Radiocaesium in forest blueberries in selected location of Jeseníky protected landscape area

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Abstract: Radioactive contamination of the Czech Republic caused by fallout after the Chernobyl nuclear power plant accident continues to be actual after 28 years. Due to the event the environment of the Czech Republic is still contaminated with radiocaesium (^{137}Cs) with average surface activity (the 19th November 2014) of 4.034 kBq·m^{-2}. Trace amount of radiocaesium (^{137}Cs) can be also identified in fruits of forest plants. This study brings new findings about the content of radiocaesium (^{137}Cs) in the wild blueberries. Also the radiocaesium transfer (T_{AG}) from soil to berries was analyzed. Samples of the fruits together with the upper soils under the plants were collected on selected locations of Jeseníky protected landscape area. The ^{137}Cs activity was measured by gamma spectrometric analysis using HPGe detector. It was found that the radiocaesium activity concentrations in blueberries (fruits) ranged from 15.66 Bq·kg^{-1} to 86.54 Bq·kg^{-1}, and correlated (r = 0.93) with the ^{137}Cs activity in soil, which reached values from 184.32 Bq·kg^{-1} to 520.54 Bq·kg^{-1}. Soil-to-fruit aggregated transfer factor was 3.839×10^{-2} m^2·kg^{-1}. The factor represented very low value of the radiocaesium transport from soil to blueberry fruits, and is also comparable with published data. The determined values of ^{137}Cs in blueberries did not exceed the intervention limit specified for food (600 Bq·kg^{-1}), and do not represent health hazard for the population.

Key words: ^{137}Cs, *Vaccinium myrtillus L.*, Jeseníky PLA, aggregated transfer factor (T_{AG})

Introduction

Accident in Chernobyl nuclear power plant (NPP) was followed with contamination of wide areas of the northern hemisphere. Huge amount of radioactive material (1.2×10^7 TBq incl. 8.5×10^4 TBq of radiocaesium ^{137}Cs) was released into the environment [1]. The radioactive contaminated clouds were transferred, disseminated and subsequently the contained radionuclides were deposited in form of rain-fall to the land surface [2]. The contamination of the Czech Republic was very unevenly distributed with average surface activity of 7.6 kBq·m^{-2} [3]. The highest ^{137}Cs deposition was in the southern and northern Moravia [4]. Especially in the Jeseníky protected land area (PLA), where radiocaesium (^{137}Cs) activity of 50 kBq·m^{-2} in forest soil was found [5]. The Environment of the Czech Republic is still burdened by this anthropogenic radionuclide, because the half-life of ^{137}Cs is 30.07 years [6]. Due to the specific properties of soil the radiocaesium is retained in natural (agriculturally uncultivated) ecosystem in high concentration [7] and the natural ecosystem can be a source of secondary contamination of plants and their fruits, e.g. of forest edible berries. The wild berries are an essential part of the diet for the general population and annual consumption is 1.8 kg per capita in the Czech Republic [8]. Blueberries are called "super fruits" for their extraordinary nutritional and pharmaceutical values [9, 10]. The fruits contain a lot of vitamins, minerals and another element, which are beneficial for human organism. Blueberries are also used in modern medicine [11-15]. The forest berries, however, contain much more post Chernobyl radiocesium (^{137}Cs) compared with fruits from agricultural field production [16].

Material and methods

For the study the protected land area (PLA) of Jeseníky (northeast upland of the Czech Republic) was chosen, because this region has the highest surface contamination of post-Chernobyl radiocaesium (^{137}Cs). The locations of sampling were identified in the destined mountain area according to soil type, altitude and mutual distance. The locations of sampling were divided into four

parcels (100 m^2). Blueberry samples were collected during the fertile seasons of plants. The blueberries were taken using standard manual process (without help of comb). During the sampling of fruits, soil samples (depth 15 cm) were also picked under the blueberry plants. Preparation of samples – blueberries were deprived of impurities, stored to small boxes (volume 100 ml), weighed, identified and laid into the freezer. Soil samples were prepared according to standard procedure – they were deprived of stones and residues of plants, dried to constant weight, crushed, stored to small boxes (volume 100 ml), weighed and labeled. Content of the radiocaesium (^{137}Cs) was measured by gamma spectrometric analysis using HPGe detector, software GENIE 2000 in 100 ml of geometry, measuring time of 10 hours. Aggregated transfer factors (T_{AG}) were defined for evaluation of radiocesium transfer from soil to fruit. Aggregated transfer factor was calculated as ratio of the radiocaesium activity concentration in native fruits ($Bq \cdot kg^{-1}$) to total ^{137}Cs surface activity of soil ($Bq \cdot m^{-2}$). Also correlation between the activity of soil and fruit was determined. The internal radiation doses for the consumer were computed for blueberry samples, which showed the highest content of radiocaesium (^{137}Cs). The analysis of the potential health hazard risk due to the consumption of blueberries was based on estimating the effective ingestion dose (D) according to the equation [17]:

$$D = h(g) \times A_e \times m \ (Sv \cdot y^{-1})$$

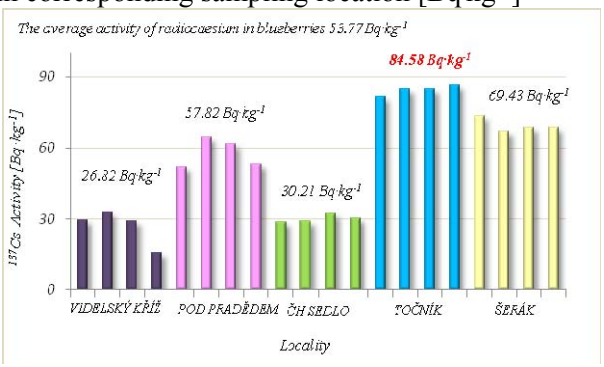
where: $h(g)$ is the effective committed dose per unit uptake of the ingested radiocaesium for an individual belonging to age group ($Sv \cdot Bq^{-1}$), A_e is the activity concentration of the radiocaesium that the blueberries contains ($Bq \cdot kg^{-1}$), and m is the fresh mass of the blueberries ingested per year by the standard individual ($kg \cdot y^{-1}$) in the respective area.

Results and discussion

Radiocaesium (^{137}Cs) activity concentration in blueberries

The ^{137}Cs activity concentrations in wild blueberries reached the values from 15.66 $Bq \cdot kg^{-1}$ to 86.54 $Bq \cdot kg^{-1}$. The lowest radiocaesium concentration was found in blueberries which were taken from the forest ecosystem at an altitude 930 m.a.s.l. – area Videlský kříž. The highest activity of radiocaesium was determined in blueberries which were picked from the homogeneous scrub of blueberries at an altitude 1143 m.a.s.l. – locality Točník. Radiocaesium (^{137}Cs) is metabolically and physiologically similar to potassium [18], so it is accepted by the plant as element which is designated for plant nutrition. Due to nutrient competition in plants species, which grow in the forest ecosystem, lower concentration in blueberries can be expected [7].

Fig. 1 ^{137}Cs activity concentration in the blueberries in corresponding sampling location [$Bq \cdot kg^{-1}$]



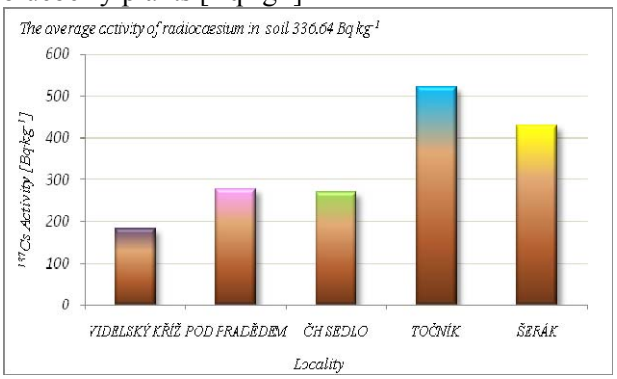
On the contrary – in blueberries, which grow in the homogeneous scrub, the radiocaesium content is higher because the element is transferred among blueberry plants via a net of roots. It conforms to results of Duff et al [19] that the blueberry plants, which grow in a higher altitude, have higher radiocaesium content than the blueberries plants which grow in a lower altitude. This fact is with high probability caused by the soils properties – the forest soils in a higher altitude have bigger content of humus and are more acidic, so allow the considerable mobility of radiocaesium. The radiocaesium is more available for plants [20]. Detected ^{137}Cs activity concentration in our blueberry samples is also comparable with published data of Solatie a Ylipieti [21]. The identified activities of radiocaesium (^{137}Cs) in blueberries were relatively high. Švadlenková et al. [22] summarized that the higher radiocaesium activities in blueberries deserve a special attention compared with another edible forest berries. Kostiainen [23] confirms this fact – the content of radiocaesium (^{137}Cs) decreases in berry fruits in this sequence: blueberries > blackberries; raspberries > strawberries > rowanberries. The ecological requirements of blueberry plants are likely reason of this fact. Acidophil blueberry plants *(Vaccinium myrtillus L.)* search acidic humus wet soils in a higher altitude where they form extensive „carpets“ of union *Vaccinion*. The plants are also bio indicator of acidic soils. The acidity of soil is the main factor which influences the availability of radiocaesium [24]. The radiocaesium uptake via roots is higher when the soil reaction (pH) is lower [25]. In addition, the radiocaesium is in negative correlation with absorption capacity of

the clay and in positive correlation with cation exchange capacity of humus [26]. A secondary contamination of blueberries with the flying of contaminated soil grain [27] or also still relatively high radiocaesium source in rooting depth [22] can be another reasons of the higher content of radiocaesium (^{137}Cs) in blueberries. Although the detected ^{137}Cs activities in blueberries were relatively high, the activities do not represent any important environmental problem and any health hazard for human. It was calculated from our results, that the T_{AG} of blueberries (3.839×10^{-2} $m^2 \cdot kg^{-1}$) shows the similar values to the artificially resulted T_{AG} category (5.5×10^{-2} $m^2 \cdot kg^{-1}$) by Howard et al. [28]. The determined values of ^{137}Cs concentrations did not exceed the intervention limit specified for food (600 $Bq \cdot kg^{-1}$) [29].

Radiocaesium (^{137}Cs) activity concentration in soils

The activity concentration of radiocesium in soil reached the values from 184.32 $Bq \cdot kg^{-1}$ to 520.54 $Bq \cdot kg^{-1}$. The lowest radiocaesium concentration was found in soil which was taken from locality Videlský kříž. The highest activity of radiocaesium was determined in soil which was picked from the locality Točník.

Fig. 2 ^{137}Cs activity concentration in soils under the blueberry plants [$Bq \cdot kg^{-1}$]



The activity concentration of radiocesium in soil reached the values from 184.32 $Bq \cdot kg^{-1}$ to 520.54 $Bq \cdot kg^{-1}$. The lowest radiocaesium concentration was found in soil which was taken from locality Videlský kříž. The highest activity of radiocaesium was determined in soil which was picked from the locality Točník. The detected activities in soil are relatively high. The forest ecosystem is the likely reason of the higher values in soils because the forest ecosystem is (compared to the agricultural ecosystem) very complicated and the ecosystem do not allow for great mobility of radiocaesium because the ecosystem contains a lot of clay minerals which can bind the radiocaesium [30]. The placement of radiocaesium (^{137}Cs) in soil profile is another likely reason. Walton [31] summarized that more than 80 % of radiocaesium (^{137}Cs) remains in upper 15 cm of surface soil. In our study, samples of soil were taken from upper 3.5 cm. The found ^{137}Cs activity in soil exceeded the intervention limit specified for soil in the Czech Republic (100 $Bq \cdot kg^{-1}$). However, this limit is determined for agricultural soils, not for natural (forest) ecosystem which represents the main reservoir of radiocaesium (^{137}Cs) in the environment of the Czech Republic.

Conclusion

It was found that the activity concentration of radiocaesium (^{137}Cs) in the blueberry fruit sampled in the Czech Republic in the PLA Jeseníky reached the maximum activity of 86.54 $Bq \cdot kg^{-1}$. If the average consumer will consume such berries (1.8 kg per year per capita), he could receive the internal radiation dose of 2.02×10^{-3} $mSv \cdot rok^{-1}$. Nevertheless, with respect to the antioxidant effects of edible forest fruit, the consumption can be considered to prevent effects ionizing radiation [32-34]. The study by Wan et al. [35] supports this fact, i.e. the presence of antioxidants in the body of the irradiated organism reduces the effect of radiation. The detected ^{137}Cs activities in soils taken under the blueberry plants were relatively high, reached values from 184.32 $Bq \cdot kg^{-1}$ to 520.54 $Bq \cdot kg^{-1}$ and correlated ($r = 0.93$) with activities in blueberry fruits. These findings correspond with characteristics of forest ecosystems, where a number of contaminants incl. radiocaesium are fixed for a long time and are conformable with earlier published data.

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