Accumulation of trace elements by wild mushrooms in West part of Russia (South-Eastern Baltic)

Accumulation de métaux lourds dans des champignons sauvages dans la partie ouest de la Russie (sud-est de la Baltique)

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Abstract

Trace elements accumulating capacity of wild mushrooms are discussing in this paper. Metals such as Ag, Cd, Co, Cu, Cr, Fe, Mn, Ni, Pb, were determined using AAS techniques in samples of fruiting bodies of 30 wild-growing mushrooms species. The concentration factors of elements were calculated. Data analyses have shown that some species of mushrooms have a high selective ability to cadmium and silver despite of negligible concentration of these elements in the substrate. B.edilis accumulated cadmium and silver extremely. There were no obvious relationships between the contents of the observed metals in fruiting bodies and the contents of total metals in the upper layer of soil. But the mass fraction of metals depended of the distance from industrial plants and cities.Mots-clés

Keywords

trace elements, toxic metals, accumulation, wild mushrooms.

Résumé

La capacité des champignons sauvages à accumuler les éléments traces est discutée ici. Des métaux tels que Ag, Cd, Co, Cu, Cr, Fe, Mn, Ni, Pb, ont été détectés par AAS dans des échantillons de 30 espèces de champignons sauvages (fructifications). Les facteurs de concentration des éléments traces ont été calculés. L'analyse des données a montré que certaines espèces de champignons ont une capacité d'accumulation très sélective au cadmium et à l'argent, alors que la concentration pour ces éléments est négligeable dans le substrat. B.edilis accumule de façon importante le cadmium et l'argent. Il n'y avait pas de relations évidentes entre le contenu en métaux observés dans les organes de fructification des champignons et le contenu en métaux totaux dans la couche supérieure du sol. La fraction massique en métaux est toutefois proportionnelle à la distance aux industries et aux villes.

Mots-clés

éléments traces, métaux toxiques, accumulation, champignons sauvages.

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1. Introduction

Species of plants capable to accumulate inorganic and organic substances are used as bioaccumulators in environmental monitoring. Lichens, mosses, fir-needles are the best known. The capacity of higher fungi to concentrate metals and radionuclides (Tsvetnova et al., 2001; Shcheglova et al., 2002; Eckl et al., 1986; Baeza et al., 2006; Malinowska et al., 2006; Kalač, 2001) is known and discussed in many papers. Wild mushrooms, as all of fungi, are not photosynthetic, they have another way to get nutrient, and they have specific affinity to same microelements, for example, metals. Some species of basidiomycetes accumulate cadmium, lead, zink, cupper, mercury more than there are metals in the substrate (Gorbunov et al., 2013).

Research data of fungi's capacity to reflect the level of pollution are contradictory (Barcan et al., 1998; Ouzouni et al., 2009; Durali et al., 2005; Poddubny et al., 1998; Popova, 2011; Garcia et al., 2013). Excessive accumulation of TM is primarily due to the nature of mushrooms than the other factors (Kalač et al., 1996, 2000, 2010; Svoboda et al., 2006; Petkovšek et al., 2013; Gast et al., 1988). But there were no obvious simple positive relationships between the contents of the metals in fruiting bodies and the contents of total metals in the soil organic layer in unpolluted areas (Kalač, 2001; Petkovšek et al., 2013; Falandysz et al., 1994). Other side the proportion of the metal contents in fruiting bodies originating from atmospheric depositions has been of less importance due to the short lifetime of a fruiting body, which is usually only 10–14 days (Tsvetnova et al., 2001; Durali et al., 2005). But it is the fact that mushrooms contamination is elevated in areas with high levels of anthropogenic impact (Kalač et al., 1996; Svoboda et al., 2006; Petkovšek et al., 2013).

The aim of the present work was to determine the contents of metals, cadmium, lead, silver, iron, nickel, copper, cobalt, chrome in fruiting bodies of commonly consumed mushrooms growing in an area with different levels of pollution.

2. Materials and methods

2. 1. The study area

Samples of 30 species of wild mushrooms were collected on august 2010. Three zones with different level of pollution were chosen (Figure 1).

The first zone is Sambian (Kaliningrad, Samland) Peninsula. It is located on the southeastern coast of the Baltic Sea, and the square of it is 1080 km^2. The activity of the atmospheric circulation increases during the cold season, from October to February, there are

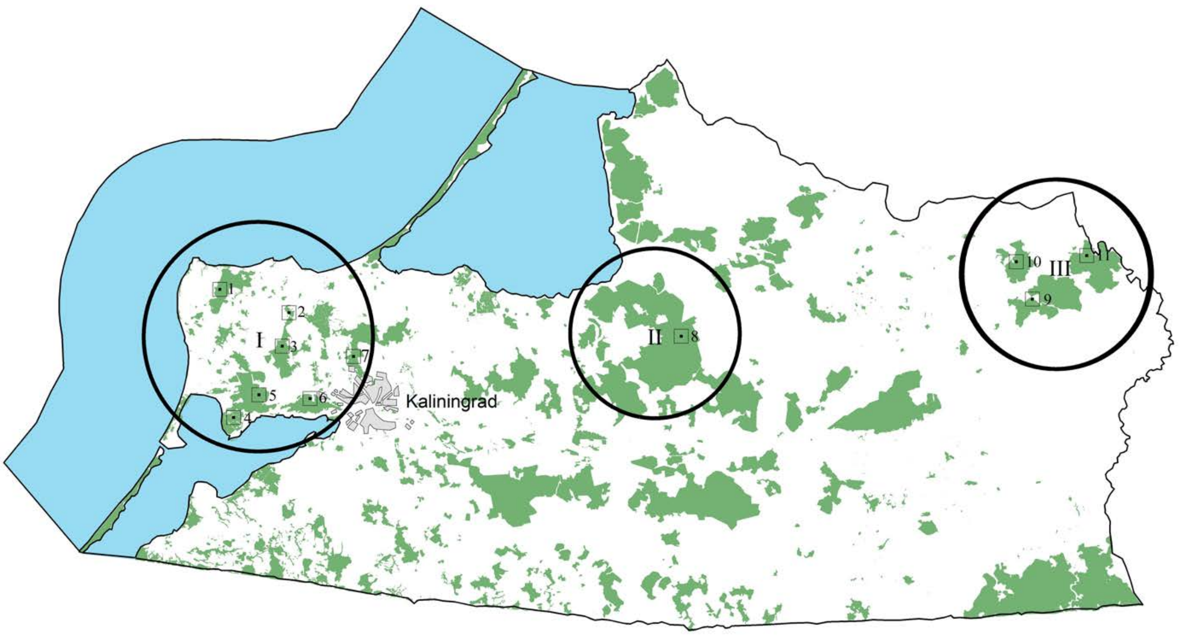

Figure 1. Study area: Zone I - Sambia peninsula; zone II - Forest area in the west part of the Polessk moraine plain; zone III - Forest area on the Sheshupe plain.
La zone d'étude : zone I - péninsule de Sambie ; zone II - zone forestière dans la partie ouest de la plaine de moraine de Polessk ; zone III - zone forestière de la plaine de Sheshupe.

warm and moist air masses from the Atlantic Ocean. Predominant directions of these masses are the west and north-west. Activity circulation decreases in warm period. Air masses come from the south and south-west. There are cool and gusty winds, heavy rains and thunderstorms in this period (Barinova, 2002).

The relief of this territory is hill; the highest point is 111 m. There are coniferous forest on the south and north cost, and mixed forest in the central part of the peninsula.

There are seven monitoring points:

1 - Delta-lacustrine and swamp bumpy sandy plain. Soddy weakly podzolic sandy soil. Type of wood - pine with birch and aspen. Key trees birch, aspen, pine, beech. Shrub layer - cowberry, blueberry.

2 - Flat and ridged sand and gravel floodplain. Unsaturated loamy brown forest soil. Forest type - Broad-pine forest. Major trees: pine, beech, hornbeam, fir. The undergrowth consists of hazel and honeysuckle.

3 - Knob-and-basin-sandy and sandy lake plain. Sod-gley weakly podzolic sandy soil. Forest type - Broad-fir forest. Major trees: pine, beech, hornbeam, fir. The undergrowth consists of hazel, honeysuckle, euonymus.

4,5 - Littoral wavy and bumpy sandy plain. Soddy weakly podzolic soil. Type of wood - grass spruce forest with green moss. Major trees: fir, beech, pine. Shrub layer: blueberry, cowberry.

6 - Hilly basins sand and gravel lake plain. Sod-podzolic loamy soils. Forest type - mixed wood. Major trees: pine, beech, hornbeam, fir. The undergrowth consists of hazel and honeysuckle.

7 - Relief and soil are analogical as in point 6. There is mixed forest with an admixture of birch, oak, shamrock, where spruce is dominating.

The territory of peninsula is the most densely populated, there are secondary production and agricultural enterprises, mining and transportation of oil. There is the largest amber deposit in the world. Sixteen samples of wild mushrooms were collected there.

The second zone is the forest area in the west part of the Polessk moraine plain, situated in the middle part of region. The main industries are agriculture and food enterprises. There are mining oil and removal a peat. The relief is the plane. The forest cover is highest in the region. There is only one monitoring point 8. Undulating, loamy and clayey morainic plain. Sod-podzolic, gleic, clay-loam soil. Forest type - Broad-fir forest. Key trees such as oak, ash, hornbeam, fir. The undergrowth consists of hazel, honeysuckle, euonymus. Samples of twenty wild mushrooms species were collected.

The third zone – the forest area on the Sheshupe plain – is the territory located in the north-east part of region and borders with Lithuania. It is a big agricultural district, but the forest occupies one quarter of territory, these are coniferous and mixed woods. There were three points of observation. Samples of nine wild mushrooms species were collected here.

9 - There is a flat plain, folded glaciolacustrine calcareous clays with sod-gley loamy cryptopodzolic soil and cryptopodatmospheric type of moisture. Forest type - linden with oak and spruce. Undergrowth: linden, spruce, hornbeam and ash. Understory - rowan, raspberries predominates in shrub layer. Herbaceous cover consists of anemone, Chickweed, buttercup, cocksfoot.

10, 11 - There is a pimple plain on aeolian sands Soil sod-podzolic illuvial surface glandular type of sand with atmospheric moisture. The sampling site 11 is on top of the hill of assorted fine grained sands with slopes of 10°. Type of wood - pine blueberry, moss with birch. Major trees: pine, birch and spruce. Shrub layer consists of blueberries and heather.

2. 2. Sampling and Sample preparation procedure

32 wild mushrooms species were selected: Armillariella mellea (Vahl) P. Karst., Boletus edulis Bull., Cantharellus cibarius Fr., Coltricia perennis (L.) Murrill, Craterellus cornucopioides (L.) Pers., Hydnum repandum L., Hypholoma fasciculare (Huds.) P. Kumm., Kuehneromyces mutabilis Singer & A.H.Sm., Lactarius camphoratus (Bull.) Fr., Lactarius helvus (Fr.) Fr., Lactarius mitissimus (Fr.) Fr., Lactarius rufus (Scop.) Fr., Leccinum aurantiacum (Bull.) Gray, Leccinum holopus (Rostk.) Watling, Lepista nuda (Bull.) Cooke, Marasmius scorodonius (Fr.) Fr., Paxillus involutus Batsch ex Fr., Pholiota aurivella (Fr.) Kumm., Pleurotus ostreatus (Jacq.) P.Kumm., Ramaria invalli (Cott. Et. Wakef.) Donk., Russula aeruginea Lindbl. Ex. Fr., Russula betularum Hora, Russula claroflava Grove., Russula cyanoxantha (Secr.) Fr., Russula decolorans (Fr.) Fr., Russula delica Fr., Russula foetens Pers., Russula paludosa Britzelm., *Russula lepida S. F. Gray.*, Russula xerampelina var. Rubra (Britz.) Sing., Tylopilus felleus (Bull.) P. Karst., Xerocomus chrysenteron (Bull.) Quél. The fruiting bodies were cleaned of all surface contamination, washing was not used. Fruiting bodies were sliced and dried at temperature 40 °C.

Digiblock digester (LabTech) EHD20 was used for sample retreatment. 0,5000 grams. Samples had been weighted and put into 50 ml tubes, 7 ml. HNO_3 (70 %) was added. Samples were standing over 12 h before insert the digestion tube into the cavity of ED20.

Then, tubes with samples were heated 15 min from room's temperature to 135 °C, and maintained 15 min. After cooling 2 ml of H_2O_2 was added and temperature was reset to 190 °C. The final solutions of about 2 ml was placed in 25 ml flask and diluted with 0,5 % HNO_3.

Elements were determined by method of atomic-absorption spectrometry (ContrAA 700, Analitikjena was used). Fe, Mn by Flame, The others by ETA.

3. Results

All of species of wild mushrooms were distributed in three ecological trophic groups: mycorrhizal, saprotrophic (soil and humus) and xylotrophic fungi. The average microelements content in fruiting bodies of Basidiomycetes of different groups were measured and there are dates in Table 1.

The highest average content of cadmium, nickel, and copper has been measured in mycorrhizal fungi. Elements such as cobalt, manganese, iron, lead, accumulate by xylotrophic fungi largely. Should be noted that the standard deviation (SD) is large, it means that there are significant species differences in the storage capacity into trophic groups. Storage capacity depends not only on understratum, but also on habitat and physiology and biochemical properties of fungi.

The mean mass fraction for each analyzed microelements in the whole fruiting body, together with details for each individual species, are shown in Tables 2, 3. Mean, standard deviation and the error were calculated only for those species, which number of samples was more than 2. The range of microelement concentrations in the fruiting bodies of mushrooms from our study concurs with literature values for wild fungi, irrespective of their geographical origin.

4. Discussion

Content of microelements in wild mushrooms varied in wide range. In accordance of literature data concentration of cadmium in fruit bodies on unpolluted areas vary between 0,5 to 5 µg/g DM, it depends on the species of fungi. The highest cadmium level was determined in *B. edulis* (point 7 of zone I) and was 8,8 µg/g, but it is normal values for this species (Ouzouni et al., 2009; Durali et al., 2005; Popova, 2011, Kalač et al., 2000; Kalač, 2010; Rudawska et al., 2005; Falandysz et al., 2008; Malinowskaa et al., 2004). Thus *B. edulis* can be considered as moderate cadmium accumulators.

The content of chromium in species ranged from 0,22 to 7,9 (*P. ostreatus*). From the data for numerous species, usual chromium contents were determined as 0,5 and 5 µg/g DM (Ouzouni et al., 2009; Durali et al., 2005; Kalač et al., 2000, Kalač, 2010; Ivanov et al., 2008; Rudawska et al., 2005; Falandysz et al., 2008; Malinowskaa et al., 2004; Svoboda et al., 2007). Probably *P.ostreatus* and *R. invalli* is accumulator of chromium.

The background copper contents in the most species from unpolluted areas are between 20 and 100 µg/g DM (Ouzoni et al., 2009; Durali et al., 2005; Kalač et al., 2000; Kalač, 2010; Malinowskaa et al., 2004; Pelkonen et al., 2008; Svoboda et al., 2007). The highest level in studying species was determined in *L. aurantiacum* (136 µg/g), this sample was selected in zone III (the Sheshupe plain), minimum is 4,4 (*P. ostreatus, point 7, zone I). C. cibarius and L. aurantiacum* have an ability to accumulate copper.

All published papers agree that cobalt contents are commonly below or around 0,5 µg/g DM, only a limited proportion exceeds 1,0 µg/g DM (Ouzouni et al., 2009; Kalač et al., 2000; Kalač, 2010; Falandysz et al., 2008; Malinowskaa et al., 2004). in Kaliningrad region maximum was 1,6 (*K. mutabilis),* minimum - *0,0026 (P. involutus).*

According to the data literature data lead contents vary between 1,0 and 10 µg/g DM (Ouzouni et al., 2009; Durali et al., 2005; Popova, 2011; Kalač et al., 2000, Kalač, 2010; Ivavnov et al., 2008; Rudawska et al., 2005; Falandysz et al., 2008; Malinowskaa et al., 2004). It was defined, that the concentration in regional samples are less than normal content, maximum is only 1,8 µg/g. This indicates the absence of lead contamination.

Mushrooms accumulate silver as cadmium. The maximal concentration of this element is 4,3 µg/g *(B.edulis)* and minimal is 0,013 µg/g *(R. paludosa.)* which are comparable with fungi data (Falandysz et al., 2008; Malinowskaa et al., 2004; Falandysz et al., 1994; Pelkonen et al., 2008; Svoboda et al., 2007). High content of cadmium and silver is connected with protein composition. Usual concentration of silver vary between 0,5 - 5,0 µg/g.

Numerous works report usual nickel content from traces to 15 µg/g DM for many species (Ouzouni et al., 2009; Kalač et al., 2000;

Table 1. Mean content of trace metals in different species of mushrooms (p<0,05).

Teneur moyenne en éléments traces dans les différentes espèces de champignons (p<0,05).

Elements	micorizal		saprotrophic		xylotrophic	
	M ± SE	SD	M ± SE	SD	M ± SE	SD
Ag	1,3 ±0,2	1,2	1,2 ±0,4	1,2	1,3 ±0,4	1,2
Cd	1,6 ±0,4	2,3	0,44 ±0,30	0,91	1,1 ±0,4	1,3
Co	0,14 ±0,02	0,14	0,25 ±0,06	0,17	0,38 ±0,25	0,76
Cr	1,2 ±0,2	1,1	2,1 ±0,7	2,0	1,8 ±0,8	2,4
Cu	44 ±5	28	31 ±6	19	18 ±4	11
Fe	141 ±23	135	225 ±64	192	340 ±153	459
Mn	18 ±2	14	34 ±9	27	33 ±14	41
Ni	9,4 ±2,4	14	3,0 ±1,0	2,9	2,9 ±0,7	2,0
Pb	0,44 ±0,07	0,39	0,51 ±0,13	0,39	0,90 ±0,21	0,62

Table 2. The mean, max and min mass fraction (µg/g DM) for each analyzed microelements in the whole fruiting body, together with details for each individual species.

Fractions massiques moyenne, maximale et minimale (µg/g DM) pour chaque microélément analysé dans l'ensemble du champignon (fructification), et ce pour chacune des espèces.

species		Cd	Cr	Cu	Co	Pb	Ag	Ni	Mn	Fe
Boletus edulis Bull.	Mean	4,4	0,74	30	0,12	0,14	2,8	5,9	9,3	61
	max	8,7	1,1	46	0,34	0,43	4,3	10	18	75
	min	1,8	0,45	8,0	0,027	0,0083	1,3	2,7	1,5	48
Pleurotus ostreatus (Jacq.) P.Kumm.	Mean	0,44	3,2	7,7	0,26	0,95	1,6	3,1	54	673
	max	1,1	7,9	12	0,53	1,7	2,7	6,2	135	1525
	min	0,092	0,67	4,4	0,013	0,18	0,32	0.72	6.0	210
Lactarius rufus (Scop.) Fr.	Mean	0,11	0,78	25	0,15	0,20	1,3	10	9,6	100
	max	0,14	1,0	31	0,27	0,32	2,7	23	20	199
	min	0,086	0,48	21	0,031	0,015	0,036	1,7	1,5	34
Tylopilus felleus (Bull.) P. Karst.	Mean	0,85	0,99	37	0,058	0,35	1,7	16	12	193
	max	2,3	1,6	50	0,12	0,43	2,5	46	23	275
	min	0,080	0,68	29	0,013	0,27	0,78	1,1	1,6	91
Cantharellus cibarius Fr.	Mean	0,081	2,2	70	0,15	0,56	0,50	3,4	26	312
	max	0,11	4,8	133	0,26	1,0	0,77	5,5	55	658
	min	0,038	0,56	34	0,0042	0,16	0,26	1,5	4,3	74
Kuehneromyces mutabilis (Schaeff.) Singer & A.H.Sm.	Mean	0,74	1,5	26	1,2	1,7	2,6	2,4	38,5	162
	max	1,2	2,4	27	1,6	1,8	3,9	4,0	39	262
	min	0,261	0,56	25	0,037	1,6	1,2	0,90	38	61
Hypholoma fasciculare (Huds.) P. Kumm.	Mean	1,9	0,57	27	0,021	0,76	0,43	4,2	13	113
	max	3,6	0,92	39	0,038	0,95	0,61	5,6	23,3	182
	min	0,19	0,22	15	0,0041	0,56	0,25	2,8	2,5	44
Paxillus involutus Batsch ex Fr.	Mean	0,26	0,33	56	0,17	0,18	0,52	4,6	15	136
	max	0,36	0,41	77	0,34	0,25	0,61	8,4	22	214
	min	0,15	0,24	34	0,0026	0,11	0,42	0,76	7,9	58
Russula xerampelina var. rubra (Britz.) Sing.	Mean	2,95	0,46	61	0,021	0,68	0,26	4,6	14	72
	max	4,7	0,46	79	0,033	1,3	0,29	5,0	15	96
	min	1,2	0,45	43	0,0085	0,072	0,22	4,2	14	48
Russula paludosa Britzelm.	Mean	1,24	0,73	35	0,036	1,2	0,89	7,2	23	57
	max	1,4	0,93	38	0,054	1,4	1,8	11	27	65
	min	1,0	0,53	33	0,019	0,98	0,013	3,6	18	49

Table 3. The mean mass fraction (µg/g DM) for each analyzed microelements in the whole fruiting body, together with details for each individual species.

Fraction massique moyenne (µg/g DM) pour chaque microélément analysé dans l'ensemble de la fructification du champignon (fructification), et ce pour chacune des espèces.

species	Cd	Cr	Cu	Co	Pb	Ag	Ni	Mn	Fe
Coltricia perennis (L.) MURRILL	2,9	0,71	23	0,43	0,87	0,31	1,9	17	72
Craterellus cornucopioides (L.) PERS.	0,046	5,0	23	0,18	0,47	0,28	2,9	93	487
Hydnum repandum L.	0,030	1,1	18	0,083	0,12	0,50	7,5	18	143
Kuehneromyces mutabilis (SCHAEFF.) SINGER & A.H.SM.	0,35	1,0	14	0,16	0,17	1,0	0,75	24	86
Lactarius camphoratus (Fr.) Fr.	0,10	0,58	49	0,0051	0,43	0,34	3,1	33	215
Lactarius helvus (Fr.) Fr.	0,061	0,57	25	0,010	0,44	2,4	1,6	15	80
Lactarius mitissimus (Fr.) Fr.	1,1	1,8	40	0,021	0,61	0,28	25	5,8	117
Leccinum aurantiacum (BULL.) GRAY	1,2	0,54	136	0,32	0,025	3,1	7,1	9,7	116
Leccinum holopus (ROSTK.) WATLING	6,3	0,49	36	0,013	0,0093	0,62	4,4	9,9	318
Lepista nuda (BULL.) COOKE	0,13	2,2	36	0,19	0,23	3,5	2,0	25	585
Marasmius scorodonius (FR.) FR.	0,16	2,0	28	0,42	0,94	1,2	1,1	40	117
Pholiota aurivella (Fr.) Kumm.	2,5	1,6	23	0,022	0,90	0,61	2,8	4,6	401
Ramaria invalli (Cott. Et. Wakef.) Donk.	0,018	6,1	7,9	0,13	0,47	1,2	1,7	19	280
Russula aeruginea Lindbl. Ex. Fr.	0,12	1,4	32	0,24	0,39	0,81	0,76	43	106
Russula betularum HORA	0,24	1,7	46	0,017	0,33	0,31	4,1	5,1	105
Russula claroflava Grove.	0,13	1,3	34	0,24	1,2	2,7	3,1	36	53
Russula cyanoxantha (Secr.) Fr.	1,9	0,82	47	0,54	0,044	0,14	2,2	10	64
Russula decolorans (Fr.) Fr.	0,22	0,63	27	0,15	0,32	0,21	24	34	65
Russula delica FR.	0,018	3,0	40	0,20	0,59	1,2	11	29	321
Russula foetens PERS.	0,38	1,0	39	0,36	0,67	2,4	2,5	42	74
Russula lepida S. F. Gray.	0,19	1,3	31	0,47	1,2	2,9	0,70	59	66
Xerocomus chrysenteron (Bull.) Quél.	7,0	4,2	27	0,23	0,43	1,4	63	9,0	118

Kalač, 2010; Ivanov et al., 2008; Malinowskaa et al., 2004). The upper level was found in *R. lepida (0,70* µg/g *)* the highest recently reported level of 24 µg/g DM in *R. decolorans*

Usual manganese content in mushrooms varies between 10 and 60 µg/g DM (Ouzouni et al., 2009; Durali et al., 2005; Kalač et al., 2000; Kalač, 2010; Ivanov et al., 2008; Falandysz et al., 2008; Malinowskaa et al., 2004; Pelkonen et al., 2008) in some species as *P. ostreatus (136* µg/g*)* and *C. cornucopioides* (93 µg/g). All of these samples were picked in the second studying zone.

As results from papers published, iron content in mushrooms on unpolluted area varies between <25 – 500 µg/g DM (Ouzoni et al., 2009; Durali et al., 2005; Kalač et al., 2000; Kalač, 2010; Ivanov et al., 2008; Rudawska et al., 2005; Falanysz et al., 2008; Malinowskaa et al., 2004; Pelkonen et al., 2008). The highest level of iron is 1525 µg/g (P. *ostreatus, zone II).*

It was suggested that there are connection between levels of industrial and agricultural loads and microelement content in fruit bodies. Micorrhizal fungi were collected in all studying zones, saprotrohic and xylotriphic fungi were gathered only in the first and second zones.

It has not been ascertained obvious depending on the degree of anthropogenic load, but obviously the content of Cd, Ni in micorrhizal, saprotrophic and xylotrophic fungi in zone I more than in others. The first zone is characterized by a high level of industrial and low agricultural load. The II-nd zone differs in content of Ag, Cr, Mn, and the IIIrd zone - Cu. THE SECOND ZONE is a medium level of industrial and agricultural load too, and the third - a low industrial, and high agricultural load. It should be noted that xylotrophic fungi - accumulate Pb, Fe, Mn and Cr more than mushrooms of other trophic groups (Figure 2). These results are comparable with literature data (Ivanov et al., 2008).

There are four genuses Boletus Fr., Cantharellus Fr., Lactarius S.F. Gray, Russula (Fr.) S.F.Gray, which are common for all studying zones; therefore, the microelements in their fruit body were compared. High accumulating capacity of Cd and Ag is peculiarity for Boletus, Cr, Pb, Mn, Cu - *Cantarella*, Co, Ni - *Luctaries*. But there are no evidence dependence between concentration metals in fruit bodies and levels of anthropogenic loads on areas. There are correlations between metals fraction in *Russula* species only (table 4). The highest concentration of metals in fruit bodies of mushrooms (except of Cd and Cu) is in the second zone. It is mean that there are cadmium and copper contamination on

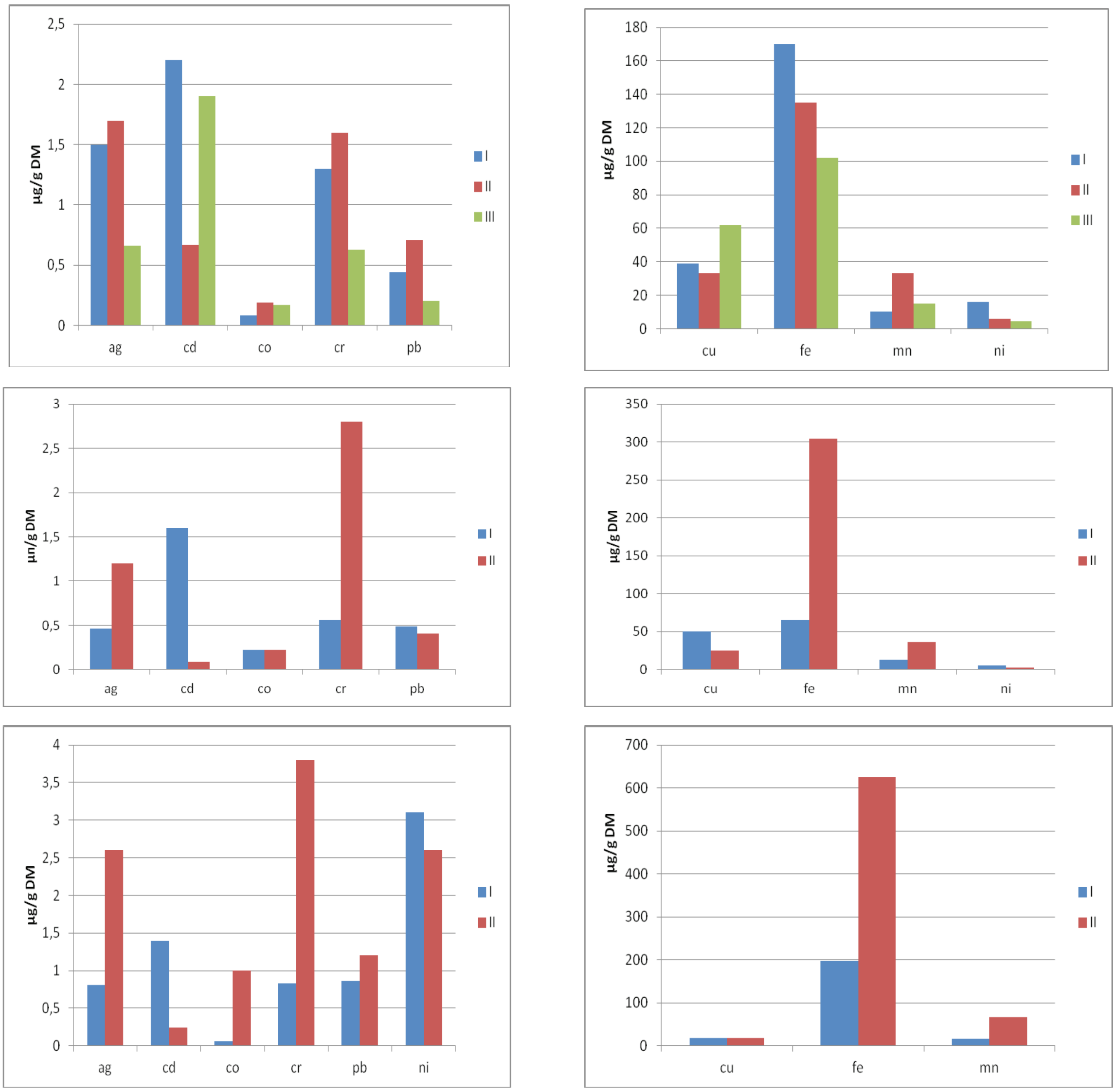

Figure 2. Means of elements in a) mycorrhizal fungus; b) saprotrophic; c) xylotophic fungi in different studying zones: I - forest area of Sambian; II - forest area in the west part of Polessk plain; III - forest area on the Sheshupe plain.

Moyennes des éléments dans a) un champignon mycorhizien ; b) saprophyte ; c) des champignons xylotrophes dans les différentes zones étudiées : I - zone de forêt de Sambian ; II - zone de forêt dans la partie ouest de la plaine de Polessk ; III - zone forestière de la plaine de Sheshupe.

Table 4. The mean mass fraction (µg/g DM) of microelements in fungi bodies collected on study sites.
Fraction massique moyenne (µg/g DM) de microéléments dans les champignons collectés sur les sites d'étude.

zone	Cd	Cr	Pb	Co	Ag	Cu	Mn	Fe	Ni
Boletus Fr.									
I	5,3	0,86	0,063	0,19	3,3	36	9,9	65	7,3
II	4,9	0,45	0,43	0,027	3,3	41	8,1	48	2,7
III	2,2	0,79	0,008	0,095	1,3	8,0	9,4	66	6,3
Cantharellus Fr.									
I	0,092	2,2	0,64	0,18	0,62	50	4,3	658	4,3
II	0,11	4,8	1,0	0,17	0,78	34	55	415	1,5
III	0,16	0,82	0,29	0,13	0,30	97	23	88	3,9
Lactarius S.F. Gray									
I	0,35	0,99	0,45	0,017	1,5	36	14	112	13
II	0,086	0,82	0,27	0,17	1,2	22	20	199	1,9
III	0,14	0,48	0,015	0,27	0,036	21	7,9	66	7,0
Russula (Fr.) S.F.Gray									
I	2,5	1,1	0,81	0,025	0,30	45	10	101	4,5
II	0,30	1,4	0,82	0,25	1,7	34	37	105	7,6
III	1,5	0,60	0,37	0,19	0,13	53	17	59	3,4

Table 5. Concentration factors (Fc) of microelements by wild mushrooms of different genus.
Facteurs de concentration (Fc) de microéléments dans différents champignons sauvages.

genus of mushrooms	Ag	Cd	Cu	Ni	Cr	Pb	Co	Mn	Fe
Boletus Fr.	32	28	1,4	0,23	0,02	0,01	0,02	0,01	0,002
Cantharellus Fr.	5,7	5,1	3,2	0,13	0,06	0,04	0,02	0,04	0,009
Coltricia S.F.Gray	4,1	6,1	0,97	0,16	0,07	0,03	0,03	0,06	0,007
Hypholoma (Fr.) Kumm.	4,9	12	1,2	0,16	0,02	0,05	0,003	0,02	0,003
Kuehneromyces Sing. et A. H. Smith	29	4,6	1,2	0,09	0,04	0,11	0,16	0,06	0,005
Lactarius S.F. Gray	13	1,7	1,4	0,39	0,03	0,02	0,01	0,02	0,003
Leccinum S.F.Gray	24	12	2,7	0,14	0,04	0,02	0,03	0,03	0,008
Lepista (Fr.) W. G. Smith	27	0,9	1,5	0,06	0,06	0,04	0,04	0,05	0,009
Paxillus Fr.	5,9	1,6	2,5	0,18	0,009	0,01	0,02	0,02	0,004
Pleurotus (Fr.) Kumm.	19	2,8	0,35	0,12	0,09	0,06	0,04	0,08	0,02
Russula (Fr.) S.F.Gray	12	6,0	1,8	0,23	0,03	0,04	0,03	0,04	0,003
Tylopilus Karst.	19	5,3	1,7	0,62	0,03	0,02	0,008	0,02	0,005
Armillariella Karst.	12	2,2	0,62	0,03	0,03	0,01	0,02	0,03	0,002
Craterellus Pers.	3,2	0,29	1,0	0,11	0,15	0,03	0,03	0,13	0,01
Hydnum Fr.	5,7	0,19	0,80	0,29	0,03	0,007	0,01	0,03	0,004
Marasmius Fr.	19	0,13	0,28	0,02	0,004	0,03	0,02	0,02	0,009
Pholiota (Fr.) Kumm.	6,9	15	1,0	0,11	0,05	0,06	0,003	0,007	0,01
Ramaria S.F. Gray	14	0,11	0,36	0,065	0,18	0,03	0,02	0,03	0,008
Xerocomus Quel.	16	44	1,2	2,4	0,12	0,03	0,03	0,01	0,003

the Sambian peninsula. Probably *Russula* are perspective for using as bioindicators.

There were no obvious relationships between the contents of the observed metals in fruiting bodies and the contents of total metals in the upper layer of soil (Koroleva, 2014). To study the storage capacity of the studied species of fungi we have compared the content of individual metals in fruiting bodies of wild mushrooms and lithosphere. In accordance with the calculated concentration factor ($Fc = C_{Me} / C_{c.e}$, where C_{Me}-content element in the sample, µg/g, $C_{c.e}$ - the average concentration of this element in crust earth, µg/g) ranges of decreasing concentrations for fungi of different family had the following form (Table 5).

How as shown in the table, the strongest silver and cadmium accumulators are *Boletus* and *Xerocomus* species, These data are comparable with fungi data from Poland, Czech Republic and Finland (Rudawska et al., 2005; Falandysz et al., 2008; Malinowskaa et al., 2004; Falandysz, 1994; Pelkonen et al., 2008). Such species as *Kuehneromyces, Leccinum, Lepista, Tylopilus Marasmius* are excellent silver concentrators too. The rest species are moderate silver accumulators. It seems that silver is essential element for fungi, and excessive content of these microelement is not connected with the transport from soil on unpolluted territory.

5. Conclusion

In general, most of fungi microelements contents are on a low level of the range of concentrations, it is indicating a low geochemical background. An exception there is capacity to accumulate cadmium by *Boletus* and *Xerocomus.* The most probable indicators may be fungi with moderate storage capacity, for example - Russula.

There are no a clear relationship between the concentration of some metals in the most species of wild mushrooms and the level of antropogenic impact. But it is obviously, the concentration of cadmium and copper in fruit fungi bodies are higher on Sambian peninsula - the territory with high level of antropogenic (industrial) load. Also there are the great amount of metals in mushrooms in samples collected in the forest in the west part of Polessk moraine plain. The main source of microelements, such as chromium, nickel, iron and manganese, emission there is maybe natural (peat fire) and technogenical (gas flaring) reasons.

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