OPEN ACCESS
Potravinarstvo® Scientific Journal for Food Industry
Crossref Similarity Check Powered by iThenticate

potravinárstvo®

Potravinarstvo, vol. 10, 2016, no. 1, p. 243-247
doi:10.5219/578
Received: 15 December 2015. Accepted: 5 April 2016.
Available online: 14 June 2016 at www.potravinarstvo.com

ISSN 1337-0960 (online)

^{137}Cs MONITORING IN THE MEAT OF WILD BOAR POPULATION IN SLOVAKIA

Katarína Beňová, Petr Dvořák, Martin Tomko, Marcel Falis

ABSTRACT

Currently, due to the elapsed time and the nature of the Chernobyl accident, the only artificial radionuclide present in the soil is ^{137}Cs, with a physical half-life conversion of 30.17 years. The ^{137}Cs is quickly integrated into a biological cycle, similar to potassium. Generally, radionuclides are characterized by their mobility in soil. Contamination of materials and food by radionuclides represent a serious problem and has a negative impact on human health. The threat of international terrorism and the inability to forestall the impact of natural disasters on nuclear energetic (Fukushima accident), are also reasons for continuous monitoring of food safety. According screening measurement performed in European countries, high radioactivity levels were reported in the wild boars muscles from Sumava (Czech Republic). Seasonal fluctuation of ^{137}Cs activity in the wild boar meat samples was observed in the forests on the southern Rhineland. Monitoring of ^{137}Cs activity in the wild boar meat samples in the hunting grounds in Slovakia was initiated based on the reports on exceeding limits of the content of radiocaesium in the meat of wild boar from the surrounding countries. The aim of this study was to determine the ^{137}Cs post Chernobyl contamination of wild boars population in different hunting districts of Slovakia during 2013 – 2014. A total of 60 thigh muscle samples from wild boars of different age categories (4 months – 2 years) were evaluated. ^{137}Cs activity was measured by gamma spectrometry (Canberra). Despite the fact Slovakia is closer to Chernobyl as Czech Republic and Germany, the ^{137}Cs activity measured was very low and far below the permitted limit. The highest radiocaesium activity level measured in muscle was 37.2 Bq.kg^{-1} ±4.7%. Wild boar originated from Zlate Moravce district. The measurement results show, that ^{137}Cs contamination levels of game in Slovakia are low. Radiocaesium activity in examined samples was very low and therefore consumption of wild boar meat does not represent a health risk problem.

Keywords: wild boar; contamination; radiocaesium; Slovakia

INTRODUCTION

In the terrestrial environment of Europe the contamination by anthropogenic radionuclides comes from two different sources. The first was the global atmospheric fallout, which appeared after the start of intensive atmospheric nuclear weapons tests in the 50-ies of the last century, and has been observed for a long time after their completion in 1963.

From the radio-ecological perspective are relevant only the long-living components of nuclear weapons tests (^{90}Sr, ^{137}Cs, ^{238}Pu, ^{239}Pu). The most significant long-lived contaminant was the cesium ^{137}Cs isotope **(Högberg, 2013)**. The level of contamination in a certain area was dependent on the latitude and a long-term weather situation, particularly precipitation **(Csupka et al., 1978)**. Currently, the ^{137}Cs from this source, is already largely immobilized in the clay fraction of the soil, with limited access for plant roots **(Nimis, 1996)**.

The second source of the terrestrial contamination was the fallout after the nuclear reactor accident at Chernobyl in 1986. The Chernobyl nuclear accident on April 26, 1986, caused the release of radioactive caesium in the amount up to 3.8 x 10^{16} Bq. The ratio of ^{137}Cs to ^{134}Cs long-term radionuclides released was approximately 2:1 **(UNSCEAR, 1988)**. The radioactive cloud passed three times over the continent. On some territories with intensive rainfalls an increased soil contamination by large amounts of radionuclides was observed. Among most affected parts of Europe, except for Ukraine, Belarus and Russia, belongs despite the distance Norway, where surface activity values reached up to 500 kBq.m^{-2} **(Pedersen et al., 1998)**.

Currently, due to the elapsed time and the nature of the Chernobyl accident, the only artificial radionuclide present in the soil is ^{137}Cs, with a physical half-life conversion of 30.17 years **(Krolak et al., 2010)**.

High mobility of radiocaesium gradually decreased after its deposition to the soil. Differences in mobility were observed especially in the non-cultivated meadow and forest soils, and were associated with the soil depth. In mineral soils by increasing depth, the amount of ^{137}Cs accessible by plants may rise, however it depends on many factors and circumstances **(Schimmack and Bunzl, 1996)**. In the Central Europe, the most contaminated animal product by Chernobyl accident was the meat of game **(Sprem et al. 2013)**.

Based on information from the neighboring countries on exceeding limits of radiocaesium content in wild boar meat, monitoring of the hunting grounds in Slovakia was initiated.

MATERIAL AND METHODOLOGY

Thigh muscle samples of 60 wild boars (*Sus scrofa*) of different age categories (4 month – 2 years) collected from different hunting districts in Slovakia were evaluated in the period of 2013 – 2014. Thigh muscle samples of 500g collected from wild boars weighing from 15 up to 35 kg and originated from 26 hunting grounds were used in the study.

^{137}Cs activity was measured by gamma spectrometry (Canberra) consisting of a Ge detector (GC 3520: 20% effectiveness, 2.0 keV resolution) and a multichannel analyzer (Desktop Inspector) in 450 mL geometry Marinelli beakers and 200 mL PE bottle. Results of mass activity Bq.kg^{-1} were determined by a 2000 Genie (Canberra) and Gamvin (Envinet) software systems. It is further stated the % of relative standard uncertainty for each sample. All geometres including the gamma-spectrometric system were certified in the Czech Metrological Institute.

RESULTS AND DISCUSSION

The highest radiocaesium activity level measured in muscle was 37.2 Bq.kg^{-1} ±4.7%. Wild boar (Table 1) sample originated from Zlate Moravce district. In 8 muscle samples the highest value was less than 3.6 Bq.kg^{-1} ±2.2%. In all other muscle samples, the radiocaesium activity levels were below the minimum detectable activity.

Due to the fact that Scandinavia was heavily contaminated by Chernobyl radiocaesium fallout, within the food chain considerable attention was paid to elk **(Palo et al., 2003)** and reindeer meat **(Skuterud et al., 2004)**. Similar attention was paid also to marine organisms (seafood), such as crab from the north of Ireland **(Copplestone et al., 2004)**. In the Central Europe, the most contaminated animal product by Chernobyl accident, was the meat of game **(Sprem et al., 2013; Škrkal et al., 2015)**. Relatively higher activity of ^{137}Cs in the wild animals is based on the mosaic pattern of contamination area after the Chernobyl accident, in the way the wild animals searches and acquires food (especially wild boars), and in a significantly greater mobility and persistence of radiocaesium in the forest ecosystems, compared to intensively used agricultural land **(Vaaramaa et al., 2009)**. The ^{137}Cs is quickly integrated into a biological cycle, similar to potassium. Generally, radionuclides are characterized by their mobility in soil **(Gadd, 1996)**. Analysis has shown, that the diffusion coefficient of radionuclides in the soil is affected by the soil moisture, presence of chemical homologs, which determine the capacity of the exchange process in the soil, soil acidity, soil humus content and temperature.

Fungi, as one of the most important constituents of forest ecosystem are capable to accumulate a significant amount of radionuclides including ^{137}Cs **(Škrkal et al., 2013; Guillen and Baeza, 2014)**. It is due to their heterotrophic metabolism, significantly different from green plants, and dependence on the supply of final organic compounds **(Yoshida and Muramatsu, 1994)**.

Some species of fungi, including edible ceps (*Boletaceae family*) growing in deciduous forests of Central Europe, are not only bio indicators of environmental contamination by radiocesium (and heavy metals as well), but do to their consumption represent a potential hygiene and health risks problem **(Linkov et al., 2000; Dvořák et al., 2006)**. Radiocesium distribution in different mushroom body parts was uneven, nevertheless higher activity was determined in the mushroom caps **(Mukhopadhyay et al., 2007)**. Ability to accumulate radionuclides from the environment differs among different species of ceps (*Boletaceae family*). This corresponds with the finding, that increased accumulation of ^{137}Cs in bay bolete (*Xerocomus badius, syn. Boletus badius*) is mainly due to the presence of a pigment norbadion A, present in the mushroom cap **(Aumann et al., 1989)**. It is assumed that, as in higher plants, the radiocesium activity in fungi is associated with the growth phase, and the total radiocesium activity decreases with the gradual growth. Mushrooms samples collected in coniferous forests, compared to deciduous forests, are characterized by a high content of radionuclides **(Čipáková, 2004)**.

Table 1 Radiocaesium activity levels in muscles.

Hunting districts, sample data	^{137}Cs (Bq.kg^{-1})	^{40}K (Bq.kg^{-1})
Uhrinc (Kosice) Juvenile female, 1 year, 35 kg	0.60 ±27.6%	81.2 ±4.8%
Jablonov n/T (Roznava) Juvenile female, 1 year, 35 kg	2.03 ±10.0%	47.4 ±4.8%
Rakos, Camovce II (Lucenec) Squeaker female, 6 month, 17 kg	1.1 ±16.6%	51.2 ±2.6%
Vidoslav, Camovce II (Lucenec) Squeaker female, 4.5 month, 15 kg	0.9 ±23.8%	73.0 ±2.6%
Sklens (Turcianske Teplice) Squeaker male, 5 month, 15 kg	0.8 ±33.0%	77.0 ±4.8%
Smolnik (Gelnica) Juvenile female, 1 year, 30 kg	1.5 ±15.5%	75.7 ±4.8%
Lovce (Zlate Moravce) Wild boar female, 2 years, 35 kg	3.6 ±2.2%	63.6 ±2.2%
Topolcianky (Zlate Moravce) Wild boar female, 15 month, 25 kg	37.2 ±4.7%	57.9 ±4.8%
Velky Krtis (Velky Krtis) Squeaker female, 8 month, 20 kg	0.47 ±34.5%	96.8 ±4.8%

Results of the radiocesium mass activity from different areas of the Czech and Slovak Republic in 2000 – 2004, were published by **Dvořák et al., (2006)**. The highest ^{137}Cs activity of 6,263 Bq.kg^{-1} dry weight (measured by gamma spectrometry method) was found in the *Xerocomus badius* from the Old Ransko area (Czech-Moravian Highlands). The highest measured ^{137}Cs level in Slovakia was 966 Bq.kg^{-1} dry weight (*Suillus luteus*), in the area of Senica. However, when converted to fresh weight this value do not exceed permitted limit. For comparison, the ^{137}Cs activity in the sample of mixed dried ceps (*Boletaceae family*) coming from the 30 km Chernobyl border zone, was 6,000 Bq.kg^{-1} dry weight. Results for the dried mushrooms show, that currently there is no ^{137}Cs activity dependency related to the distance from the place of radioactive accident or the location altitude. These results also indicate significantly lower values of ^{137}Cs activity in the Slovak Republic compared to the Czech Republic, despite the fact Slovakia is closer to Ukraine. Explanations should be sought in the airborne radioactive cloud movement through the various parts of Europe after the Chernobyl disaster. In the fresh mushrooms collected in the French Alps in 1999 – 2002, the value of the ^{137}Cs activity ranged from 273 – 1,165 Bq.kg^{-1} **(Pourcelot et al., 2003)**.

After a gradual decline of the radiocaesium (^{137}Cs) activity in the game muscles in the 1990s, unexpected activity increase occurred after the floods in North-East Moravia in 1997. In the meat of wild boars, the activity exceeded the hygienic limit set for EU countries (600 Bq.kg^{-1}), especially in the age category up to 1 year. Since 2000 the ^{137}Cs activity was reduced back to the level before the flood **(Obzina, 2002)**. Seasonal fluctuation of ^{137}Cs activity in the wild boar meat samples was observed in the forests on the southern Rhineland. The stomach contents were examined as well. A positive correlation (0.66) for the activity of the stomach contents and the activity of muscle was found, but the stomach contents were usually less contaminated compared to muscles; the median of the stomach content was 22 Bq.kg^{-1}, the maximum 1,749 Bq.kg^{-1}, while the median of muscle was 129 Bq.kg^{-1}, and the maximum 5,573 Bq.kg^{-1}. No difference in the specific activities of female and male muscles was proved **(Hohmann and Huckschlag, 2005)**. From 1998 to 2008, 656 samples from the wild boars were analysed in the district of Ravensburg (southern Germany). The activity was variable from less than 5 up to 8,266 Bq.kg^{-1}, depending on the season, weather conditions and the associated changes in dietary habits and food availability **(Semizhon et al., 2009)**. High radioactivity levels (up to 10,699 Bq.kg^{-1}) were reported in the wild boars muscles from Sumava (Czech Republic) **(Latini, 2011)**. In 2012, the highest measured value was 14,252 Bq.kg^{-1} **(Kouba et al., 2013)**. In Croatia, some locations were monitored during the years 2000 and 2002 **(Vilic et al., 2005)**; radiocesium in boar muscles ranged from 0.4 to 611.5 Bq.kg^{-1}. The highest muscle contamination was observed in autumn. The authors interpreted this fact as a result of higher mushroom intake by boars at that time. Our muscle samples were collected during different annual periods, however no significant seasonal differences in the radiocaesium activity we observed. This was probably due to low radiocaesium activity in fungi in the observed area, and thus subsequently in our samples as well.

The **Recommendation of the European Commission (2003)** highlights the existence of limit exceeding activity of radiocaesium in the meat of game, and call the Member States to act, in order to protect consumers. Member states should implement steps to ensure that the limits set by **Directive no. 737/90 / EEC (2000)** for placing the game meat, wild berries, mushrooms, and predatory lake fish to the market, are respected. At the same time it recommends to warn the inhabitants of affected regions on the health risks resulting from contaminated food consumption. Member States are asked to prepare for the European Commission and other EU Member States a feedback on the implementation of this Directive.

Wild boar muscles contamination is mainly due to the consumption of the underground fruiting bodies of the mushroom genus of *Elaphomyces sp.* (*E.granulatus* - deer truffle, hart's truffles) **(Hohmann and Huckschlag, 2005; Dvořák et al., 2010)**. The highest ^{137}Cs specific activity of 4,743 Bq.kg^{-1} was detected in the mushroom fruiting bodies in the area of Šabrava, while the other components of the food chain of feral pigs do not exceed few tens of Bq.kg^{-1} **(Dvořák et al., 2010)**. The results of stomach content analysis showed the considerable importance of additional feeding and beechnuts in the food of boars while rootlets and sprouts were less important, and the importance of animal components was minimal. Mushrooms were not identified in any stomach, probably due to their relatively high digestibility in boars. Furthermore, the following food components of boars manifested the ^{137}Cs specific activities higher then MDA in the samples tested: 16 Bq.kg^{-1} in meadow earthworms, 200 Bq.kg^{-1} in rootlets at the Šabrava location, and finally 4,743 Bq.kg^{-1} and 2,858 Bq.kg^{-1} in *Elaphomyces granulatus* fruiting bodies. The fruiting bodies were not found in the boar stomach as other mushrooms, however, they were found in the marginal areas around the rooted locations. We may assume that this mushroom with a vegetation season from September to April is searched and consumed by boars, similarly as e.g. the truffles in France. For example, considering the high activity of 4,743 Bq.kg^{-1} measured in one sample and taking into account the high mushroom digestibility in boars, the specific activity of chyme can be estimated to about 237 Bq.kg^{-1} only due to the intake of the mushroom when 5% intake in 1 kg of the stomach content was taken into account. For monogastric animals, the radiocaesium resorption can reach up to 100% while excretion is about 25%, which would mean a daily growth of specific activities of 21 Bq.kg^{-1} in the net muscle weight of 25 kg (for a boar life weight of 100 kg and food consumption of 3 kg daily). However, such chyme usually does not consist only of the fruiting bodies of the above mentioned mushroom and other components with the specific activities below MDA. The following example based on our results (muscle sample with the specific activities of 4,743 Bq.kg^{-1}, soil elements 173 Bq.kg^{-1}, rootlets 200 Bq.kg^{-1}, earthworms 16 Bq.kg^{-1}, all at the Šabrava location) shows the importance of other ^{137}Cs sources. The proved presence of soil, earthworms, rootlets and other components increases the ^{137}Cs activity in the stomach content. In case of food consumption of 3 kg.day^{-1} at the

Šabrava location with the individual contributions, i.e. 5% fruiting body of *Elaphomyces granulatus* (total 711 Bq), 5% soil elements (26 Bq), 20% rootlets (120 Bq), 2% earthworms (1 Bq) and other components with the specific activities below MDA, the total activity of the stomach content would be 858 $Bq.day^{-1}$. For the stomach content of 1 kg, this means the specific activity of 286 $Bq.kg^{-1}$. The daily increase of the specific activity in muscle would be 26 $Bq.kg^{-1}$. However, the increase due to other components in the food chain is only 5 $Bq.kg^{-1}$, i.e. an increase by 25%. *Elaphomyces granulatus* is mainly found in soils with high content of humus, especially in sandy pine and spruce forests. It grows under the ground and appears on the ground surface usually due to wild game (wild boar) activity. The main period of the fungi growth is from September to April. This is the time when animals have limited access to food sources. In Slovakia, the occurrence of this fungus is very rare, and is mainly present in protected landscape areas, where hunting is not allowed. Compared to the situation in livestock, limited possibility of protective measures implementation represents the biggest problem of ^{137}Cs contamination in game. The only possible solution remains to check each hunted animal individually. One possibility of preventing the game contamination is the supplementary feeding.

The use of alternative food sources as prevention, may result in reduced consumption of natural food, including *Elaphomyces granulatus*, to cover organism energy needs. Slovakia has so far monitored very limited number of hunted animals. The value of ^{137}Cs samples activity collected are still very low **(Beňová et al., 2014)**, what is consistent with our results.

CONCLUSION

In recent years, the wild game meat is more frequently present on menus of variety of restaurants and is becoming very popular in consumers. Despite the fact Slovakia is closer to Chernobyl as Czech Republic and Germany, the ^{137}Cs activity measured was very low and far below the permitted limit. The measurement results show, that ^{137}Cs contamination levels of game in Slovakia are so low, that they do not represent an increased health risk for humans.

REFERENCES

Aumann, D. C., Clooth, G., Steffan, B., Steglich, W. 1989. Komplexierung von Caesium-137 durch die Hutfarbstoffe des Maronenröhrlings (*Xerocomus badius*). *Angewandte Chemie,* vol. 101, no. 4, p. 495-496. http://dx.doi.org/10.1002/ange.19891010429

Beňová, K., Dvořák, P., Tomko, M., Čurlík, J., Lazar, P. 2014: Radiocaesium in the meat in Slovakia. In *Hygiena Alimentorum XXXV*. Košice: UVLF, 2014, p. 168-170. ISBN 978-80-8077-401-1.

Commission Recommendation 2003/120/EC, On the protection and information of the public with regard to exposure resulting from the continued radioactive cesium contamination of certain wild food products as a consequence of the accident at the Chernobyl nuclear power station, Official Journal of the European Union. L47, 21.2.2003, p. 53-55.

Copplestone, D., Jackson, D., Hartnoll, R. G., Johnson, M. S., McDonald, P., Wood, N. 2004: Seasonal variation in activity concentrations of Tc-99 and Cs-137 in the edible meat fraction of crabs and lobsters from the central Irish Sea. *Journal of Environmental Radioactivity*, vol. 73, p. 29-48. http://dx.doi.org/10.1016/j.jenvrad.2003.06.001 PMid:15001294

Council Regulation 616/2000/EC, Council Regulation of 20th March 2000 amending Regulation (EEC) No 737/90 on the conditions governing imports of agricultural products originating in third countries following the accident at the Chernobyl nuclear power station, Official Journal of the European Union. L75, 20.3.2000, p. 1.

Csupka, Š., Carach, J., Petrášová, M. 1978. *Environmental Radioactivity in Slovakia / Czechoslovakia in 1961–1975*. Regional Public Health Authority, Bratislava, 226 p.

Čipáková, A. 2004. Cs – 137 content in mushrooms from localities in eastern Slovakia. *Nucleonika*, vol. 49, suppl. 1, p. 25-29.

Dvořák, P., Kunová, V., Beňová, K., Ohera, M. 2006. Radiocesium in mushrooms from selected locations in the Czech Republic and the Slovak Republic. *Radiation Environmental Biophysics*, vol. 45, no. 2, p. 145-151. http://dx.doi.org/10.1007/s00411-006-0044-5 PMid:16628432

Dvořák, P., Snášel, P., Beňová, K. 2010. Transfer of radiocesium into wild boar meat. *Acta Veterinaria Brno*, vol. 79, p. 85-91. http://dx.doi.org/10.2754/avb201079S9S085

Gadd, G. M. 1996. Influence of Microorganisms on the Environmental Fate of Radionuclides, *Endeavour*, vol. 20, no. 4, p. 150-156. http://dx.doi.org/10.1016/S0160-9327(96)10021-1

Guillen, J., Baeza, A. 2014. Radioactivity in mushrooms: A health hazard? *Food Chemistry*, vol. 154, p. 14-25. http://dx.doi.org/10.1016/j.foodchem.2013.12.083 PMid:24518310

Hohmann, U., Huckschlag, D. 2005. Investigations on the radiocesium of wild boar (*Sus scrofa*) meat in Rhineland – Palatine: a stomach content analysis. *European Journal of Wildlife Research*, vol. 51, no. 4, p. 263-270. http://dx.doi.org/10.1007/s10344-005-0108-x

Högberg, L. 2013. Root Causes and Impacts of Severe Accidents at Large Nuclear Power Plants. *A Journal of the Human Environment*, vol. 42, no. 3, p. 267-284.

Kouba, F., Cipínová, E., Drápal, J., Hanzal, V., Malena, M., Vernerová, K. 2013. The radioactivity monitoring of wild boars in the South Bohemian Region. *Mäso*, vol. 3, p. 151-154.

Krolak, E., Kwapulinski, J., Fischer, A. 2010. (137)Cs and (40)K isotopes in forest and wasteland soils in a selected region of eastern Poland 20 years after the Chernobyl accident. *Radiation And Environmental Biophysics*, vol. 49, no. 2, p. 229-237. http://dx.doi.org/10.1007/s00411-010-0265-5 PMid:20076963

Latini, T. 2011. The presence of radioactivity in the feral pigs. *Mäso*, vol. 5, p. 24-26.

Linkov, I., Yoshida, S., Steiner, M. 2000. Fungi contaminated by radionuclides. Critical review of approaches to modeling. In *Proceedings of the 10th International Congress of the International Radiation Protection Association*, Hiroshima, p. 1-10.

Mukhopadhyay, B., Nag, M., Laskar S., Lahiri S. 2007. Accumulation of radiocesium by *Pleurotus citrinopileatus* species of edible mushroom. *Journal of Radioanalytical and Nuclear Chemistry*, vol. 273, no. 2, p. 415-418. http://dx.doi.org/10.1007/s10967-007-6875-y

Nimis, P. L. 1996. Radiocesium in Plants of Forest Ecosystems. *Studia Geobotanica*, vol. 15, p. 3-49.

Obzina, J. 2002. *Presence of radiocesium the game meat from the districts Šumperk and Jeseník in-between 1992-2002*. Postgraduate certificate, Brno: University of Veterinary Medicine and Pharmacy. 35 p.

Palo, R. T., White, N., Danell, K. 2003. Spatial and temporal variations of Cs-137 in moose *Alces alces* and transfer to man in northern Sweden. *Widlife Biology*, vol. 9, p. 207-212.

Pedersen, Ch. S., Nyb, S., Varskog, P. 1998. Seasonal variation in radiocesium concentration in Willow Ptarmigan and Rock Ptarmigan in Central Norway after the Chernobyl Fallout. *Journal of Environmental Radioactivity*, vol. 41, p. 65-81. http://dx.doi.org/10.1016/S0265-931X(97)00095-7

Pourcelot, L., Renaud, P., Louvat, D., Gurriaran, R., Richon, P. 2003. Influence of hot spots on cesium-137 contamination of an alpine food chain and doses associated with it, Environnement. *Risques et Santé*, vol. 2, no. 2, p. 112-120.

Semizhon, T., Putyrskaya, V., Zibold, G., Klemt, E. 2009. Time-dependency of the ^{137}Cs contamination of wild boar from a region in Southern Germany in the years 1998 to 2008. *Journal of Environmental Radioactivity*, vol. 100, no. 11, p. 988-992. http://dx.doi.org/10.1016/j.jenvrad.2009.06.023 PMid:19616349

Schimmack, W., Bunzl, K. 1996. Mobility of Chernobyl – Derived Radiocesium in the Soil, Proceesings of the International Symposium on Radioecology. In: *Mitteilungen Osterreichische Bodenkundliche Gesellschaft*. Vienna : International symposium on radioecology 1996, vol. 53, p. 11-18. ISSN 0029-893X.

Skuterud, L., Pederson, O., Staaland, H., Roed, K. H., Salbu, B., Liken, A., Hove, K. 2004. Absorption, retention and tissue distribution of radiocaesium in reindeer: effects of diet and radiocaesium source. *Radiation and Environmental Biophysics*, vol. 43, no. 4, p. 293-301. http://dx.doi.org/10.1007/s00411-004-0257-4 PMid:15459770

Sprem N., Babic I., Barisic D., Barisic D. 2013. Concentration of ^{137}Cs and ^{40}K in meat of omnivore and herbivore game species in mountain forest ecosystems of Gorski Kotar, Croatia. *Journal of Radioanalytical and Nuclear Chemistry*, vol. 298, no. 1, p. 513-517. http://dx.doi.org/10.1007/s10967-013-2475-1

Škrkal, J., Rulik, P., Fantinova, K., Burianová, J., Helebrant, J. 2013. Long-term Cs-137 activity monitoring of mushrooms in forest ecosystems of the Czech Republic. *Radiation Protection Dosimetry*, vol. 157, no. 4, p. 579-584. http://dx.doi.org/10.1093/rpd/nct172 PMid:23838098

UNSCEAR. 1988. *Sources, Effects and Risks of Ionizing Radiation*, New York: UN. 647 p., ISBN 92-1-142143-8.

Vaaramaa, K., Solatie, D., Aro, L. 2009. Distribution of Pb-210 and Po-210 concentrations in wild berries and mushrooms in boreal forest ecosystems. *Science Of The Total Environment*, vol. 408, no. 1, p. 84-91. http://dx.doi.org/10.1016/j.scitotenv.2009.09.005 PMid:19800659

Vilic M., Barisic D., Kraljevic P., Lulic S. 2005. 137Cs concentration in meat of wild boars (*Sus scrofa*) in Croatia a decade and after the Chernobyl accident. *Journal of Environmental Radioactivity*, vol. 81, no. 1, p. 55-62. http://dx.doi.org/10.1016/j.jenvrad.2004.12.001 PMid:15748661

Yoshida, S., Muramatsu, Y. 1994. Accumulation of radiocesium in basidiomycetes collected from Japanese forests. *Science of the Total Environment*, vol. 157, p. 197-205. http://dx.doi.org/10.1016/0048-9697(94)90580-0

Acknowledgments:

This study was carried out in the framework of VEGA 1/0415/13.

Contact address:

Katarína Beňová University of Veterinary Medicine and Pharmacy in Košice, Department of Biology and Genetics, Komenského 73, 041 81 Košice, The Slovak Republic, E-mail: katarina.benova@uvlf.sk.

Petr Dvořák University of Veterinary and Pharmaceutical Sciences in Brno, Faculty of Veterinary Hygiene and Ecology, Department of Biochemistry and Biophysics, Palackeho 1-3, 612 42 Brno, The Czech Republic, E-mail: dvorakp@vfu.cz.

Martin Tomko University of Veterinary Medicine and Pharmacy in Košice, Department of Biology and Genetics, Komenského 73, 041 81 Košice, The Slovak Republic, E-mail: martin.tomko@uvlf.sk.

Marcel Falis University of Veterinary Medicine and Pharmacy in Košice, Department of Pharmacology and Toxicology, Komenského 73, 041 81 Košice, The Slovak Republic, E-mail: marcel.falis@uvlf.sk.