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# BEHAVIOUR OF Cd, Cr, Cu, Pb, AND Zn IN FLUVISOL AND CAMBISOL FERTILIZED WITH COMPOSTS

## ZACHOWANIE Cd, Cr, Cu, Pb I Zn W GLEBACH NAPŁYWOWEJ I BRUNATNEJ NAWOŻONYCH KOMPOSTAMI

**Abstract:** Risk elements contents play important role in compost quality determination. The aim of the work was to evaluate main risk elements availability in two soils with various parameters after composts application. The changes of risk elements mobility in soils fertilized with composts differed in dependence on soil parameters (risk elements contamination of soil, clay particles content, organic matter content and pH value) and on used extraction agent. Cadmium, zinc and partly chromium extracted in 0.01 mol · $dm^{-3}$ $CaCl_2$ solution were immobilized and lead was released to soil solution of both soils. The remediation ability of composts in cadmium and lead contaminated soil was found only for cadmium.

**Keywords:** heavy metals, compost, soil, availability

Council Directive 1999/31/EC on the landfill of waste enacts that member states of European Union are obliged to reduce the amount of biodegradable municipal waste placing on the dumps. Composting and the application of compost to the soil follow the principle of recycling and sustainability. The major limitation of soil application of compost can be the total heavy metal contents and their bioavailability within the soil-plant system.

Because mineralization results in a reduction in organic matter content, the actual amounts of heavy metals in the finished compost usually increased during composting. This means that although the original feedstock may have acceptable heavy metal levels, the concentration in the final compost may exceed regulatory levels [1]. Total content of risk elements and especially their bioavailability in soil-plant system can be limiting factor for compost application into agricultural soil. Cadmium, zinc, and in

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lesser extent copper belong to the most mobile risk elements, respectively. On the other hand, lead and chromium are ranked among the least mobile elements [2]. The mobility of risk elements is affected especially by pH value, clay mineral content and organic matter content and its quality [3–6]. The organic matter contained in composts may provide additional sites for metal adsorption to take place, which can increase metals retention and the cation-exchange capacity in the soils and therefore composts can be convenient application for remediation of contaminated soils [7]. Knowledge of risk elements mobility in composts and subsequently in soil is very important for decision about suitability of compost application into soils of various agrochemical parameters.

Our study was implemented to assess behaviour of cadmium, chromium, copper, lead and zinc in two different soil types after 2 doses of 6 various composts application.

## Material and methods

The experimental composts consisted from: 1) anaerobically stabilized sewage sludge (I and II) from two different wastewater treatment plants; 2) wood chips I obtained from leafy trees and were finely cut (< 10 mm); 3) wood chips II obtained from coniferous trees which were cut on larger pieces (< 50 mm); 4) grass originated from intensively cultivated lawn. The individual components differed in content of studied risk elements (Table 1).

Table 1

Total content of risk elements in components [$mg \cdot kg^{-1}$ of dry matter]

| Component | Cd | Cr | Cu | Pb | Zn |
|---|---|---|---|---|---|
| Sewage sludge I | 4 | 65 | 165 | 80 | 784 |
| Sewage sludge II | 7 | 220 | 173 | 137 | 1824 |
| Wood chips I | 0.1 | 8 | 7.5 | 3 | 18 |
| Wood chips II | 0.5 | 56 | 7.3 | 8 | 75 |
| Grass | 0.2 | 4 | 7.9 | 5 | 64 |

Thoroughly mixed materials were composted in aerated fermenters with air supply in the rate of 40 $dm^3$ per hour for 12 weeks. The composition of individual composts was mainly optimised according to the C:N ratio. The composition is shown in Table 2.

Table 2

Design of the experiment

| Treatment | Weight portion of components in raw compost (in fresh matter) |
|---|---|
| 1 | Sewage sludge I (1/3) + wood chips I (1/3) + grass (1/3) |
| 2 | Sewage sludge I (1/3) + wood chips II (1/3) + grass (1/3) |
| 3 | Sewage sludge II (1/2) + wood chips I (1/4) + grass (1/4) |
| 4 | Sewage sludge II (1/2) + wood chips II (1/4) + grass (1/4) |
| 5 | Sewage sludge I (1/2) + wood chips I (1/2) |
| 6 | Grass (6/7) + wood chips I (1/7) |

The effect of composts treatments was assessed in pot experiment with oat (*Avena sativa* L., 'Atego' cv.). Soil was passed through a 5 mm sieve, air-dried, and 5 kg of each soil (based on dry weight) was thoroughly mixed with N, P, K applied in ammonium nitrate (1 g N per pot) and potassium hydrogen phosphate (0.16 g P and 0.4 g K) in control treatments and with the same amount of nutrients plus composts from experiment described above in the rate of 48 g and triple rate of 144 g per pot. The composts for the pot experiment were sampled from the fermenters at the end of the incubation experiment. All treatments were set up in three replications. Agrochemical parameters of used soils are described in Table 3.

Table 3

Agrochemical parameters of used soil

| Soil | pH $CaCl_2$ | $C_{org.}$ | $P_{MIII*}$ | $K_{MIII*}$ | $Cd_{tot}$ | $Cr_{tot}$ | $Cu_{tot}$ | $Pb_{tot}$ | $Zn_{tot}$ |
|---|---|---|---|---|---|---|---|---|---|
| | | $[g \cdot kg^{-1}]$ | $[mg \cdot kg^{-1}]$ | | | | | | |
| Fluvisol | 5.5 | 5.7 | 384 | 158 | 0.255 | 8.6 | 5.62 | 10.8 | 50.0 |
| Cambisol | 6.2 | 17.0 | 51.3 | 188 | 6.16 | 50.8 | 35.7 | 1022 | 228 |

* MIII = Mehlich III extraction.

Available portion of risk elements in compost and soil was determined in the extract of 0.01 mol · $dm^{-3}$ $CaCl_2$ [8] and 0.11 mol · $dm^{-3}$ $CH_3COOH$ solutions [9]. Contents of risk elements in soils, plants, and soil extracts were determined by inductively coupled plasma optical emission spectrometry (ICP-OES, VARIAN VistaPro, Varian, Australia).

Data were evaluated by one-way analyses of variance. Tukey's test was used for means comparison and statistical significance of hypotheses was assessed at $\alpha = 0.05$. All statistical analyses were performed using Statgraphics programme, version 5.1 [10].

## Results and discussion

The changes of risk elements bioavailability in Fluvisol and Cambisol after application of composts (average of 6 treatments) in 2 doses determined in the extract of 0.01 mol $CaCl_2$ · $dm^{-3}$ and 0.11 mol $CH_3COOH$ · $dm^{-3}$ are shown in Figures from 1 to 4.

**Cadmium** is ranked among the most dangerous risk element in food chain [11]. In presented study case, the total cadmium content in Cambisol exceeded significantly the threshold limits allowed in notice number 13/1994 of Ministry of Environment of the Czech Republic [12]. Soil sorption capacity for Cd was enhanced by addition of composts into Fluvisol (Fig. 1) and immobilization of cadmium extractable with 0.01 mol $CaCl_2$ · $dm^{-3}$ was observed. The differences caused by various rates of composts were not significant. In the opposite, the increasing compost rate in Cambisol resulted in more apparent decrease of extractable cadmium content. Application of triple rate of compost with sewage sludge I and wood chips I significantly increased available Cd content in soil compared with single rate of the same compost. Higher sewage sludge sorption capacity obviously took effect. Different behavior of cadmium extracted with 0.11 mol $CH_3COOH$ · $dm^{-3}$ was found. Cadmium was released from the oxidizable

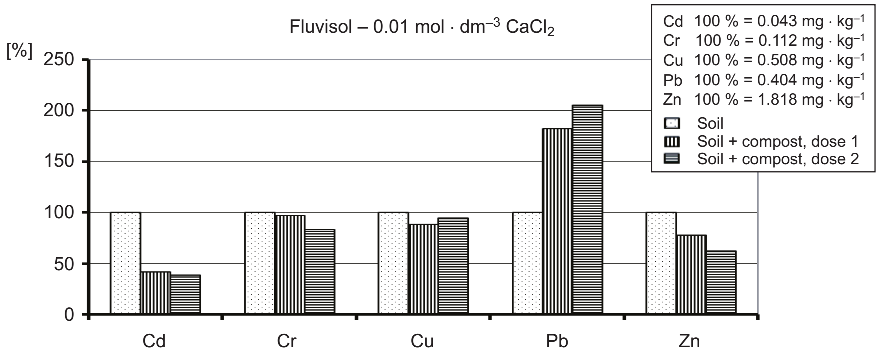


Fig. 1. Relative content of risk elements [%] determined in the extract of 0.01 mol $CaCl_2 \cdot dm^{-3}$ in Fluvisol after composts application

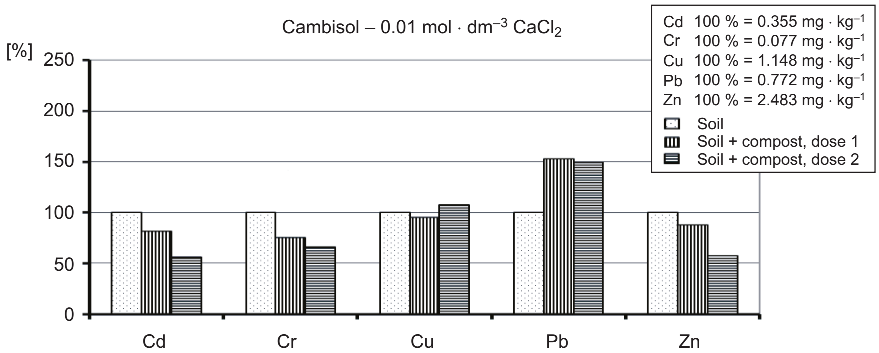


Fig. 2. Relative content of risk elements [%] determined in the extract of 0.01 mol $CaCl_2 \cdot dm^{-3}$ in Cambisol after composts application

fraction after triple rate of compost application. The effect was caused by higher mineralization of composts in the sandy Fluvisol. Decrease of Cd extracted with 0.01 mol $CaCl_2 \cdot dm^{-3}$ was found in Cambisol (Fig. 2) after triple rate of compost in relation to control soil (by 40–50 %) and simple compost rate (by 20–30 %). It is consistent with Perez-de-Mora et al [13] who found the decline of Cd released with the same extracting agent in their experiment with heavy metals contaminated soil, especially in the first two years after compost application. No statistical differences were found in Cd extracted with 0.11 mol $CH_3COOH \cdot dm^{-3}$ among treatments in Cambisol containing higher amount of organic matter and higher pH value (Table 3) compared with Fluvisol. Compost addition to the soil decreased the Cd content by 6 % compared with control.

Bioavailability of **chromium** in both soil and compost is low [14] and the effects of individual treatments on its mobility were expectably lower compared with more mobile elements. Although total contents of Cr were 6 times higher in Cambisol, the differences in extraction efficiency of used agents were not found in control treatment. Chromium extracted with 0.11 mol $CH_3COOH \cdot dm^{-3}$ was released into Fluvisol from compost by mineralization process. Relative high heterogeneity of chromium in treated soils together with low levels of extractable portions of chromium resulted in non-significant differences among the groups of experimental data.

**Copper** is bound predominantly in organic fraction of soil [15]. Relative contents of Cu strong fluctuated in individual treatments. However, copper was released markedly from compost containing sewage sludge I (1/2 of weight) and wood chips I (treatment 5). It was probably caused by the highest content of Cu in sewage sludge from used components. Moreover, the sewage sludge I was stabilized for shorter time compared with sewage sludge II and Cu bonds with organic matter were less stable. Significant differences in Cu content were not found between two rates of compost. Available Cu content (0.11 mol $CH_3COOH \cdot dm^{-3}$) decreased by 14 % in Cambisol fertilized with composts compared with control. It was apparently caused by higher portion of organic matter and clay particles [16].

Cambisol contained 7 times more total **lead** than is allowed in notice number 13/1994 of Ministry of Environment of the Czech Republic [12]. The contamination was mainly of anthropogenic origin. Portion of Pb extracted with 0.01 mol $CaCl_2 \cdot dm^{-3}$

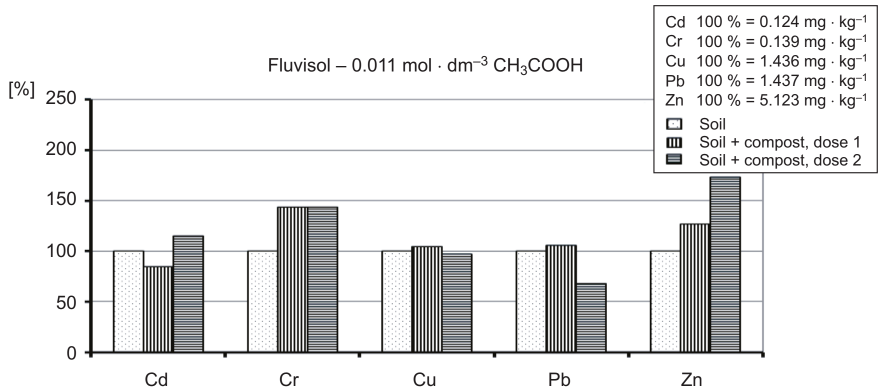


Fig. 3. Relative content of risk elements [%] determined in the extract of 0.11 mol $CH_3COOH \cdot dm^{-3}$ in Fluvisol after composts application

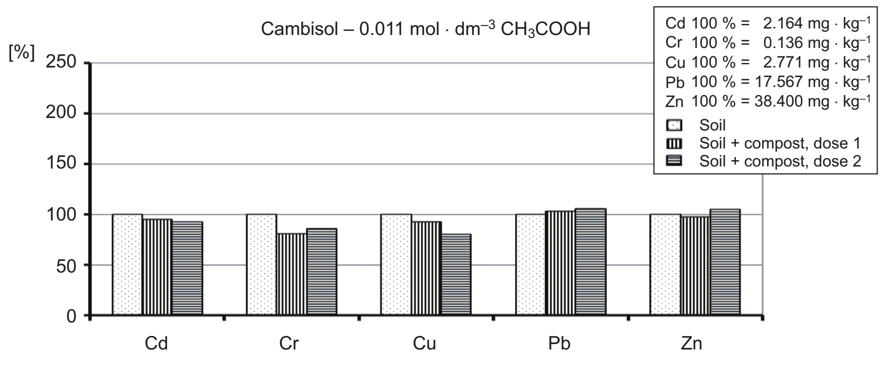


Fig. 4. Relative content of risk elements [%] determined in the extract of 0.11 mol $CH_3COOH \cdot dm^{-3}$ in Cambisol after composts application

and 0.11 mol $CH_3COOH \cdot dm^{-3}$ from this soil only 0.08 % and 1.7 %, respectively, of total content. Compost application released the weakest bound Pb. The Pb content extracted with 0.01 mol $CaCl_2 \cdot dm^{-3}$ was increased by 93 % in Fluvisol fertilized with compost. Compost application decreased Cd amount extracted with 0.11 mol $CH_3COOH \cdot dm^{-3}$ in this soil by 13 % compared with unfertilized soil. Composts applicated in triple rate (144 g per pot) participated predominantly in the decrease Cd extract concentration thanks to sufficiency of organic matter.

The availability of **zinc** was affected by individual compost rates. Zinc content extracted with 0.01 mol $CaCl_2 \cdot dm^{-3}$ was regularly decreased in both soils after application of higher rate of compost. Available Zn contents in soils fertilized with composts correlated with zinc content in used composts. It was seen eg in treatment 3 and 4 fertilized with sewage sludge II with high content of zinc. Opposite situation was observed in the case of 0.11 mol $CH_3COOH \cdot dm^{-3}$ extractable portion of zinc. Available Zn extracted with that agent was released into solution in proportion to compost rate due to convenient conditions for mineralization. Significant differences among treatments and rates were found out in light Fluvisol uncontaminated with risk elements. In regard of total Zn content was only 40 % of permissible limit given by above-mentioned notice, compost fertilization can be convenient way for supply of this important micronutrient into the soil.

## Conclusions

The change of elements mobility in soil fertilized with composts differed in dependence on soil properties (risk elements soil contamination, clay particles content, amount and quality of organic matter and pH value) and used extraction agents. Application of composts decreased plant-available portions (extracted with 0.01 mol $CaCl_2 \cdot dm^{-3}$) of cadmium, zinc and partly chromium in soil. On the contrary, the application of compost resulted in more intensive release of available lead from compost to soil solution. Therefore, remediation effect of compost treatment in Cd and Pb contaminated soil was determined only for cadmium.

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## ZACHOWANIE Cd, Cr, Cu, Pb I Zn W GLEBACH NAPŁYWOWEJ I BRUNATNEJ NAWOŻONYCH KOMPOSTAMI

**Abstrakt:** Zawartość pierwiastków szkodliwych odgrywa ważną rolę w wyznaczaniu jakości kompostu. Celem badań była ocena przyswajalności głównych pierwiastków szkodliwych w dwóch glebach o różnych parametrach po zastosowaniu kompostów. Zmiany mobilności tych pierwiastków w glebach nawożonych kompostami różniły się w zależności od właściwości gleby (zanieczyszczenia gleb pierwiastkami szkodliwymi, zawartości frakcji iłu, zawartości materii organicznej i wartości pH) i od użytego odczynnika ekstrakcyjnego. Kadm, cynk i częściowo chrom ekstrahowane roztworem 0,01 mol $CaCl_2 \cdot dm^{-3}$ były unieruchamiane, a ołów był uwalniany do roztworu glebowego obydwu gleb. Zdolność remediacyjną kompostu w glebach zanieczyszczonych kadmem i ołowiem stwierdzono tylko w przypadku kadmu.

**Sowa kluczowe:** metale ciężkie, kompost, gleba, przyswajalność