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ESTIMATION OF RADIOACTIVITY DOSE RATE ABSORBED WITH INGESTED MUSHROOMS AND RELATED HEALTH RISK

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Abstract: The fruiting bodies of fungi sprout from mycelium are capable of accumulating significant amounts of trace elements, both metals and metalloids. Content of these elements in fruiting bodies may exceed their concentration in the substrate where fungi develop. Among the elements the radioactive nuclides are also present. In this work health risk caused by increased radioactivity dose absorbed with *Xerocomus badius* bay bolete consumption was estimated. In analysis concentrations of radioactive isotopes ^{137}Cs and ^{40}K were taken into consideration. It was found that moderate ingestion of bay bolete does not create health risk due to increased radioactive substances intake. The amount of consumed mushrooms that could deliver the dose exceeding the safe one, is rather improbable in real life.

Keywords: fungi, isotopes, radioactivity dose

Mushrooms can accumulate heavy metals in general, including radionuclides found in the nature. Radionuclides present in the environment are absorbed both from soil through mycelium, and directly through the whole fruiting body surface [1]. The examination of ^{137}Cs content in fungi demonstrated significant selectivity in absorbing this radionuclide from soil. The following species demonstrated the highest level of caesium absorption: poisonous (though sometimes consumed) brown roll-rim (*Paxillus involutus*), as well as the tasty and popular bay bolete (*Xerocomus badius*) [2-6]. The mechanism of absorbing caesium by bay bolete was explained by the presence in its fruiting body cap of phenyl dye (the so-called badion A), which complexes potassium ions and alternatively caesium ions [7]. To evaluate the radiological impact we calculated the dose due to mushroom consumption. This parameter is primarily conditioned by the radionuclide concentrations in the mushrooms.

Materials and methods

The samples of bay bolete were collected in three areas:

A - forests in the Hradce Kralove area,
B - forests near Trebechovice pod Orebem,
C - forests of Kotlina Klodzka, the border zone between Poland and Czech Republic.

The measurement of ^{137}Cs and ^{40}K activity in mushrooms were carried out by means of a gamma-spectrometer with a germanium detector HPGe (Canberra) of high resolution: 1.29 keV (FWHM) at 662 keV and 1.70 keV (FWHM) at 1332 keV. Relative efficiency: 21.7%. Energy and efficiency calibration of the gamma spectrometer was performed with

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the standard solutions type MBSS 2 (Czech Metrological Institute, Prague, CZ) which covers an energy range from 59.54 to 1836.06 keV. Geometry of calibration source was Marinelli (447.7 ± 4.48 cm^3) with density 0.985 ± 0.01 g/cm^3, containing ^{241}Am, ^{109}Cd, ^{139}Ce, ^{57}Co, ^{60}Co, ^{137}Cs, ^{113}Sn, ^{85}Sr, ^{88}Y and ^{203} Hg. Geometry of samples container was Marinelli, 450 cm^3. Measuring process and analysis of spectra were computer controlled with use of the software GENIE 2000. The radiation spectrum was recorded day and night.

Results and discussions

The obtained measurement results, as well as the information published in relevant legal acts binding in Poland, were used for the assessment of risk related to the consumption of bay bolete. The indicators included in the Regulation [8] were applied in order to calculate the annual dose of internal exposure, caused by the consumption of bay bolete collected in the examined area. The loading effective dose *E*, being a result of a nuclide penetrating through the digestive system, was calculated from the formula:

$$E = e(g)A \qquad (1)$$

where *e*(*g*) is conversion factor for persons in the age group *g* expressed in [Sv/Bq], and *A* is the activity of a radionuclide, which penetrated into the organism through the digestive and respiratory systems, expressed in [Bq].

Together with the consumed fungus, our organism is penetrated not only by the natural radioactive isotopes (especially ^{40}K), but also by the radioactive ^{137}Cs, which is accumulated in all soft tissues, and consequently removed from the organism.

The committed effective doses of ^{137}Cs and ^{40}K, included in Table 4 of the Regulation for the total population, related to the penetration of a nuclide with the activity concentration of 1 Bq, are shown in Table 1.

It can be noticed that with the same level of nuclide activity penetrating the organisms of a child and adult, the child will receive a bigger dose. Due to the smaller total weight, the absorbed energy for one body weight unit will be higher for a child than for an adult.

Table 1

Values of the committed effective doses of ^{137}Cs and ^{40}K in different age groups *g*, related to penetration of a nuclide with the activity concentration of 1 Bq [30]

e(*g*) [Sv/Bq]	*g* ≤ 1 year	*g* > 1 year	*g* = 2-7 years	*g* = 7-12 years	*g* = 12-17 years	*g* >17 years
^{137}Cs	$2.1 \cdot 10^{-8}$	$1.2 \cdot 10^{-8}$	$9.6 \cdot 10^{-9}$	$1.0 \cdot 10^{-8}$	$1.3 \cdot 10^{-8}$	$1.3 \cdot 10^{-8}$
^{40}K	$6.2 \cdot 10^{-8}$	$4.2 \cdot 10^{-8}$	$2.1 \cdot 10^{-8}$	$1.3 \cdot 10^{-8}$	$7.6 \cdot 10^{-9}$	$6.2 \cdot 10^{-9}$

Considering the fact that fungi are not an obligatory component of children's diet and are introduced only for older children, there were two age groups - 12-17 and above 17 - taken into account.

In order to calculate the committed effective dose *E*, resulting from the penetration of a nuclide through the digestive system (*ie* by the consumption of the examined fungi), it was assumed on the basis of EFSA data [9, 10] that the maximum fungus consumption in a longer period may reach the level of 100 g per week. This amount corresponds to the consumption of approximately 5 kg of fresh fungi per year and a higher level of consumption should only take place sporadically. Taking into consideration the fact that fresh fungi contain 90% of water, while dry fungi contain 15% of water, the adopted annual consumption level of dry fungi for further calculations of loading effective dose was determined at the level of 0.5 kg.

Table 2 presents data characterizing the distribution of committed effective dose as a result of the absorption of ^{137}Cs and ^{40}K together with the consumed fungus, for persons in a relevant age group. Minimum (*Min*) and maximum (*Max*) values, lower quartiles (Q_1), medians (Q_2), upper quartiles (Q_3), arithmetic mean values (*mean*) and standard deviation (*SD*) were presented.

Table 2

Distribution of committed effective dose as a result of ^{137}Cs and ^{40}K absorption together with the consumed fungus, for persons in a relevant age group

E [mSv/year]	**Min**	**Max**	**Q_1**	**Q_2**	**Q_3**	**mean**	***SD***
	g = 12-17 years						
^{137}Cs	0.003	0.016	0.005	0.006	0.009	0.008	0.005
^{40}K	0.002	0.004	0.002	0.003	0.004	0.003	0.001
	$g \geq 17$ years						
^{137}Cs	0.003	0.016	0.005	0.006	0.009	0.008	0.005
^{40}K	0.001	0.004	0.002	0.002	0.003	0.002	0.001

The data included in the table indicate that the effective dose received together with the consumed fungus from ^{137}Cs is significantly higher than the dose from ^{40}K. Therefore, it can be ascertained that a diet rich in fungi may cause an increase of the received annual effective dose.

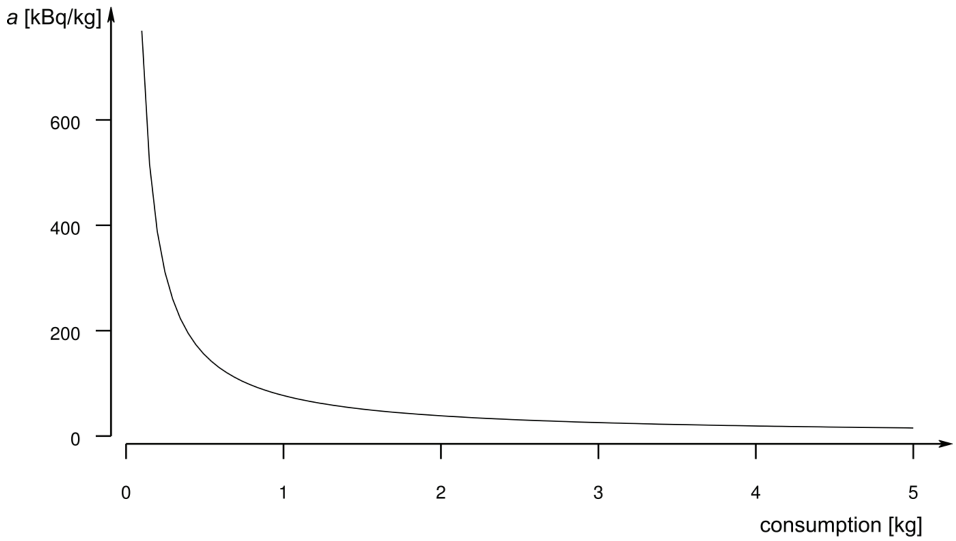

Fig. 1. The relationship between the consumption rate of bay boletes contaminated with ^{137}Cs and the level of this contamination, assuming that the dose of 1 mSv will not be exceeded (conversion factor $1.3 \cdot 10^{-8}$)

The analysis of data presented in the table allows to notice that the calculated maximum value of effective dose originating from ^{137}Cs amounts to 0.016 mSv/year, which is only 1.6% of the limit dose referred to in Regulations [8].

Figure 1 presents the relationship between the consumption rate of bay boletes contaminated with ^{137}Cs and the level of this contamination, assuming that the dose of 1 mSv will not be exceeded (for conversion factor $1.3 \cdot 10^{-8}$).

Assuming that a human being does not consume any other contaminated fungi or stay in a contaminated environment, the dose of 1 mSv will only be exceeded after consuming the amount of 0.25 kg of dried bay bolete with the activity of 300 kBq/kg. Also the consumption of 5 kg of dried fungi with the activity of approximately 15 kBq/kg will cause the dose of 1 mSv to be exceeded. Due to a small presence of fungi in the annual diet, as well as the maximum ^{137}Cs activity in dried bay bolete, amounting to approximately 1.2 kBq/kg, it can be acknowledged that the health risk related to the consumption of bay bolete collected in the examined area is insignificant.

Conclusions

Moderate ingestion of bay bolete collected in the investigated area does not create health risk due to increased radioactive substances intake. The amount of consumed mushrooms that could deliver the dose exceeding the safe one, is rather improbable in real life. The risk is also lowered because of obvious decrease of ^{137}Cs content in bay bolete.

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OCENA DAWKI WCHŁANIANEJ W WYNIKU SPOŻYCIA GRZYBÓW I RYZYKO DLA ZDROWIA Z TYM ZWIĄZANE

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Abstrakt: Owocniki grzybów wyrastające z grzybni są zdolne do gromadzenia znacznych ilości pierwiastków śladowych zarówno metali, jak i niemetali. Zawartość tych pierwiastków w owocnikach może wielokrotnie przekroczyć ich stężenia w podłożu. Wśród pochłoniętych pierwiastków są również nuklidy promieniotwórcze. Dokonano oceny potencjalnych dawek skutecznych promieniowania gamma w wyniku wchłonięcia ^{137}Cs i ^{40}K wraz ze spożywanym grzybem. Na podstawie wyników pomiarów stwierdzono, że umiarkowane spożycie podgrzybka brunatnego nie stwarza zagrożenia dla zdrowia ze względu na zwiększone spożycie substancji radioaktywnych.

Słowa kluczowe: grzyby, radionuklidy, metale alkaliczne