THE EFFECT OF VARIETY ON HEAVY METALS INTAKE BY ONION GROWN IN CONTAMINATED SOIL

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ABSTRACT

The environmental study, carried out in Slovak Republic, was aimed at assessment of quality of onion based on the contents of heavy metals (Zn, Cu, Ni, Pb, Cd) as well as the possible correlations among selected heavy metals in soil and onions (*Allium cepa* L.). Seven different varieties were analysed (Sherpa, Boston, Bingo, Shakespeare, Lusy, Všetana, Radar). Seven sampling sites were selected and the analyses of pH_{KCl} , P, K, Mg and chosen heavy metals in 2 different extracts were carried out (*aqua regia*, 1 M NH_4NO_3). Gained results showed that in some sampling sites the measured values were exceeded in comparison with limit values given by the law no. 220/2004 (valid in the Slovak Republic - SR) as well as threshold values proposed by European Commission (EC) (2006). In our paper the values of total cadmium content were in range from 1.10 to 1.28 mg/kg and the content of mobile form of lead was in range from 0.13 to 0.33 mg/kg. In the case of onion the highest acceptable amounts for cadmium and lead were also exceeded and the values ranged from 0.09 to 0.38 mg/kg and 0.56 to 1.80 mg/kg. Among the varieties statistically significant differences ($P < 0.05$) in intake of heavy metals were found (Multiple Range Tests for heavy metal by variety, Method: 95.0 percent LSD).

Keywords: onions, lead, cadmium, permissible limits

1. Introduction

Onion (*Allium cepa* L.) is one of the most important vegetable worldwide. Onion is an important ingredient in all dishes around the world.

The scientific investigations showed that onions contain high quantities of bioactive compounds which are effective in prevention of cancer and heart diseases and has a beneficial effects on the human health (Geetha *et al*., 2011; Bernaert *et al*., 2012).

The production of high quality bulbs requires, quality soil with favourable physical, biological and chemical conditions. Different types of soils have different characteristics that influence growth and yield of crops.

At present time the contamination of environment with heavy metals and consequently food chain preferably draw great attention. Sometimes, vegetable species may accumulate significant amounts of heavy metals, decreasing the quality and biological value of products without visible symptoms of their damage (Maksimović *et al*., 2012). As potential sources of soil contamination with heavy metals are human industrial activities and different substances applied into the soil mainly fertilizers and crop protection chemicals. The toxic effects of heavy metals on human health and ecosystem are well documented (Maksimović *et al*., 2012; Qu *et al*., 2013).

Ecological risks from accumulation of heavy metals in soil are reflected on soil ability to provide hygienic safe foodstuffs.

Lead is a toxic element that occurs in elevated concentrations in soils, mostly as a result of anthropogenic activities (Senila, 2014).
The aim of the present study was an assessment of quality of onion based on the contents of selected heavy metals as well as the possible correlations between selected heavy metals in soil and in onions (*Allium cepa* L.).

2. Material and methods

This study was carried out in Pružina (Slovak Republic). The altitude of the village is in the middle of 381 m a.s.l.

2.1. Plant material

7 cultivars of onions (Sherpa, Boston, Bingo, Shakespeare, Lusy, Všetana, Radar) were obtained from Pružina. The investigated onion cultivars were conventionally cultivated in the same locality under the same conditions.

Collection of samples:
Samples of 7 cv. of onions were collected at full maturity stages from area of Pružina. From the same places, from the arable layer (0-20 cm), soil samples were also taken.

2.2. Chemicals

High-purity analytical reagents were used for all operations.
Conventional chemicals: ammonium nitrate (Merck, Germany), hydrochloric acid (Merck, Germany), nitric acid (Merck, Germany).

Chemical analysis of the soil:
Pseudototal content of risk metals was assessed in soil extract by aqua regia and content of mobile forms of selected heavy metals in soil extract by NH_4NO_3 (c = 1 mol/dm^3). Analytical ending was flame AAS (AAS Varian AA Spectr DUO 240 FS/240Z/UltrAA).

Heavy metals in the plant material:
Homogenized onion samples were mineralized in a closed system of microwave digestion using Mars X-Press 5 (CEM Corp., USA) in a mixture of 5 cm^3 HNO_3 (Suprapur, Merck,) and 5 cm^3 deionized water (0.054 mS/cm) from Simplicity 185 (Millipore, UK). Digestive conditions for the applied microwave system comprised heating to 160 °C for 15 min. and keeping it constant for 10 min. A blank sample was treated in the same way. The solutions were analyzed by flame AAS (AAS Varian AA Spectr DUO 240 FS/240Z/UltrAA).

2.3. Statistical analysis

Results were statistically evaluated by the Analysis of Variance (ANOVA – Multiple Range Tests, Method: 95.0 percent LSD) using statistical software STATGRAPHICS and the regression and correlation analysis (Microsoft Excel) was used.

3. Results and discussion

The element mobility in soils depends not only on heavy metal contents in soils but is also determined by soil pH value, and clay contents and influenced by the fertilization (Fytianos *et al*., 2001). The monitored soils on which the onions were grown, can be characterized as acidic to neutral. The soil reaction in soil samples in the area Pružina had the average value 5.90.

Many of the heavy metals are actually micronutrients, that are essential in small quantities for normal growth of plants and animals. Cu, Mn, Mo, Ni and Zn are the heavy metals that are essential for higher plants (Alloway, 2013).

After overload the certain concentration (excess will) the health of consumer through the food chain can be seriously threatened.

Pseudototal content of risk metals was assessed in solution of *aqua regia*. The results are shown in Table 1.

After evaluation of content of Zn, Cu and Pb no contamination was determined in any of collecting places. In either case the critical value given by Law No. 220/2004 for aqua regia as well as threshold values proposed by European Commission (EC) (2006) was not exceeded. Only in one sampling place Ni content was on the threshold limit given by Law No. 220/2004 for *aqua regia*. In collecting site number 1, where the variety Radar was grown, Ni content was 1.68 times higher than threshold values proposed by European Commission (EC) (2006).

Table 1: Content of heavy metals (mg/kg) in soil extract by *aqua regia*

Locality	Cultivar	Zn	Cu	Ni	Pb	Cd
1	Radar	84.3±0.09	28.67±0.25	50.25±0.86	26.85±0.78	1.13±0.03
2	Boston	85.37±1.01	29.57±0.26	48.27±0.94	24.9±0.44	1.21±0.35
3	Všetana	86.7±1.28	30.85±1.10	49.03±0.51	25.28±0.40	1.19±0.01
4	Scherpa	76.23±0.29	28.63±0.31	46.42±0.87	24.73±0.41	1.26±0.02
5	Lusy	82.25±1.38	30.73±0.81	46.83±0.24	26.07±0.49	1.16±0.02
6	Bingo	86.63±0.94	31.45±0.26	49.50±0.49	22.95±0.13	1.20±0.02
7	Štutgarska	86.98±0.25	29.07±0.33	41.97±0.57	25.30±0.522.35	1.18±0.21
Limit*		150	60	50	70	0.7
Treshold value**		100	40	30	50	0.5

**Limit value for aqua regia – Law No. 220/2004*
***European Commission (2006)*

The higher concentration of Ni is associated with serpentine soils, inhibition of root and shoot growth (Hussain *et al*., 2013). The limit values for Cd were exceeded on all observed sites. In collecting site, where the cv. Scherpa was grown, Cd content was 1.80 times higher than limit value valid in the SR (0.7 mg/kg). On the other hand the high Cd content in the soil extract by *aqua regia* does not inevitably result in the high content in agricultural plants. The mobile form of heavy metals is very important, because is more accessible to plant. The results are shown in Table 2.

Table 2: Content of heavy metals (mg/kg) in soil extract by NH_4NO_3 (c = 1 mol/dm^3)

Locality	Cultivar	Zn	Cu	Ni	Pb	Cd
1	Radar	0.078±0.005	0.042±0.002	0.38±0.006	0.33±0.005	0.041±0.001
2	Boston	0,04±0.008	0.037±0.001	0.27±0.006	0.22±0.03	0.037±0.001
3	Všetana	0.026±0.005	0.034±0.005	0.20±0.008	0.22±0.009	0.030±0.001
4	Scherpa	0.04±0.007	0.026±0.001	0.23±0.005	0.13±0.006	0.026±0.007
5	Lusy	0.048±0.003	0.028±0.001	0.19±0.005	0.21±0.01	0.029±0.001
6	Bingo	0.07±0.005	0.038±0.001	0.26±0.006	0.22±0.01	0.038±0.001
7	Štutgarska	0.041±0.003	0.028±0.01	0.21±0.008	0.22±0.01	0.027±0.001
Limit*		2.00	1.00	1.50	0.10	0.10

**Law No. 220/2004*

From observed heavy metals in 1 M NH_4NO_3 only the contents of Pb in all observing sites were exceeded. In our work the values of lead ranged from 0.14 to 0.33 mg/kg. The highest value (0.33 mg/kg) was measured in site where cv. Radar was grown. Pb content determined in the soil extract by NH_4NO_3 was 3.3-fold higher than limit values.

The contents of all other heavy metals in 1 M NH_4NO_3 were lower than hygienic limits (see Table 2).

Soil to plant transfer is one of the key components of human exposure to metals through food chain (Cui *et al*., 2004). The accumulation of heavy metals in different cv. of onion are shown in Table 3.

From observed heavy metals content of Pb and Cd in onions was exceeded. The highest value of lead (0.27±0.03) was recorded in the cv. Štutgarska. Pb content in the cv. Štutgarska was 2.7 times higher than limit value (0.1 mg/kg) according to EC 1881/2006.The cadmium content in varieties of onion ranged from 0.02 to 0.05 mg/kg (FW). The highest value of cadmium was recorded in collecting site where the cv. Scherpa and Štutgarska was grown, and represented value 0.05±0.02 and 0.05±0.03 respectively. The limit values for Cd in the fresh mater of samples were not exceeded.

The contents of other heavy metals in yellow varieties of onions varied at different intervals (see Table 3). Content of this heavy metal in varieties of onion were lower than limit value according the *Food Codex of the SR* as well as values according *EC 1881/2006 (CR).* Similar results were published also by other authors (Maksimović *et al*., 2012; Hellen and Othman, 2014). Akinwande and Othman (2015) reported higher values for cadmium and lead 0.93 – 1.21 mg/kg and 0.24 – 0.54 mg/kg respectively.

The mechanisms of uptake and availability of heavy metals are influenced by various factors, including soil pH, chemical properties of soil and concentration of other elements (Tangahu *et al*., 2011; Pinto *et al*., 2014). Heavy metal accumulation may also differ greatly within cultivars of an individual species when grown on the same soil (Tang *et al*., 2012), as can be confirmed also by our results (see Table 3).

Table 3: Content of risk metals (mg/kg) in cultivars of onion

Locality	Cultivar	Zn	Cu	Ni	Pb	Cd
1	Radar	20.6±1.94c	6.80±0.33e	0.60±0.02a	0.12±0.05b	0.02±0.01a
2	Boston	15.8±1.10b	6.80±0.43e	2.0±0.82c	0.12±0.05b	0.04±0.03c
3	Všetana	12.0±0.82a	5.6± 0.39c	0.60±0.06a	0.09±0.03a	0.03±0.01b
4	Scherpa	22.0±2.23c	6.40±0.41dc	0.60±0.01a	0.24±0.06c	0.05±0.02e
5	Lusy	17.2±0.60b	5.0± 0.48b	1.0±0.11b	0.09±0.04a	0.02±0.02a
6	Bingo	11.0±1.68a	4.40± 0.4a	0.60±0.03a	0.12±0.03b	0.02±0.01a
7	Štutgarska	12.8±1.72a	6.0± 0.21cd	0.60±0.03a	0.27±0.03d	0.05±0.03d
Limit according to the Food codex of the Slovak Republic					0.10	0.10
Maximal level according 1881/2006					0.10	0.05

In presents work we have found positive correlation between the content of Pb and Cd in the soil and the content of Pb and Cd in the studied onion cultivars (see Figure 1 – 2).

This finding is in agreement with the findings by Rafique *et al*. (2011), who reported significant positive correlation between trace metal contents in the soil and the plant.

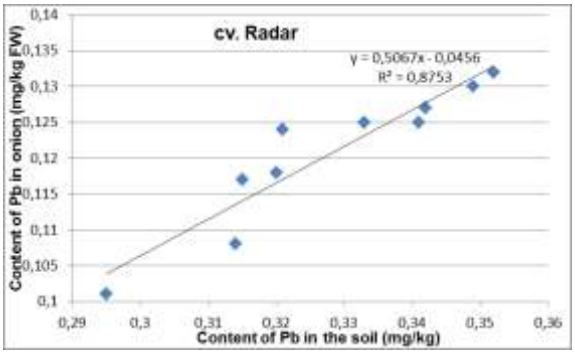

Figure 1: Relationship between content of Pb in the soil and content of Pb in cv. of onions

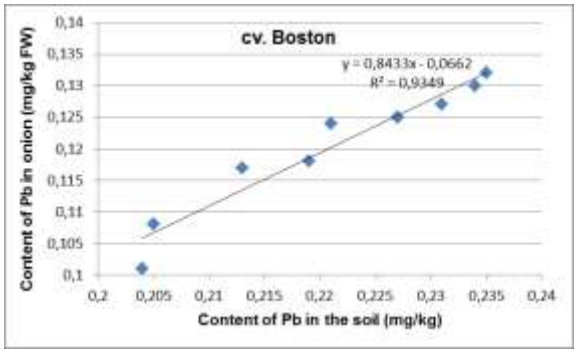

Figure 2: Relationship between content of Pb in the soil and content of Pb in cv. of onions

4. Conclusions

Monitoring of heavy metals in vegetables can provide useful information for promoting food safety. Observed results are important because human health is directly affected by ingestion of vegetables. Our gained results showed, that the content of Pb in the soil is the main polluting factor in this region.

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