ОРИГИНАЛЬНАЯ СТАТЬЯ

SELENIUM ACCUMULATION BY MUSHROOMS OF THE DNIESTER RIVER VALLEY

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ABSTRACT. Selenium (Se) is an essential element for human being, although it is toxic at high concentrations. Many mushroom species are known to easily accumulate Se. Studies on Se levels in mushrooms of the Dniester river valley are especially urgent due to previously detected high Se concentrations in water and soils of separate areas of the region. Peculiarities of Se accumulation by 13 mushrooms species from 4 regions of the Dniester river valley were studied. Fluorometric method was used for Se determination. Observed Se concentration range for wild species was 0.147–25 mg/kg d.w. The lowest levels were typical for *Armillaria* species (0.147–0.252 mg/kg), the highest – for *Agaricus bisporus* from Slobodzeya region. Mushrooms of this region were shown to be especially rich in Se. To evaluate ecological risk of wild and cultivated champignons analysis of 24 elements (Al, As, B, Ca, Cd, Co, Cr, Cu, Fe, Hg, I, K, Li, Mg, Mn, Na, Ni, P, Pb, Si, Sn, Sr, V, Zn) was achieved by MS-ICP and AES-MS. Daily intake of 300 g of fresh wild growing *Agaricus bisporus* from Slobodzeya region was shown to be toxic for human beings: the excess of maximum permissible daily consumption level for Se was equal to 1.67 and 14 for Cd. On the contrary, cultivated champignons of the Southern part of the Dniester river valley were proved to be safe for human health and were considered as significant nutritional sources of Cu, K, P, Se and Fe.

KEYWORDS: edible mushrooms, selenium, geographical and species peculiarities of accumulation, ecological risks, dniester river valley.

INTRODUCTION

Mushrooms are distinguished from other groups of living organisms by striking ability to accumulate significant amounts of macro- and trace elements. Incidences of hyperaccumulation of elements by mushrooms are registered more frequently than in plants and the toxicological effect of high doses of elements on mushrooms is practically unknown. High capacity of mushrooms to accumulate elements essential for human beings defines their important nutritional value and as least partially increasing expansion of utilization of several mushrooms species in medicine due to wide spectrum of their beneficial effect on human health. Thus mushrooms are recommended in cases of cardiovascular diseases, lung, kidney, brain and blood diseases, for optimization of vegetative nervous system, prevention of hypertension and obesity. Mushrooms display antiallergenic, anticarcinogenic, immunomodulating and adaptogenic properties, protect the organism against harmful bacteria and viruses, slow aging processes (Kalac, 2013).

Being a natural antioxidant Se demonstrates many of the above mentioned biological effects: possesses anticarcinogenic, cardioprotective and antiallergenic effect, protects against viral diseases, is known to be a powerful immunomodulator and adaptogen, plays an important role in brain functioning (Golubkina, Papazyan, 2006). Among different chemical elements Se in particular is supposed to promote an increase of human longevity (Gavrilov, Gavrilova, 1991).

The ability of wild growing mushrooms to accumulate significant amount of macro- and trace elements, including Se, is undoubtedly connected with quick growth, enormous area of mycelium distribution and multiple increase of metals and metalloids circulation due to the ability of mushrooms to excrete vigorous biologically active compounds such as enzymes and mineral acids (Falandysz, Borovicka, 2013).

Levels of Se accumulation by mushrooms are studied to a much lesser extent than the appropriate data for other elements, such as Zn, Cu, Cd (Falanzysz, Borovicka, 2013; Campos et al., 2012; Mleczek et al., 2013). Thus, among 2000 known at present edible mushrooms species only about 180 are characterized for their ability to accumulate Se. Furthermore one should mention serious problems in determination of mushrooms Se content resulting in the existence of significant differences in registered Se

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levels by one and the same mushrooms species (Racz et al., 2000; Raczand Oldal, 2000; Falandysz, 2008, 2013). Frequently results of mushrooms Se analysis may differ by tens and hundreds times.

At present well known hyper accumulators of Se are *Boletus edulis* and other representatives of *Boletus* genus, several species of *Albatrellus* (able to accumulate up to 20–370 mg Se/kg d.w.) and a large group of mushrooms from *Amanita* genus. High levels of the element are found in several species of *Lycoperdon, Tricholoma, Calocybe, Lepiota* and wild growing *Agaricus* (2–8 mg/kg), where biological accumulation factor (the ratio of Se content in mushroom fruitbody and soil Se concentration) may reach 10□60 (Quinche, 1983; Racz, Oldal, 2000). And the lowest Se accumulation capacity (<0.5 mg/kg) is typical for *Russula, Cantharellus, Cratellus, Hudnum, Laccaria, Armillariella, Gyromitra, Morchella, Helvella* and *Boletopsis* species.

Chemical forms of Se in mushrooms are studied very fragmentary. Nevertheless it is shown that the main chemical Se forms in *Agaricus* are Se-containing aminoacids: selenomethionine (SeMet), selenocystein (SeCys) and also their methylated derivatives (Maseko et al., 2013). SeCys is known to be the 21st essential aminoacid for human organism while SeMet is considered to be the main Se-containing compound in plants. Forming the so called «Se deposit» in muscle tissues, SeMet supplies the organism with the element for the synthesis of Se-containing enzymes. Methylated forms of the above aminoacids are shown to possess significant anticarcinogenic properties (Golubkina, Papazyan, 2006).

An important aspect of investigation of Se accumulation by mushrooms is the possibility of toxicity caused by excessive concentrations of this trace element. This question may become especially important due to extremely narrow range of safe consumption levels for Se: only 50–200 µg/day. Particularly serious this problem may become in regions with elevated Se levels in the environment and in cases of additional anthropogenic pollution of the territory with Se, Hg, Cd, Pb, Cu and As.

Geochemical conditions of the Dniester river valley are known to be favorable for Se bioaccumulation by plants (Kapitalchuk et al., 2013), demonstrating local high Se concentrations in surface water, soils and plants. Taking into account the possibility of Se hyperaccumulation by several mushrooms species it is important to evaluate the risks, connected with mushrooms consumption.

The aim of the present study is evaluation of Se content in mushrooms from the Dniester river valley and estimation of risk factors connected with mushroom consumption.

MATERIALS AND METHODS

Samples of 12 mushroom species (*Boletus pulchrotinctus, Lepiota aspera, Leucoagaricus leusothites, Suillus luteus, Clitocybe nebularis, Lepista inversa, Armillaria gallica, Armillaria mellea, Agaricus bisporus, Lepista nuda, Tricholoma populinum, Lycoperdon perlatum)* were gathered in Kamensk, Dubossary, Slobodzeya, Ribnitsy regions and in Bender during autumn 2013 (Fig. 1).

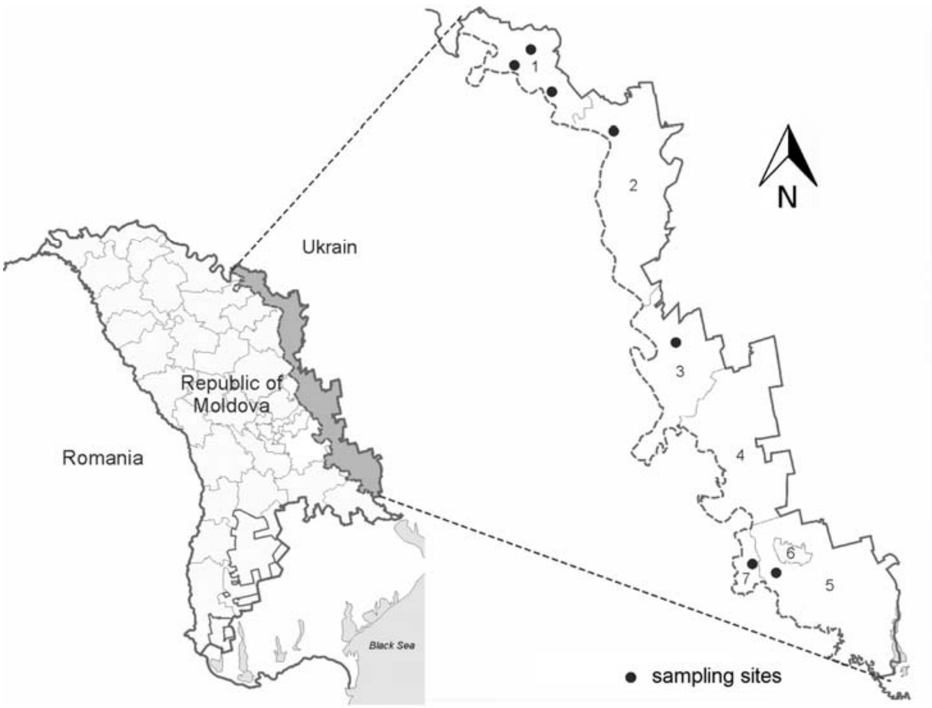

Fig. 1. *Sampling sites of mushrooms in the Dniester river Valley:*
1 – Kamensk region, 2 – Rybnitsky region, 3 – Dubossary region, 4 – Grigoriopol region,
5 – Slobodzeya region, 6 – Tiraspol, 7 – Bender

For each species collected at each site, several or many specimens (5−10) depending on size and availability, were sampled. Taking into account great dependence of Se content in mushrooms on age (Golubkina et al., 2000), old or extremely young specimens were rejected. The fungi were cleaned from external contamination, chopped up with plastic knife, dried at room temperature to constant weight, powdered in a porcelain pestle and mortar and kept in closed polyethylene containers till the beginning of the analysis. Thus, a single value for each species represents the average value for the specimens collected at given site.

Se content was determined by fluorometric method, based on wet digestion of samples with a mixture of $HN0_3$ and $HCl0_4$, reduction of Se^{+6} to Se^{+4} and formation of fluorescent complex between selenic acid and 2,3-diaminonaphtalene (Alfthan, 1984). All samples were analyzed in duplicate. Reference-standards: lyophilized cabbage, wheat flour and dry milk- with regulated Se levels (150, 57 and 115 µg/kg accordingly) were used in each determination. For estimation of elemental composition of champignons samples dry mushrooms were digested in microwave oven using a mixture of $HN0_3$, H_20_2 and $HCl0_4$. The resulting HN03 solutions were subjected to ICP-MS (Al, As, B, Ca, Cd, Co, Cr, Cu K, Hg, Li, Mg, Mn, Na, Ni, Pb, Sn, Sr, V, Zn) and AES-ICP analysis (Si, P, Fe) on quadruple mass-spectrometer Nexion 300D and atomic-emission spectrometer Optima 2000DV («Perkin Elmer», USA). The analysis was achieved in the Center of Biotic Medicine, Moscow.

Statistical analysis was achieved by Student's *t*-test.

RESULTS AND DISCUSSION

The results of Se determination in 13 mushroom species from the Dniester river valley are presented in Table 1.

Se Concentration range is found to be extremely wide: from 0.147 mg/kg to 24.920 mg/kg d.w. Such variations are undoubtedly connected both with differences in Se accumulation levels between species investigated and with geochemical conditions of the habitats.

Table 1. ***Se Accumulation by mushrooms of Dniester river valley (mg/kg d.w.)***

Region*	Mushroom	Se concentration	Habitat
1	*Boletus pulchrotinctus*	5.403 ± 0.367	Kamenka forest
	Lepiota aspera	2.097 ± 0.143 ^{4}	Severinovka forest
	Leucoagaricus leusothites	1.982 ± 0.190 ^{4}	
	Suillus luteus	0.879 ± 0.023	
	Clitocybe nebularis	0.302 ± 0.010	
	Lepista inversa	0.194 ± 0.010	
	Armillaria gallica	0.158 ± 0.016 ^{2}	
	Armillaria mellea	0.147 ± 0.042 ^{2}	Rashkov forest
2	*Agaricus bisporus*	4.275 ± 0.057	Belochi forest
	Armillaria mellea	0.252 ± 0.026	
3	*Lycoperdon perlatum*	2.200 ± 0.055 ^{4}	Doibany
	Suillus luteus	1.351 ± 0.108	
	Agaricus bisporus	0.782 ± 0.045 ^{3}	
5	*Agaricus bisporus*	24.921 ± 0.540	Kitskany floodplain forest
	Lepista inversa	4.224 ± 0.347	
	Lepista nuda	3.202 ± 0.600 ^{1}	
	Tricholoma populinum	3.030 ± 0.230 ^{1}	
	Inocybe sp	0.396 ± 0.036	
	Agaricus bisporus	0.583 ± 0.036	Cultivated
7	*Agaricus bisporus*	0.828 ± 0.055 ^{3}	cultivated
	Armillaria mellea	0.150 ± 0.018 ^{2}	Bender park

* – number of regions, according to Fig.1; (^{1}–^{1}), (^{2}–^{2}), (^{3}–^{3}), (^{4}–^{4}) – differences are not significant, $p > 0.5$.

Epiphytic mushrooms. The lowest Se levels (0.147–0.252 mg/kg) are registered in *Armillari*a, corresponding to a group of epiphytic mushrooms with typical low capability to accumulate Se (Campos et al., 2012). Similar levels have been found earlier in *Armillari*a species of Moscow region (0.050–0.201 mg/kg; Golubkina, Papazyan, 2006). At the same time it should be mentioned that geochemical peculiarities of *Armillari*a habitat and the effect of anthropogenic factors may become crucial for Se concentration in fruitbody of these mushrooms. Thus *Armillari*a mushrooms in Switzerland contain 0.250–0.380 mg Se/kg d.w., while in Italy appropriate values reach 0.350–1.200 mg/kg (mean 0.790 mg/kg, Falandysz, 2008).

Among the studied regions Rybnitsy is characterized by elevated Se concentration in *Armillari*a species exceeding 0.250 mg/kg.

Ectomicorizal mushrooms. Ectomicorizal symbionts (*Boletus, Suillus, Inocybe*) in conditions of the Dniester river Valley accumulate from 0.396 to 5.400 mg Se/kg d.w. and demonstrate significant differences in Se accumulation levels among species investigated: the lowest Se concentrations are registered for *Inocybe sp*., the highest – for *Boletus pulchrotinctus* (Table 1). Se-Accumulation capacity of *Boletus pulchrotinctus* is described by us for the first time and Se levels in fruit bodies of this species are in good agreement with the known data of Se hyperaccumulation by *Boletus* genus (Table 2).

Table 2. ***Se variations among different species of genera Boletus and Agaricus (mg/kg)***

Mushroom species	Mean Se level	Geographical variations	References
Boletus pinicola	40.0	27 – 50	Falandysz, 2008
B. aereus	25.0	16 – 32	Cocchi et al, 2006
B. edulis	18.0	7.5 – 33	Falandysz, 2008
B. aestivalis	16.0	11 – 21	Falandysz, 2008
B. regius	14.0	–	Quinche, 1983
B. erythropus	5.5	2.5 – 7.5	Falandysz, 2008
B. appendiculatus	4.9	2.3 – 7.3	Falandysz, 2008
B. radicans	3.45	2.4 – 4.5	Falandysz, 2008
B. cavipes	1.4	1.3 – 1.5	Borovika&Randa, 2007
Agaricus lanipes	39.0	–	Andersen et al, 1982
A. silvaticus	14.3	1.0 – 31	Falandysz, 2008
A. excellens	13.0	–	Borovika&Randa, 2007
A. squamulifer	12.2	8.3 – 16	Borovika&Randa, 2007
A. aestivalis	9.4	–	Quinche, 1983
A. littoralis	8.1	–	Andersen et al, 1982
A. langei	6.3	–	Stijve&Besson, 1976
A. bitorquis	5.9	1.9 – 13	Falandysz, 2008
A. moelleri	5.6	–	Borovika&Randa, 2007
A. haemorrhoidalis	5.5	4.2 – 6.8	Falandysz, 2008
A. edulis	5.0	2.1 – 7.8	Stijve, 1977
A. macrocarpus	4.9	1.9 – 11	Falandysz, 2008
A. campestris	4.3	0.66 – 4.7	Falandysz, 2008
A. silvicola	3.4	0.62 – 7.0	Falandysz, 2008
A. caesarea	3.3	2.6 – 4.1	Cocchi et al, 2006
A. arvensis	3.1	1.1 – 7.8	Falandysz, 2008
A. nivescens	3.0	–	Cocchi et al, 2006
A. essettei	2.9	2.4 – 3.5	Cocchi et al, 2006
A. augustus	1.9	1.3 – 2.2	Falandysz, 2008
A. benessi	1.4	–	Stijve&Besson, 1976
A. aegeria	1.4	1.1 – 1.8	Cocchi et al, 2006
A. bisporus	0.21	0.08 – 0.34	Falandysz, 2008

Despite lack of the data about Se accumulation by different *Boletus* species in the same conditions of habitat it seems possible to refer *B.pulchrotinctus* to a group with moderate Se accumulation levels close to the appropriate data for *B.appendicuatus, B.erythropus* and *B.radicans*. Apparently a group of distinctive Se hyperaccumulators among *Boletus* genus includes *B.edulis, B.pinocola, B.aereus, B.aestivalis* and *B.regius* with a leading place belonging to *B.pinocola*. The lowest Se concentration registered in *Boletus* genus belongs to *B.cavipes (*Falandysz, 2008). Taking into account available data on Se accumulation among Boletus species (Falandysz, 2008), one can conclude that Se seems to be an essential trace element for this group of ectomycorizal fungy, that is proved by the existence of maximum corresponding to 20 mg Se/kg d.w., on the appropriate histogram (Fig. 2).

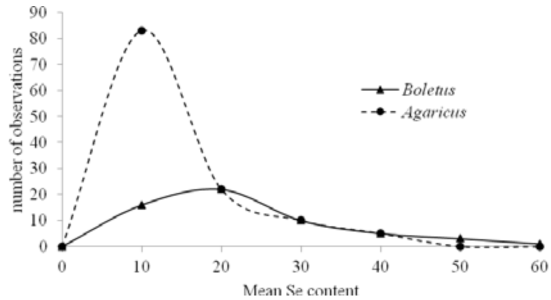

***Fig. 2**. Frequency distribution of Se concentrations in Boletus and Agaricus genera*

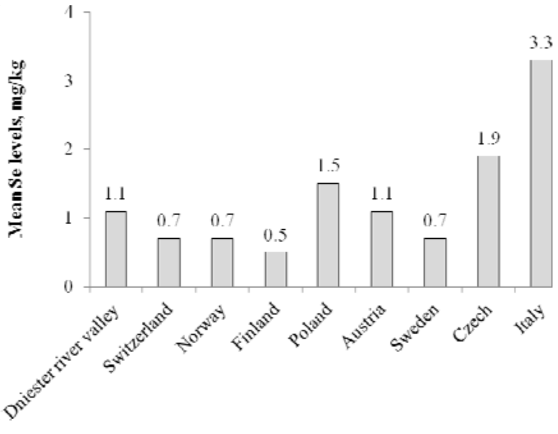

***Fig. 3.** Mean levels of Se accumulation by Suillus luteus (Falandysz, 2008 and results of the present sudy)*

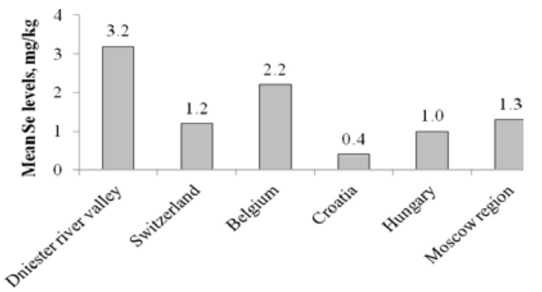

***Fig. 4.** Mean levels of Se accumulation by Lepista nuda (Falandyszg, 2008; Golubkina et al., 2000 and the results of the present study)*

Comparison of received pattern with that for *Agaricus* species (Fig. 2), and with analogous data for other mushrooms (Byrne et al., 1976) indicates the existence of specific variations of "Se-mushroom" interaction from powerful hyperaccumulation in genus *Boletus* to lack of essentiality in other species (for example, genus *Armillaria*).

Limited data on Se accumulation peculiarities in different *Suillus* species allow to indicate only approximately the most typical Se levels in *Suillus* genus (about 0.8 mg/kg). Se concentrations found in *Suillus luteus* from the Dniester river valley are close to that received for mushrooms of Austria and exceed ($p < 0.01$) Se concentrations in mushrooms of Switzerland, Norway, Finland and Sweden (Fig. 3) – countries with Se deficiency in soils (Combs, Combs, 1986). It may be noted that Se content in *Suillus luteus* from Kamensky region happens to be 2.94 times lower than values found in Italy (Cocchi et al., 2006). The same pattern is demonstrated for *Armillaria mellea* (mean values differing 4.5 times).

Saprotraphic mushrooms. But the highest Se levels happen to be typical for saprotrophic mushrooms. Thus demonstrated Se concentrations in *Agaricus*, *Lycoperdon perlatum*, *Tricholoma populinum*, *Lepiota aspera*, *Lepista sp.* are in the range from 2 to 4 mg/kg. The lowest concentrations are found for *Lepista inversa* of Kamensk region (<0.2 mg/kg), the highest – for *Agaricus bisporus* from Slobodzeya region (about 25 mg/kg). It seems significant that *Lepista inversa*, gathered in Slobodzeya region, contains 22 times more Se than mushrooms of Kamensk region which is situated in the Northern part of the studied area.

Se level in *Lepista nuda* from Slobodzeya region is shown to be 2.46 times higher than in appropriate mushrooms of Moscow region (Golubkina et al., 2000). Similar Se levels are demonstrated ($p > 0.5$) also for *Tricholoma populinum* of Slobodzeya region ($p > 0.5$). According to the literature data for *Lepista nuda* from different countries of the world Se levels for this species range from 0.4 to 2.2 mg/kg (Fig. 4).

Thus the received data prove the existence of elevated Se levels in the environment of Slobodzeya region.

The data on Se accumulation by champignons is of particular interest as they are acknowledged as functional food and the most frequently cultivated mushrooms. Despite rather limited data about geographical impact on Se accumulation by these mushrooms, one pays attention to high Se accumulation ability of champignons providing Se concentrations in wild growing mushrooms from 1.4 до 39 mg/kg d.w. (Fig. 2). Data of Table 2 show that among the great number of *Agaricus* species, used for nutrition, the leading place in Se accumulation occupies *A.lanipes* (up to 40 mg/kg) and to a lesser extent *A. silpvaticus* and *A.excellens* (13–14 mg/kg). *A.leusothites* of Kamensk region accumulates relatively moderate amount of Se (about 2 mg/kg). *A.bisporus*, gathered in Rybnitsy region demonstrates

Se concentrations not differing from the analogous data for Moscow region mushrooms – about 4 mg/kg ($p > 0.5$; Golubkina et al., 2000). Significantly lower Se levels are found in cultivated champignons (0.78–0.83 mg/kg) that is in good agreement with the data for industrially produced *Agaricus* mushrooms (Falandysz, 2008).

But the most significant data are received for anomalous Se accumulation by *Agaricus bisporus* grown in the floodplain forest of Slobodzeya region compared to the data for the Northern areas (Dubossary and Rybnitsy regions). Taking into account the easiness of cultivated champignon fortification with Se (Falandysz, 2008) values up to 25 mg Se/kg d.w. registered in wild growing champignons of Slobodzeya habitat apparently reflect high Se concentrations in the environment. Calculation of daily Se consumption level with 300 g of fresh *A.bisporus* in Slobodzeya region reveals the value (0.75 mg) that exceeds the adequate daily consumption level of the element (RDA) by 10.7 times and that of maximum permissible consumption level (MPCL) by 1.67 times.

For more complete assessment of the ecological risks connected with champignons consumption in the Southern part of the Dniester river valley elemental composition has been analyzed in fruit bodies of wild and cultivated *Agaricus bisporus* (Table 3).

This allows to reveal anomalously high concentrations not only of Se, but also Cd, Cu, Co and Hg (Table 4). Among the above mentioned elements in wild growing mushrooms the most dangerous seems to be Cd, which daily consumption with 300 g of fresh champignons exceeds the MPCL value by 14 times.

Extremely high Cd levels may be connected with either local peculiarities of the area or with remote Cd sources, as this element is characterized by high volatility and penetrating ability and as a result, extremely high rate of expansion in biosphere and the ability to be accumulated in areas which are remote from the emission sources by hundreds and even thousands kilometers (Volkova, 2003).

Besides this high concentrations of Cu and Co in wild growing champignons lead to the excess of RDA for these elements by 2.67 and 1.2 times respectively, though the values are statistically lower than MPCL values. Data presented in Table 3 indicate also elevated levels of Hg in wild growing champignons corresponding to 81% Hg of MPCL value. Demonstrated high concentrations of Se, Cd, Cu and Hg in *A.bisphorus* are in good agreement with the known data of preferable accumulation of these elements by A*garicus* genus (Byrne, et al., 1976). It also seems to be important that there exists a direct correlation between Se, Cu and Hg in different mushrooms species (Byrne, et al., 1976). Furthermore, one should take into account that Se proves to be an antagonist of Cu, Cd and Hg in biological systems (Kabata-Pendias, 2011), that supposes a decrease in Cu, Cd and Hg toxicity of wild growing champignons from Slobodzeya region due to high Se levels.

The present investigation and literature data demonstrate that cultivated champignons accumulate lower Se concentrations (about 0,6–0,8 mg/kg d.w.) than wild growing species. Such mushrooms seem to be safe as they contain insignificant amounts of heavy metals and are good sources of essential macro and trace elements. Indeed daily Se consumption with 300 g of cultivated mushrooms in the studied area reaches 18 μg or 26 % of RDA, Cu- 0.57 mg or 57% of RDA value. These mushrooms may provide about 44% of RDA for K, 11–16% for Fe, 38% for P, 7.5–9.6% for Mg, Mn, Cr and Zn, about 20% for Si. Intake levels of other elements with cultivated champignons are of minor importance

Table 3. ***Elemental composition of champignons (Agaricus bisporus) from Slobodzeya region (mg/kg d.w.)***

Element	Element concentration of champignons	
	Cultivated	Wild growing
Al	18.35 ± 1.83	77.00 ± 7.70
As	0.36 ± 0.04	0.45 ± 0.05
B	49.53 ± 4.95	1.13 ± 0.11
Ca	528 ± 53	721 ± 72
Cd	0.050 ± 0.008	47.690 ± 4.770
Co	0.020 ± 0.004	0.410 ± 0.050
Cr	0.140 ± 0.017	0.300 ± 0.036
Cu	18.97 ± 1.90	88.98 ± 8.90
Fe	55.1 ± 5.5	144.0 ± 14.0
Hg	0.060 ± 0.008	1.350 ± 0.130
I	0.110 ± 0.013	0.340 ± 0.041
K	36536 ± 3654	24397 ± 2440
Li	0.100 ± 0.012	0.109 ± 0.023
Mg	1136 ± 114	830 ± 83
Mn	5.03 ± 0.50	7.31 ± 0.73
Na	1049 ± 105	1053 ± 105
Ni	0.25 ± 0.03	1.03 ± 0.10
P	10229 ± 1023	5694 ± 569
Pb	0.110 ± 0.013	0.470 ± 0.057
Si	33.18 ± 3.32	31.68 ± 3.17
Sn	0.010 ± 0.002	0.020 ± 0.003
Sr	3.18 ± 0.32	4.61 ± 0.46
V	0.070 ± 0.010	0.280 ± 0.033
Zn	38.50 ± 3.85	43.45 ± 4.35

Table 4. ***Consumption levels of elements with 300 g of fresh Agaricus bisporus***

Element	Adequate level of consumption (RDA), mg/day	Maximum permissible consumption level (MPCL), mg/day	% from RDA (MPCL)	
			Cultivated	Wild
V	0.04	0.100	5.25	21.0
B	2.0	6.0	74.3	3.4
Fe	10□15	45	11.0□16.5	28.8□43.2
K	2500	3500	43.8	29.3
Ca	1250	2500	1.3	1.3
Co	0.01	0.03	6.0	**123.0**
Si	5.0	10	19.9	19.0
Li	0.1	0.3	3.0	3.3
Mg	400	800	8.5	6.2
Mn	2.0	11.0	7.5	11.0
Cu	1.0	5.0	56.9	**266.9 (53.4)**
Se	0.07	0.450	34.3	**1068 (166.1)**
P	800	1600	38.4	21.4
Cr	0.05	0,25	8.4	18.0
Zn	12	20	9.6	10.9
Pb	–	0.5	(0.66)	(2.8)
Cd	–	0.1	(1.5)	**(1430.7)**
As	–	0.5	(2.2)	(2,7)
Hg	–	0.05	(3.6)	(81.0)

CONCLUSIONS

Evaluation of Se accumulation levels by different mushrooms species gathered in various regions of the world, opens a possibility of determination of specific peculiarities and may become the basis for revealing the main mechanisms of Se assimilation by mushrooms of different genera. Several species, especially responsive to high concentrations of macro- and trace elements in the environment (for example, *Agaricus bisporus*), may become prospective objects for ecological risks assessment of environmental pollution. In regions with elevated values of Se in objects of the environment consumption of wild growing mushroom species (contrary to cultivated ones) may have an adverse effect for human health.

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АККУМУЛИРОВАНИЕ СЕЛЕНА ГРИБАМИ ДОЛИНЫ РЕКИ ДНЕСТР

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РЕЗЗЮМЕ. Селен (Se) является эссенциальным элементом для человека, хотя проявляет токсичность при высоких концентрациях. Известно, что многие виды грибов легко аккумулируют Se. Исследование уровней накопления Se грибами долины реки Днестр представляется особенно важным, поскольку ранее были установлены высокие концентрации Se в воде и почвах отдельных районов Приднестровья. В работе исследованы особенности аккумулирования Se 13 видами грибов, произрастающих в 4 районах Приднестровья. Для определения Se использовался флуорометрический метод анализа. Интервал наблюдаемых концентраций Se для диких видов грибов составил 0,147–25 мг/кг сухой массы. Наиболее низкие значения были характерны для опят *Armillaria* (0,147–0,252 мг/кг), наиболее высокие – для шампиньонов *Agaricus bisporus* из Слободзейского района. Было показано, что грибы, собранные в этом районе, особенно богаты Se. Для оценки экологического риска использования в пище диких и культивируемых шампиньонов был осуществлен анализ 24 элементов (Al, As, B, Ca, Cd, Co, Cr, Cu, Fe, Hg, I, K, Li, Mg, Mn, Na, Ni, P, Pb, Si, Sn, Sr, V, Zn) с использованием MS-ICP и AES-MS. Установлено, что потребление 300 г свежих шампиньонов *Agaricus bisporus* в Слободзейском районе может вызвать токсикозы у человека: превышение максимально допустимого суточного уровня потребления Se составил 1,67 раз и 14 раз для Cd. Напротив, культивируемые шампиньоны юга Приднестровья не опасны для здоровья человека и могут рассматриваться как хорошие диетические источники Cu, K, P, Se и Fe.

КЛЮЧЕВЫЕ СЛОВА: съедобные грибы, селен, географические и видовые особенности накопления, экологические риски, Приднестровье.