RADIOACTIVE CONTAMINATION OF UKRAINIAN WILD-GROWING MUSHROOMS

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ABSTRACT

By the activity of accumulated radiocaesium mushrooms, especially mycosymbiotrophs, prevail both plants and forest litter (which during the all post-Chornobyl period is the main depot of radionuclides) by several to hundreds times. This fact allows to use species-hyperaccumulators, for instance of radiocaesium, as bioindicators for radioactive contaminated territories. They include certain representatives of *Cortinariaceae*, *Russulaceae*, *Boletaceae*, *Suillaceae*, *Hydnaceae*, *Paxillaceae*, *Tricholomataceae*, *Gomphidiaceae*. Among them, as widely spread edible species *Boletus badius* (Fr.) Kühn., and as common species *Lactarius rufus* (Scop.) Fr. and *Paxillus involutus* (Batsch) Fr., not consumed by population because of their inedibility and toxicity, had been recommended as most convenient objects for long-term radioecological monitoring of contaminated territories of Ukrainian Polissya. Accumulation of radiostrontium was in 10-10^2 times less than radiocesium. The use of mushrooms-bioindicators let give the prognosis estimation of the situation with contamination levels of soils, other wild-growing mushrooms and berries. At the same time it should be noted that it's not possible to use them for exact statistically reliable estimation of the territories contamination levels taking into account the high level of variability observed even in the samples of the same species in the same location.

Keywords: bioindication, ^{137}Cs, ^{90}Sr, the Chornobyl catastrophe.

INTRODUCTION

The Chornobyl catastrophe is unprecedented both by the territory of radioactive contamination and by intensity of doses absorbed by biota objects. Even 25 years after the accident radioactive contamination of mushrooms is quite significant, in some cases reaching very high levels, and creates human health problems resulting from their nutritional and medicinal use. The capacity of mushrooms to be concentrators of heavy metals and radionuclides of natural and technogenous origin is well documented in special literature [1-8]. A strong argument in favor of use of macromycetes as bioindicators is a clear prevailance of radiocaesium contamination for the whole post-Chornobyl period in some macromycetes species relative to forest litter (by several to hundreds times), which, in turn is the main

radionuclides depot [9-11]. It must be noted that the radioactively polluted areas of Ukraine are characterized by the mosaic pattern of contamination that complicates the estimation and forecast of radionuclides uptake by biota objects. ^{137}Cs (during the first post-catastrophe period in combination with ^{134}Cs) was confirmed to be the main doze-forming radionuclide in the contaminated area, and that conditioned a priority given to the uptake of this element by mushrooms. However, fruiting bodies having a high activity are only an insignificant part of the total mycelial biomass which is situated in the organic soil layer. An essential contribution of the macro-and micromycetes mycelia biomass and its ability to uptake and retain radionuclides play a very important role in its migration and distribution processes.

MATERIALS AND METHODS

^{137}Cs activity in fruiting bodies of wild growing mushrooms (207 species) and substrates from their habitats, collected in 1990-2010 at 159 locations of Kyiv (including the Chornobyl zone), Chernihiv, Zhytomyr, Cherkassy, Volyn', Rivne, Ivano-Frankivs'k, Poltava, L'viv, and Zakarpattia regions of Ukraine have been studied using gamma-spectrometry. Some samples were analyzed on ^{90}Sr using radiochemical methods on the basis of the accumulation of ^{90}Y. Samples weighed from 1 to 200 g and had 3 to 30 fruiting bodies. Soil samples were taken at the depth of 0-5 cm. Mushroom samples cleaned from soil and plant particles as well as samples of soil (substrate) were dried at 40-50^{o}C and ground to fine-dispersed condition. Then they were dried at 80^{o}C for 24 hours and placed in plastic Petri dishes, or plastic bags. The counting time was 6-36 hours. Counting errors for the measurements of ^{137}Cs were usually lower than 20%. Average levels of soil surface contamination with ^{137}Cs were defined during field measurements, according to the maps presented in the National report [12], Atlas of radioactive contamination of Ukraine and data in General dosimeter certification.

RESULTS AND DISCUSSIONS

Researches of radionuclide accumulation in mushrooms of Ukrainian Polissya which is the most polluted region as a result of failure on Chornobyl Nuclear Power Plant (ChNPP) in 1986, have shown that during all period after catastrophe mushrooms constantly demonstrated high levels of radiocesium contamination**.** It is clear that mushrooms contamination levels is mainly correlated with soil contamination levels. The maximum radiocaesium levels (up to millions Bq per kg of dry weight) in species taken from the Chornobyl exclusion zone were observed in mycosymbiotrophic species - *P.involutus* – 31 MBq/kg d.w.(Shepelychi forestry, 1996), *Boletus subtomentosus* (L.) Quél.– 20 (Shepelychi forestry, 2004), *Gomphidius glutinosus* (Schaeff.)Fr. – 17 ("Red"forest, 1993), *Lactarius turpis* (Weinm.) Fr. – 19 and *Suillus luteus* (L.) Roussel – 15 (Kopachi, 2004), *B. badius* – 12 ("Red" forest, 1996), *B. edulis* Bull. - 11 MBq/ kg d.w. (Janiv, 1998). In general, ^{90}Sr uptake in wild-growing mushrooms is not as intensive as that of radiocesium. Samples from that zone were shown have a ratio of ^{137}Cs/^{90}Sr within the range 10-10^{3} (mean - 10^{2}).

However, it is not the reason to ignore ^{90}Sr, that element presenting a great danger for the human organism. In cultivation condition it was shown increasing of radiostrontium accumulation in edible and medicinal species such as *Lentinula edodes* (Berk.) Pegler and *Pleurotus ostreatus* (Jacq.) Kumm. [13]. This phenomenon can be connected with higher biological availability of ^{90}Sr from mixed and watered substrates which are used in mushroom industrial culture. It can be assumed that an increase of ^{90}Sr activity in wood (observed last years at the contaminated territories) will inevitable cause increase of its content especially in lignotroph species. Therefore, the selective control of ^{90}Sr accumulation in lignotrophs and especially cultivated ones even at the areas with low surface soil contamination is strongly recommended.

The most numerous group of mushroom specimens was taken from region with the surface contamination of 37 – 185 kBq/m^2 (i.e.zone of an intensified radiation control). Presently over 1.5 million people of Ukraine live at such contamination level [12]. Here, despite the considerable variability of the obtained data, that is typical for radiobiological research, quite high levels of radiocesium accumulation were observed. Coefficients of accumulation (which are equal to the ratio between activity of radiocesium in mushrooms and its activity in the substrate/soil in the location) reach tens, hundreds, and during the first post-accident years even thousands. For instance, during the period from 2000 to 2005 the maximum levels of radiocesium in the studied locations with this average levels of surface contamination of soils with ^{137}Cs have been observed in *L. rufus* – 375294 (vil.of Kolentzi), *P. involutus* – 282764 (vil.of Fenevychi), *Cortinarius sp.* – 269692 (vil. of Lutizh), *Pluteus cervinus* (Schaeff.) P.Kumm.– 161643, *B. badius* - 120711, *S. luteus* – 117771 (near city of Ivankiv), *Hebeloma crustuliniforme* (Bull.) Quél.– 100519 Bq/kg dry weight (settl.of Klavdievo-Tarasove). High levels of radiocaesium uptake constantly were shown by *B. badius* from different locations (Fig. 1). A considerable decrease in levels of radiocaesium was observed only in drough-affected years. During all period of investigations accumulation of radiocesium in wild growing mushrooms represents a damped wave process with rises in wet years and lowest values in dry years.

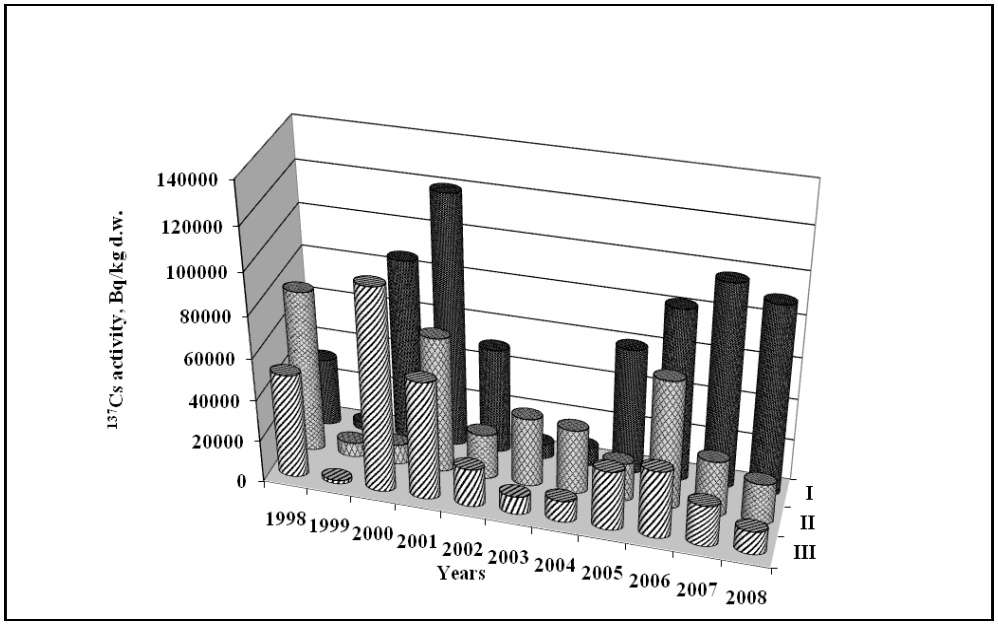

Figure 1. Activity of ^{137}Cs in fruiting bodies of *B.badius* from locations with average soil surface contamination 37 – 185 kBq/m^2 (I – city of Ivankiv, II – vil. of Shpyli, vil.of Lutizh, Kyiv region).

The ratio ^{137}Cs/^{90}Sr was quite high (Fig.2).

On the whole, during the last years the levels of ^{137}Cs contamination of up to 80% of edible species samples (*Boletus* spp., *Suillus* spp., *Leccinum spp., Cantharellus cibarius*, *Lactarius deliciosus*, *Tricholoma* spp. etc.) traditionally included into a diet of Slavic people exceeded the maximum permissible norms accepted in Ukraine (2,5 kBq/kg d.w.).

At levels of ^{137}Cs contamination $\leq$ 1 Ci/km^2 in macromycetes also quite high level of radiocaesium were observed.

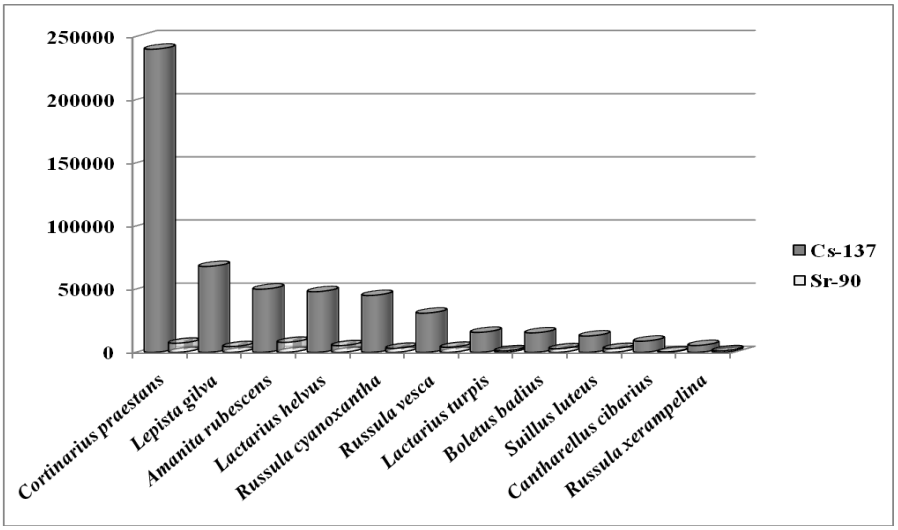

Figure 2. ^{137}Cs and ^{90}Sr activities in mushrooms in 2010 (vil.of Karpylivka, Chernihiv region).

Analysis of literature and our results of 1990-2010 monitoring allows concluding that level of radionuclide accumulation in mushroom depends both on specific radioecological situation in the area of mushroom sampling (quantitative and qualitative composition, forms of radionuclides present in soil, moisture, pH, type of soil, climatic factors, landscape peculiarities etc) and on mushroom species specificity, belonging to ecological trophic groups, depth of mycelia location in soil. It must be noted that the tendency of increase of accumulation ability in the sequence from lignotrophs →humus saprotrophs →litter saprotrophs →mycosymbiotrophs, described earlier [9, 11] apparently concerns only the accumulation of radiocesium. It is clear that in case of ^{90}Sr this sequence will be of other kind.

In spite of positive correlation is marked between the level of contamination of soils, humidity and level of contamination of mushrooms on the whole, mosaic pattern of contamination of territory of Ukraine, complex of the controlled and non-controlled factors, and especially extraordinarily high variability of mushrooms contamination levels (Table 1) complicate the prognosis estimation of the dose loadings on the human as a result of consumption of wild growing mushroom species.

Table 1. The estimation of variability of mushrooms contamination levels in 1990-2010

The average level of soil surface contamination with ^{137}Cs, kBq/m^2	The range of mushrooms contamination with ^{137}Cs, kBq/kg d.w.
3,7-18,5	BDL – 150
18,5-37	BDL – 300
37-185	BDL – 350
185-370	100 – 350
370-555	600 – 1 300
555 – 1480	4 000 – 17 000
>1480	Up to 32 000

BDL = below detection limit

The conducted investigations on wild growing mushrooms of Ukrainian Polissya made it possible to single out species with hyper-accumulative ability. Certain mycosymbiotrophic representatives of families *Cortinariacea*e [*Cortinarius* spp., *Rosites caperata* (Pers.) P.Karst., *Hebeloma crustuliniforme* (Bull.) Quél.], *Russulaceae* (especially *Lactarius* spp.), *Boletaceae* [*Boletus* spp., *Leccinum scabrum* (Bull.) Gray, *Tylopilus felleus* (Bull.) P.Karst.], Suillaceae (*Suillus* spp.), *Paxillaceae* [*Paxillus involutus* (Batsch) Fr.], *Hydnaceae* [*Sarcodon imbricatus* (L.) P.Karst., *Hydnum repandum* L.], *Tricholomataceae* [*Tricholoma flavovirens* (Pers.)S.Lundell], *Gomphidiaceae* [*Gomphidius glutinosus* (Schaeff.) Fr. and *G.rutilus* (Schaeff.) S.Lundell] have shown steadily high levels of contamination that makes it possible to use them for bioindication purposes. Among them widely spread and common species in Ukraine *L.rufus* and *P.involutus* may be regarded as the most convenient bioindicators since inedibility of the first and toxicity of the second allow to reduce the influence of the antropogenic factor in the estimation environmental radiocesium contamination. Use of *B. badius* as the bioindicator is of some interest in terms of comparison with the data obtained for other countries**.** The coefficients of accumulation of these three species reach tens and even hundreds.

Mapping that involved bioindicative mushroom species (Figure 3) shows an evident gradient of radioactive-induced contamination effects on mushroom fruiting bodies from northern and northwest part to southern and central part of Kyiv region of Ukraine. Figures show a coincidence, in general, of contamination intensity with the soil contamination levels presented on maps published in the National report [12].

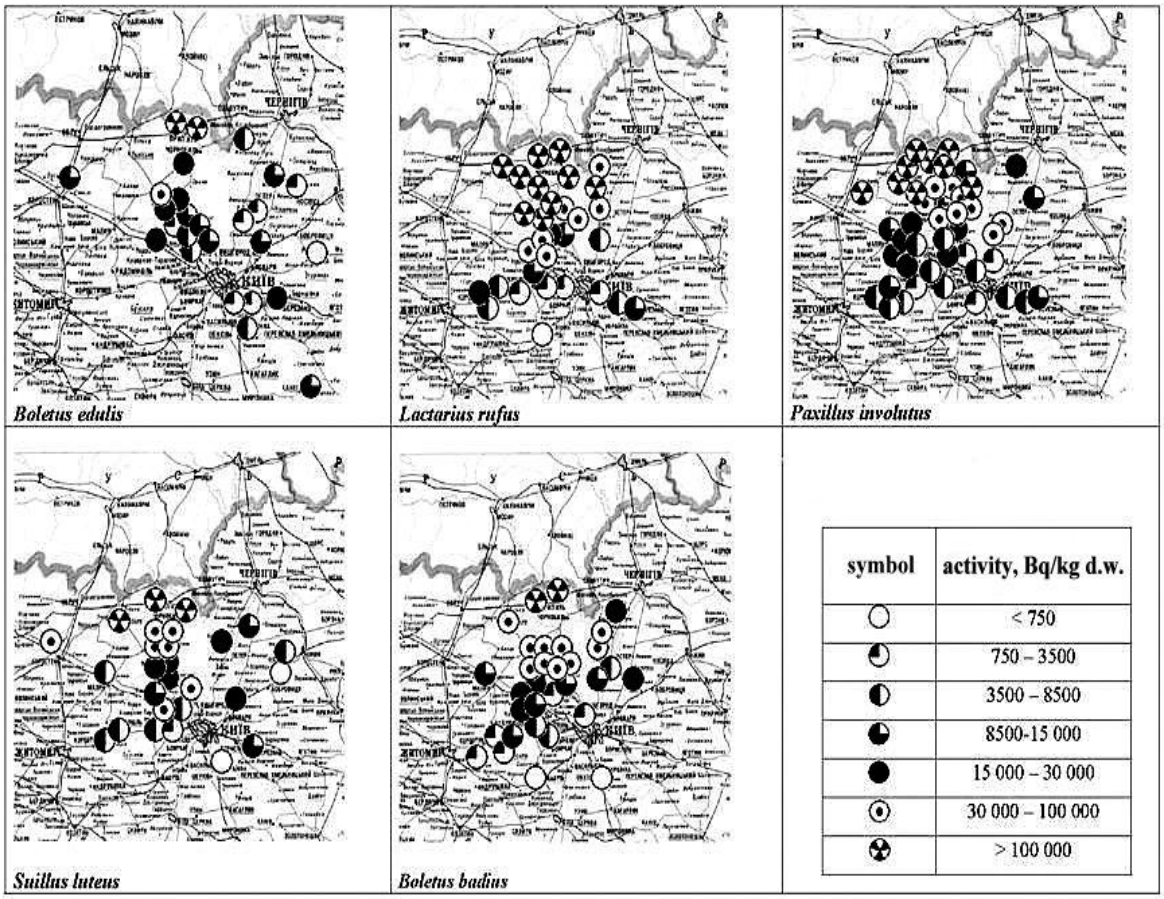

Figure 3. Mapping of Kyiv and part of Zhytomyr region with species-bioindicators.

The use of selected mycoindicators is an express-technique that enable to assess and extent of risk of mushroom consumption in that area, to forecast the development of situation regarding contamination levels of soils, other wild-growing mushrooms and berries. At the same time it should be noted that it is not possible to use them for exact statistically reliable estimation of the territories contamination levels due to the high level of variability observed even in the samples of the same species in the same location.

Literature data regarding a radioactive danger of mushrooms are numerous and as a result it is quite natural to ask a question about the reasons of a mass character of wild-growing mushrooms consumption by the population of Ukraine. In our opinion the reasons are several. They lie in the traditional perception of «the gifts of forest», in lack or complete absence of information concerning mushroom radioactive contamination in each area, in the syndrome of «tiredness» of negative information published in mass media and in sense of being doomed that in combination with a finance modest means of the majority of people living in the contaminated areas form that vicious circle that is hard to get out from. It should be mentioned that for some country people wild growing mushroom collection for sale forms a significant part of their family's budget. Thus, a specific scientific problem has deep social grounds.

CONCLUSIONS

The analysis of radiocesium accumulation dynamics in wild growing mushrooms gives evidence of a long-term radiological risk resulting from their consumption as food and medicine on the territory with ^{137}Cs contamination more than 37 kBq/m^2. It can be said that this situation will remain dangerous for many years. In these conditions the only reasonable alternative is to increase the industrial mushroom cultivation involving new perspectives with species having high nutritional and medicinal properties on tested free from ^{137}Cs and ^{90}Sr substrates.

ACKNOWLEDGEMENT

Authors express their gratitude to Professor Solomon P. Wasser (University of Haifa, Israel) and Prof. Kurt Haselwandter (Institute of Microbiology, Innsbruck, Austria) for long-term collaboration.

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