinity of Vlasina Lake. As a first step, all samples were thoroughly cleaned of impurities. Since mushroom fruit bodies are often consumed completely, the stalks and caps of each sample were initially sundried together for several days and then dried at 105 °C for 24 h in a temperature-controlled oven. Each dried mushroom sample was separately homogenized to a fine powder using a laboratory blender and stored in a suitable standard cylindrical PVC container with a volume of 125 ml prior to analysis. The mass of each individual sample was up to 30 g, adequate to the working standard, which contains dried grass as a matrix. The matrix of dried grass was spiked with a radioactive solution with a common mixture of gamma ray emitters (^{241}Am, ^{109}Cd, ^{139}Ce, ^{57}Co, ^{60}Co, ^{137}Cs, ^{113}Sn, ^{85}Sr, and ^{88}Y) purchased from CMI (Czech Metrology Institute). The working standard was prepared at the Laboratory for Nuclear and

Plasma physics, "Vinča" Institute of Nuclear Sciences, National Institute of Republic of Serbia, University of Belgrade [11,12].

The samples were analyzed using a Canberra GX5019 coaxial HPGe spectrometer with a 55% relative efficiency and 1.9 keV resolution for ^{60}Co at 1332.5 keV, in close detector geometry. The spectra of wild mushrooms samples were recorded and analyzed using Canberra Genie2000 software. To obtain reliable results, the samples were measured for up to 575,000 seconds to ensure acceptable statistical accuracy.

The activity concentrations of radionuclides ^{210}Pb, ^{137}Cs, and ^{40}K in wild mushroom samples were determined directly by analyzing full-energy peaks at 46.54 keV, 661.66 keV, and 1460.82 keV, respectively. Corrections for background were taken into account. It should be noted that the net peak area at 1460.82keV was corrected for the contribution of the ^{228}Ac peak at 1459.13 keV energy. The uncertainty of measurement was determined by applying the general law of propagation of uncertainty. The largest contribution to the total uncertainty was due to the statistical uncertainty (in some samples more than 40% for ^{137}Cs) and efficiency calibration (5%), whereas uncertainty due to measured mass of the sample could be neglected.

The individual annual effective dose, E_{ing}, received by an individual adult due to yearly ingestion of 0.5 kg dry mass of the wild mushrooms is calculated according to the following formula [5]:

$$E_{\text{ing}} = \Sigma E_{\text{ingj}} = \Sigma A_{\text{sj}} H DF_{\text{ingj}} \quad (1)$$

where E_{ingj} is the individual annual effective dose due to ingestion of specific radionuclide j in the wild mushrooms [Sv], A_{sj} is the activity concentration of specific radionuclide j in dried wild mushrooms sample [Bq/kg], H is the annual amount of dry mass of the wild mushroom ingested per year by the standard individual [kg], and DF_{ingj} is the effective dose coefficient for ingestion of specific radionuclide j [Sv/Bq].

The effective dose coefficients for ingestion of specific radionuclide are: 6.8 10^{-7} Sv/Bq for ^{210}Pb, 1.3 10^{-8} Sv/Bq for ^{137}Cs, and 6.2 10^{-9} Sv/Bq for ^{40}K and [13,14].

RESULTS AND DISCUSSION

The activity concentrations of ^{210}Pb, ^{137}Cs, and ^{40}K radionuclides in fourteen dried samples of nine different wild mushroom species collected in the region of Fruška gora, the suburban areas of Belgrade, and the vicinity of Vlasina Lake (Serbia) with uncertainties of measurement at the confidence level 1 σ, are presented in Table 1.

The activity concentration of radionuclides presented in Table 1. are given for dried wild mushroom samples in order to compare our experimental data with the literature ones obtained for fresh mass. A dry/wet ratio of 0.1 can be used, according to the mean value reported in literature [2,5,15].

Table 1 *^{210}Pb, ^{137}Cs, and ^{40}K specific activities in dried samples of wild mushrooms with uncertainties of measurement at the confidence level of 1σ, and calculated values of total individual annual effective doses due to ingestion of ^{210}Pb, ^{137}Cs, and ^{40}K radionuclides within a 0.5 kg of dry mass of the wild mushrooms*

Mushroom species	Family	Ecology	Edibility	Location	A_s [Bq/kg]			E_{ing} [μSv/y]
					^{210}Pb	^{137}Cs	^{40}K	
Amanita pantherina	Amanitaceae	m	p	a	5.82 ± 0.63	0.89 ± 0.35	1464 ± 75	6.52
Amanita vittadinii	Amanitaceae	m	u	b	8.67 ± 0.93	1.19 ± 0.35	2530 ± 130	10.81
Cantharellus cibarius	Cantharellaceae	m	e	c	2.76 ± 0.59	7.30 ± 0.98	967 ± 50	3.99
Boletus edulis	Boletaceae	m	e	b	8.19 ± 1.22	1.40 ± 0.31	973 ± 50	5.81
Boletus edulis	Boletaceae	m	e	c	2.87 ± 0.72	19.3 ± 1.3	704 ± 37	5.08
Hypsizygus Tessularus	Lyophyllaceae	s	e	b	6.70 ± 0.88	3.07 ± 0.36	1187 ± 60	5.98
Hypsizygus Tessularus	Lyophyllaceae	s	e	b	3.25 ± 0.40	2.49 ± 0.35	1056 ± 54	4.39
Clytocybe rivulosa	Omphalotaceae	s	p	a	5.53 ± 0.52	1.20 ± 0.21	1380 ± 70	6.17
Clytocybe rivulosa	Omphalotaceae	s	p	b	5.73 ± 0.66	0.95 ± 0.20	1776 ± 90	7.47
Lepiota lilacea	Agaricaceae	s	p	a	5.38 ± 0.56	0.76 ± 0.27	1223 ± 62	5.62
Lepiota lilacea	Agaricaceae	s	p	b	9.21 ± 0.80	< 0.3	1464 ± 74	7.67
Lepiota lilacea	Agaricaceae	s	p	b	9.74 ± 1.06	< 0.2	2010 ± 100	6.52
Macrolepiota procera	Agaricaceae	s	p	a	4.94 ± 0.53	< 0.2	1036 ± 53	4.89
Macrolepiota konradii	Agaricaceae	s	p	b	2.05 ± 0.25	1.18 ± 0.33	1980 ± 100	6.86

m – mycorrhizal fungi, s – saprophytic fungi; p – poisonous, u – unknown, e – edible; a – Fruška gora, b – suburban areas of Belgrade, c – vicinity of Vlasina lake.

The activity concentrations of all measured dried wild mushrooms is for ^{210}Pb: between 2.05 Bq/kg (*Macrolepiota konradii* from suburban area of Belgrade) and 9.74 Bq/kg (*Lepiota lilacea* from suburban area of Belgrade); for ^{137}Cs: between < 0.2 Bq/kg (*Lepiota lilacea* from suburban area of Belgrade and *Macrolepiota procera* from Fruška gora) and 19.3 Bq/kg (*Boletus edulis* from vicinity of Vlasina lake); for ^{40}K between 704 Bq/kg (*Boletus edulis* from vicinity of Vlasina Lake) and 2530 Bq/kg (*Amanita vittadinii* from suburban area of Belgrade).

The activity concentration values of radionuclides presented in Table 1 can be considered to be at very low contamination levels, compared to the specific activity concentration limits set by the international legislation. The limits are: 113 Bq/kg d.m. for ^{210}Pb, 6000 Bq/kg d.m. for ^{137}Cs, and 12581 Bq/kg d.m. for ^{40}K [2,5,16].

The total individual annual effective doses due to ingestion of ^{210}Pb, ^{137}Cs, and ^{40}K radionuclides within a 0.5 kg of dry mass of the wild mushrooms, calculated according Equation (1), with corresponding uncertainties at the confidence level of 1σ are also given in Table 1.

The total individual annual effective doses calculated by Equation (1) are based on the conservative assumption that all species of mushrooms are edible, consumed raw, and the entire radionuclide content in the mushroom can be assimilated by the human body [2].

The individual annual effective doses due to ingestion radionuclides within a 0.5 kg dry mass of the wild mushrooms is for ^{210}Pb: between 0.70 µSv (*Macrolepiota konradii* from suburban area of Belgrade) and 3.31 µSv (*Lepiota lilacea* from suburban area of Belgrade); for ^{137}Cs: between < 1 nSv (*Lepiota lilacea* from suburban area of Belgrade and *Macrolepiota procera* from Fruška gora) and 125 nSv (*Boletus edulis* from vicinity of Vlasina Lake); for ^{40}K between 2.18 µSv (*Boletus edulis* from vicinity of Vlasina Lake) and 7.85 µSv (*Amanita vittadinii* from suburban area of Belgrade).

The total individual annual effective doses due to ingestion of ^{210}Pb, ^{137}Cs, and ^{40}K radionuclides within a 0.5 kg of dry mass of the wild mushrooms is between 3.99 µSv (*Cantharellus cibarius* from vicinity of Vlasina Lake) and 10.81 µSv (*Amanita vittadinii* from suburban area of Belgrade), and are much lower than the recommended level for the public (1 mSv/y) [2,5,17].

CONCLUSION

The total individual annual effective doses due to ingestion were estimated based on measured activity concentration of ^{210}Pb, ^{137}Cs, and ^{40}K in 14 samples of 9 different species of wild mushrooms collected in the region of Fruška gora, the suburban areas of Belgrade, and the vicinity of Vlasina Lake (Serbia). All values of measured can be considered as a very low contamination level, compared to the specific activity concentration set by the international legislation. The calculated total individual annual effective doses resulting from ingestion of ^{210}Pb, ^{137}Cs, and ^{40}K radionuclides within a 0.5 kg of dry mass of the wild mushrooms are significantly lower than the recommended level for the public (1 mSv/y).

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