# The Transfer of Heavy Metals from Contaminated Soils into Agricultural Plants in High Tatras Region

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**Abstract**: The problems of soil hygiene and contents of the following heavy metals: cadmium, cobalt and nickel in the productive parts of plants in the location of Agricultural Cooperative Štrba in Poprad County were discussed in the presented work. Above-mentioned location is found in the neighbourhood with a chemical factory Chemosvit Svit. The achieved results show that the soil hygiene in this region is mainly affected by the activity of this chemical factory. This factory is producing many risky substances and their results can be seen in the condition of soil hygiene and in the quality of farmed plants. The results of monitored heavy metals (Cd, Co, Ni) prove that the content of cadmium and nickel is the main polluting factor of soil in this region. The increased contents of these elements in soil produce a high risk of the uptake to plants. This further affects the technological quality along with the quality of hygiene of farmed products and finally the food itself as well. A higher attention needs to be paid to cobalt too, because it proved quite high cumulation ability in soil.

**Keywords**: transfer; cadmium; cobalt; nickel; soil hygiene; heavy metals

## INTRODUCTION

The soil quality is derived from its loading by hazardous substances. There are many risky substances in Slovak Republic but many problems are caused by heavy metals. The categories of soils in Slovakia are the following: noncontaminated soil 69.5%; risky soil 28.7%; contaminated soil 1.4% and highly contaminated soil 0.4%. It has been proved that the determined limits for uncontaminated soil do not guarantee that the biomass produced on the uncontaminated soil and the productive parts of plants should not contain values of heavy metals above the limit (Matúšková 1999; Harangozo *et al*. 2008; Lahučký *et al*. 2008). The results of the determination of total contents of Cd, Ni and Co in soils of Slovakia are discussed and at the same time it presents the assessment results in 2M $HNO_3$. The acquired experience shows that the contents of heavy metals in weaker extractants will represent the potentially mobilisable forms (in $HNO_3$). Biologically important microelements or nonessential chemical elements (Cd, Pb, Cr, etc.) belong to heavy metals (Beneš 1993; Čéry *et al*. 2008; Peltznerová *et al*. 2008). The important parameters for the input of heavy metals from soil into plants are: the soil reaction, the content and the quality of organic matter, the nutrition of plants, cation exchange and sorptive capacity, the microbiological activity, the oxidation and reduction potential, the amount and the quality of the clay fraction of soil and the methods of soil cultivation, etc. (Alloway *et al*. 1990; Vollmannová *et al*. 2004; Stanovič *et al*. 2008).

## MATERIAL AND METHODS

The heavy metals (Cd, Co, Ni) was determined in soils and in cultivated crops (barley, wheat, triticale, alfalfa, grass land, potato). The monitoring of risky elements in soil and in cultivated agricultural plants was made on the parcels of Agricultural Cooperative PD Štrba in Poprad County. These parcels lay 850 meters above the sea level at the foot of the High and Low Tatras. Samples were taken from the testing area annually with a pedological probe from three various depths: 0–0.10 m, 0.20–0.30 m

and 0.35–0.45 m according the methodology for "Soil monitoring in SR". Analyses were made from the samples of soil, which were sorted primarily to fine-grained soil I (calibre 2mm). The contents of heavy metals were monitored in the following leach: Total content – It is one of the mayor criteria in judging the limit content of risky elements in soil. Principle of the method: total content was determined after mineralisation by wet way (acids mixture HF-$HNO_3$-$HClO_4$). The analytic mode was determined by the method of atomic absorption spectrometry (AAS Varian AA Spectr DUO 240FS/240Z/UltrAA ). Potentially mobilised forms – It includes various fractions of elements from the point of view of their dissolving capacity. Principle of the method: the extraction of diluted 2M $HNO_3$ is suitable for determination the potentially mobilised forms of heavy metals in soil. It is used to estimate the probable contamination of soil with some risky heavy metals within the ambit of the limit norm of the risky element. The analytic mode was determined by the method AAS. The biomass was analysed from grain crops, oil-bearing plants and grassland.

## RESULTS AND DISCUSSION

The contents of the monitored heavy metals in soil advert the increased ecological ballast on these soils. From the point of view of soil hygiene, a higher attention needs to be paid to this area. The measured values were compared with the limit value for the total content of heavy metals in soil (value A) and further with limit value $A_1$. The limit value $A_1$ is determined for the content of potentially mobilised forms of heavy metals in a leach of 2M $HNO_3$ (Decision of the Ministry of Agriculture of Slovac Republic No. 531/1994-540). The content of cadmium was higher than the limit norm A, which is 0.8 mg/kg in average about 107.5% in all monitored areas. The limit norm $A_1$ for cadmium, which is 0.3 mg/kg, was not crossed in any of the monitored areas. The limit norm A for cobalt is 20 mg/kg, however it was surpassed in the locations number 2, 4, 5 and 6. The content of Co in the rest of the monitored locations was under the limit norm. The total content of nickel in soil was higher in the locations number 2, 3, 4 and 5 than the norm A, which is 35 mg/kg. The norm A was surpassed in average about 46%. In the rest of the monitored locations, the content of Ni was under the limit norm. The measured contents of heavy metals in soil are shown in Table 2.

The samples of growing plants were obtained in a full ripeness to determinate the content of monitored heavy metals in plants. The measured contents of heavy metals are shown in Table 3 along with the highest allowed limit norm, given by legislation – No. 1497/1997-100 and No. 981/1996-100 about feed raws and farm feeds. The content of Cd in biomass of alfalfa was only 80.4% from the legislative given hygienic limit in food-stuffs (Food-stuffs Codex) so it did not exceed the norm given by legislation. The analysis of the biomass obtained from grassland showed an increased level of Cd, which exceeded in 63% the limit comparing the results with hygienic limit. The content of Cd in barley was higher in 131% than hygienic limit, in wheat in 70% and in triticale it was 300% more then legislative given hygienic limit in food-stuffs. Concerning Co, it has to be said that there does not exist any limit for the content of Co in food. However there is a limit norm for cobalt in forage crops (2.0 mg/kg). The content of Ni reached in forage crops (alfalfa and grassland) only 53.8% of the hygienic limit which is 5.0 mg/kg.

The results of monitored heavy metals (Cd, Co, Ni) prove that the content of Cd and Ni is the main polluting factor of soil in this region. The grain crops as wheat, barley and triticale along with grassland have shown an increased level of cadmium. On the other side, alfalfa does not prove any sights of higher cumulation ability or increased level of cadmium or nickel. However, a special attention needs to be paid to potatoes grown in this region, because the content of cadmium and nickel proved very high cumulation ability. So as a result, it may affect the quality of potatoes for consummation, feeding and for further processing and exploitation. A higher attention needs to be paid in the monitored area to the input of risky

Table 1. Grown produce on minitored county

| Stand | Crop-plants |
|---|---|
| 1 | Barley (*Hordeum vulgare*) |
| 2 | Wheat (*Triticum aestivum*) |
| 3 | Triticale (*Triticale*) |
| 4 | Alfalfa (*Trifolium*) |
| 5 | Grass land |
| 6 | Potato (*Solanum tuberosum*) |

Table 2. Heavy metal contents in soil (mg/kg)

| Stand | Level depth (m) | Cd | | Co | | Ni | |
|---|---|---|---|---|---|---|---|
| | | total content | 2M $HNO_3$ | total content | 2M $HNO_3$ | total content | 2M $HNO_3$ |
| 1 | 0–0.10 | 1.36 | 0.304 | 15.6 | 4.72 | 22.8 | 2.28 |
| | 0.20–0.30 | 1.64 | 0.264 | 12.8 | 4.18 | 23.6 | 2.12 |
| | 0.35–0.45 | 1.84 | 0.154 | 5.2 | 2.74 | 20.3 | 1.38 |
| | Mean | 1.61 | 0.241 | 11.2 | 3.88 | 22.2 | 1.92 |
| 2 | 0–0.10 | 1.08 | 0.138 | 32.0 | 3.70 | 49.6 | 3.32 |
| | 0.20–0.30 | 1.44 | 0.252 | 24.4 | 5.90 | 48.0 | 5.60 |
| | 0.35–0.45 | 1.88 | 0.260 | 20.8 | 5.82 | 50.8 | 5.98 |
| | Mean | 1.47 | 0.217 | 25.7 | 5.14 | 49.4 | 4.96 |
| 3 | 0–0.10 | 1.44 | 0.288 | 16.8 | 3.74 | 41.6 | 7.58 |
| | 0.20–0.30 | 1.88 | 0.244 | 14.4 | 2.94 | 45.2 | 5.24 |
| | 0.35–0.45 | 2.20 | 0.220 | 10.0 | 2.68 | 58.0 | 7.80 |
| | Mean | 1.84 | 0.251 | 13.7 | 3.12 | 48.2 | 6.87 |
| 4 | 0–0.10 | 1.28 | 0.240 | 28.8 | 4.54 | 38.8 | 5.02 |
| | 0.20–0.30 | 1.84 | 0.248 | 22.8 | 4.68 | 40.0 | 5.10 |
| | 0.35 –0.45 | 1.84 | 0.292 | 14.4 | 5.14 | 44.4 | 6.56 |
| | Mean | 1.65 | 0.260 | 22.0 | 4.78 | 41.1 | 5.56 |
| 5 | 0–0.10 | 1.48 | 0.228 | 29.2 | 6.52 | 62.0 | 14.78 |
| | 0.20–0.30 | 1.76 | 0.204 | 29.6 | 4.98 | 69.6 | 13.24 |
| | 0.35–0.45 | 2.12 | 0.174 | 26.4 | 4.30 | 66.0 | 12.38 |
| | Mean | 1.78 | 0.202 | 28.4 | 5.26 | 65.8 | 13.46 |
| 6 | 0–0.10 | 1.36 | 0.286 | 34.8 | 5.60 | 32.4 | 3.68 |
| | 0.20–0.30 | 1.44 | 0.248 | 27.6 | 4.16 | 30.0 | 2.98 |
| | 0.35–0.45 | 2.04 | 0.116 | 20.8 | 2.18 | 27.2 | 1.76 |
| | Mean | 1.61 | 0.216 | 27.7 | 3.98 | 29.8 | 2.80 |

Table 3. Heavy metal contents in crop plants along with highest allowed limit norms (LN)

| ST | Crop – plants | Cd | LN | Co | LN | Ni | LN |
|---|---|---|---|---|---|---|---|
| 1 | Barley – straw | 0.463 | – | 0.323 | – | 0.646 | – |
| | Barley – corn | 0.162 | 0.07 | 0.108 | – | 0.215 | 3.0 |
| 2 | Wheat – straw | 0.506 | – | 0.216 | – | 0.323 | – |
| | Wheat – corn | 0.119 | 0.07 | 0.001 | – | 0.215 | 3.0 |
| 3 | Triticale – straw | 0.927 | – | 0.431 | – | 0.646 | – |
| | Triticale – corn | 0.280 | 0.07 | 0.431 | – | 0.431 | 3.0 |
| 4 | Alfalfa – 1st harvest | 0.916 | 1.0 | 1.293 | 2.0 | 1.724 | 5.0 |
| | Alfalfa – 2nd harvest | 0.711 | 1.0 | 0.969 | 2.0 | 3.125 | 5.0 |
| | Alfalfa – 3th harvest | 0.785 | 1.0 | 0.647 | 2.0 | 3.232 | 5.0 |
| 5 | Grass land | 1.638 | 1.0 | 0.647 | 2.0 | 2.047 | 5.0 |
| 6 | Potato | 1.875 | 0.05 | 1.939 | – | 4.31 | 0.5 |

elements into soil, to the plant uptake of above-mentioned elements and finally to their input to nutritive string. It is also important to eliminate the effect and the mobility of heavy metals in soil.

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