Heavy metal concentration in plants growing on the vicinity of railroad tracks: a pilot study

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Railway transport is a source of various heavy metals arising from abraded metallic train elements and rails. These metals accumulate in neighboring soils and may pose particular health risk for railway workers or people who simply pass through the railroad tracks. Plants are able to uptake metals from soil, thus reduce soil contamination and movement of pollutants. Individual species are characterized by different accumulation efficiency. In this study fifteen species were examined for accumulation of 14 metals. *Cerastium dubium* accumulated the majority of metals most efficiently.

Keywords: railway pollution, heavy metals, phytoextraction, herbaceous plants.

Introduction

Transportation is, apart from industry, one of major sources of pollution. Elevated levels of various contaminants, such as heavy metals, are recorded in air and soil in the vicinity of transport-related linear emission sources — roads and railways. The impact of road traffic on the environment has been widely studied since the number of cars started to increase rapidly worldwide. However, only a decade ago, first studies referring to the contamination on railway vicinity were carried out [1]. Heavy metals, which origin mainly from abraded metallic train units and rails, accumulate in soils neighboring the railroad tracks in considerable amounts with highest content of iron, zinc, lead and copper [2]. In some areas, their concentration may exceed permissible levels determined in Poland by Regulation of Minister of Environment (Table 1). This may cause various adverse effects to the natural environment with affecting public health as the most important one [3, 4].

Plants with their ability to uptake elements from soil solution are sometimes bioindicators [6] and/or effective accumulators [7] of heavy metal pollution. This is a basis of phytoextraction — environmental biotechnology used for removing soil contaminants with harvested aboveground plant organs or whole plants [8, 9]. Apart from this, if plants are present, contamination is stabilized and cannot be easily blown out from topsoil to more distant areas.

The aim of this study was to gain the preliminary information about possible differences in accumulation of heavy metals between various plant species growing along the railroad tracks.

Materials and methods

The sampling area was the vicinity of two parallel railroad tracks in the suburban Warsaw on the railway connection form Warsaw to Otwock between Warsaw-Miedzeszyn and Warsaw-Falenica stations (Fig. 1). Plant samples were collected in spring 2011 from about 100 m long

Table 1. Permissible levels of heavy metal concentration in surface soils, depending on the terrain usage: urban lands or transport/industrial lands [5].

Land type	As	Ba	Cr	Sn	Zn	Cd	Co	Cu	Mo	Ni	Pb	Hg
Urban	20	200	150	20	300	4	20	150	10	100	100	2
Transport	60	1000	500	350	1000	15	200	600	250	300	600	30

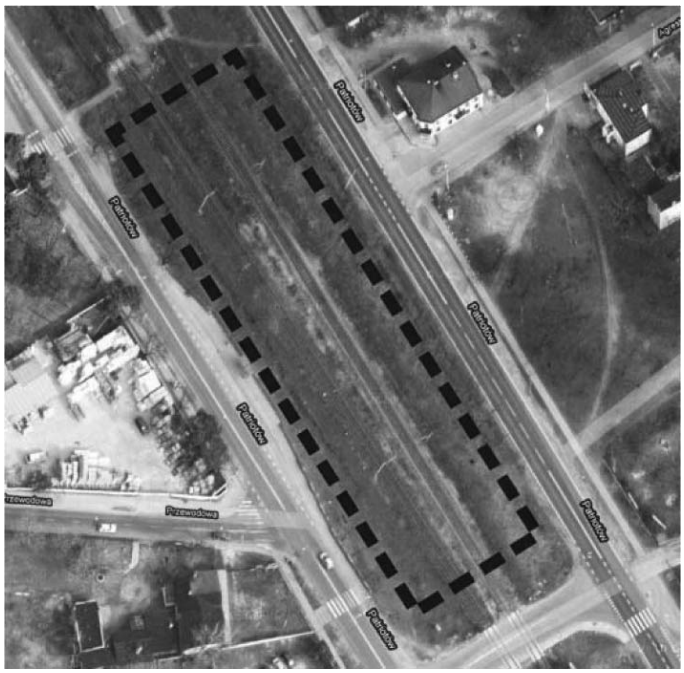

Fig. 1. Localization of sampling area.

Fig. 2. *In situ* analysis of heavy metals in topsoil using handheld XRF analyzer.

section, 1–2 meters from the tracks (0–1 m from the track embankments).

Fifteen herbaceous plant species, represented by highest number of specimens within the sampling area, were selected for the research. These were: *Artemisia campestris*, *Capsella bursa-pastoris*, *Cerastium dubium*, *Dactylis glomerata*, *Equisetum arvense*, *Euphorbia cyparissias*, *Melilotus officinalis*, *Oenothera biennis*, *Papaver rhoeas*, *Rumex acetosa*, *Sedum acre*, *Senecio vernalis*, *Tragopogon pratensis*, *Vicia cracca* and *Viola arvensis*.

For each species 8–20 shoots were collected depending on their size in order to receive similar samples. Samples were gently cleaned up from soil particles with a soft brush, air dried, ground to powder and representative parts were packed into XRF-certified sampling containers. In order to determine concentrations of arsenic (As), barium (Ba), chromium (Cr), tin (Sn), zinc (Zn), cadmium (Cd), cobalt (Co), copper (Cu), manganese (Mn), molybdenum (Mo), nickel (Ni), lead (Pb), mercury (Hg), iron (Fe) and antimony (Sb) in each sample analyses were performed for 8 minutes using handheld XRF spectrometer Alpha 4000 (Innov-X Systems, USA).

For reference, heavy metal concentration in surface soil was screened. It was performed *in situ* due to the mobility of the used XRF unit (Fig. 2).

Measurements were performed in three 1 m wide rows neighboring to the stony railway embankments: two located on the outer sides of tracks and one between tracks. Sixty measurements were performed for 30 seconds each and the mean values were calculated for particular metals.

Results and discussion

Mean concentration of detected heavy metals in topsoil at the study area are presented in Table 2. Comparing to previous studies [2] where zinc, lead, copper and iron were the prevailing metals, in this study content of Zn and Pb were rather low. The highest concentrations were reported for Fe > Mn > Ba > Cu > Cr. As a result barium, chromium and copper slightly exceeded the present legal levels in Poland, established for transportation sites [5]. Due to short analysis time (30 seconds for rapid *in situ* soil analysis) and low density of not prepared soil, the levels of detection (LOD) were high, therefore some metals suspected to appear along railways, were not detected. These were: arsenic (< 41 μg g^{-1}), tin (< 187 μg g^{-1}), cadmium (< 119 μg g^{-1}), cobalt (< 1502 μg g^{-1}) and antimony (< 218 μg g^{-1}).

Table 2. Mean heavy metal concentration in topsoil at study area with standard deviation.

Metal	Concentration [μg g^{-1}]	Std. Deviation [μg g^{-1}]
Ba	1092.1	299.1
Cr	1108.4	331.4
Zn	142.4	17.7
Cu	894.3	41.5
Mn	1528.9	160.9
Mo	18.0	4.0
Ni	588.1	101.1
Pb	65.0	8.3
Hg	25.3	6.0
Fe	196112.7	3909.8

In the study considerable differences in heavy metal accumulation between species were reported and several species were characterized by a significant concentration of particular metals in shoots. Some metals were not detected in any plant sample because the concentration in dry mass did not exceed levels of detection (LOD) of used XRF unit. These were: arsenic (< 2 μg g^{-1}), tin (< 20 μg g^{-1}), nickel (< 27 μg g^{-1}) and mercury (< 2 μg g^{-1}). Other metals were detected in at least one species. The concentration of zinc, cadmium, copper, molybdenum, lead, iron and antimony that were detected in six or more species are presented in Fig. 3. Highest concentrations of most metals were found in *Cerastium dubium*. That corresponds with previous findings, that plants from *Caryophylaceae* family are able to grow on heavily contaminated sites and uptake metals efficiently [8].

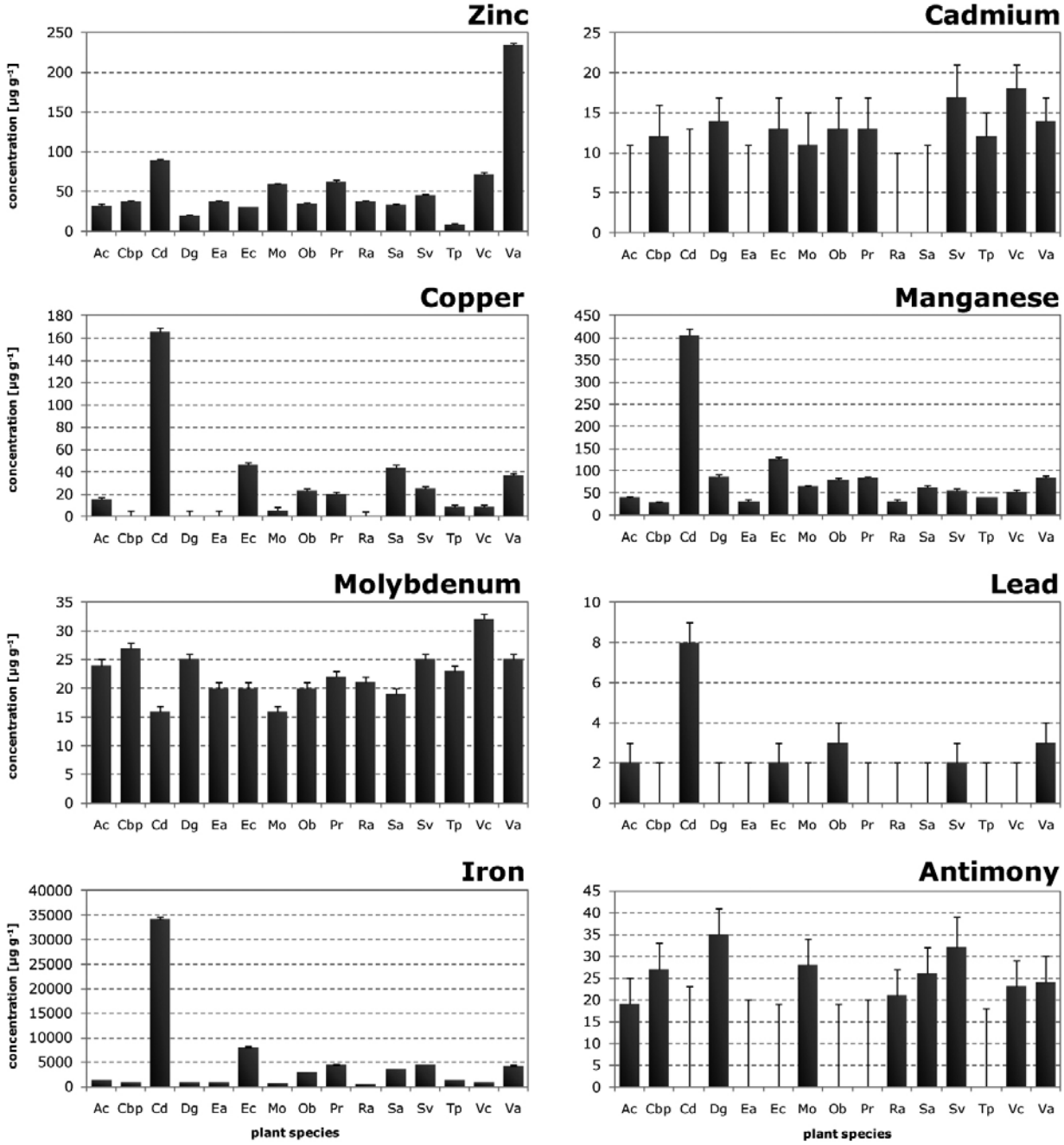

Fig. 3. Zinc, cadmium, copper, manganese, molybdenum, lead, iron and antimony concentration in plants growing in close vicinity of railroad tracks. Abbreviations on the horizontal axis represent plant species as follows: Ac (*Artemisia campestris*), Cbp (*Capsella bursa-pastoris*), Cd (*Cerastium dubium*), Dg (*Dactylis glomerata*), Ea (*Equisetum arvense*), Ec (*Euphorbia cyparissias*), Mo (*Melilotus officinalis*), Ob (*Oenothera biennis*), Pr (*Papaver rhoeas*), Ra (*Rumex acetosa*), Sa (*Sedum acre*), Sv (*Senecio vernalis*), Tp (*Tragopogon pratensis*), Vc (*Vicia cracca*), Va (*Viola arvensis*).Thin bars represent standard error or, if element was not detected — LOD.

Zinc as an important micronutrient was present in all species at significant levels, however the most effective accumulator of Zn was *Viola arvensis* with almost 3-fold higher concentration than the second *Cerastium dubium* and much more than other species. Accumulation of cadmium did not differ that much between species with highest concentrations in *Vicia cracca* and *Senecio vernalis*, while in other species it was slightly above the detection level (< 11 μg g^{-1}) or below it. Regarding copper, manganese, lead and iron, their concentrations were in similar proportion between species, with *Cerastium dubium* accumulating about or over fourfold more of these four elements than other species. Molybdenum was found in all species and differences in concentration was not as big as in major part of analyzed elements, however the most effective *Vicia cracca* accumulated twofold more Mo than the less effective *Cerastium dubium* and *Melilotus officinalis*. Also the accumulation of antimony was not very variable in those species where it was detected. The only analyzed species of grass, *Dactylis glomerata*, presented highest concentration of Sb.

In several species other metals were detected as well. Chromium was detected in *Cerastium dubium* (63 μg g^{-1}) and *Euphorbia cyparissias* (13 μg g^{-1}), while in other species Cr concentration was below detection limit 10 μg g^{-1}. *Cerastium dubium* accumulated high amounts of barium (129 μg g^{-1}), and only in one more species *Viola arvensis* (49 μg g^{-1}) the concentration exceeded LOD (20 μg g^{-1}). In case of cobalt, *Cerastium dubium* and *Euphorbia cyparissias* accumulated 275 μg g^{-1} and 64 μg g^{-1} respectively, while other species below 20 μg g^{-1}.

Conclusions

Soils at railroad areas contain significant amounts of toxic metals, especially Cu, Ba and Cr, thus research should be conducted to estimate the impact of these contaminants on environment and human health. Plants of various species are able to grow at these sites, uptake metals and accumulate them in tissues. They often belong to botanical families whose representatives are known for tolerance to heavy metal pollution and phytoremediation abilities. There is notable difference between species in the efficiency of heavy metal uptake from track-neighboring soils. Among fifteen tested species, *Cerastium dubium* accumulates highest levels of 8 out of 10 metals (Ba, Co, Cr, Cu, Fe, Mn, Pb, Sb). For Zn, highest concentration is reported in *Viola arvensis* while for Mo in *Vicia cracca*.

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