POLISH JOURNAL OF SOIL SCIENCE
VOL. XLV/2 2012 PL ISSN 0079-2985

Soil Chemistry

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ACCUMULATION OF HEAVY METALS (Cd, Cr, Cu, Pb, Zn) IN SOILS AND GRASS SWARDS IN ROADS OF LUBLIN CITY

Abstract. The aim of this study has been to determine the level of contamination of the soils and grass swards abutting the selected busiest traffic routes of Lublin City with heavy metals: Cu, Cd, Cr, Pb, Zn. 36 surface soil samples (0–20 cm) and grass swards (roots and above ground parts) were collected. The goal of the research has been to assess the impact of road traffic on the content of heavy metals and to determine indicators of migration between the soil and the plant based on the enrichment factor. The examined soils were characterized by a high content of heavy metals, on average: Cu 80.14 mg kg^{-1}, Cd 0.97 mg kg^{-1}, Cr 12.80 mg kg^{-1}, Pb 56.89 mg kg^{-1}, Zn 87.31 mg kg^{-1}. Grass swards in the immediate vicinity of the examined roads had the following average content of heavy metals: Cu 46.91 mg kg^{-1}, Cd 1.41 mg kg^{-1}, Cr 16.36 mg kg^{-1}, Pb 15.05 mg kg^{-1}, Zn 129.01 mg kg^{-1}. The accumulation of heavy metals in the experimental soils and plants was varied. The impact of the content of heavy metals designated in the soils on their concentration in the grass swards collected from the busiest traffic routes in Lublin were considered to be significant.

Heavy metals (Cd, Cr, Cu, Pb and Zn) are pollutants of a very high degree of potential hazards posed to the biological environment. Drawing trace elements from contaminated soils by plants often exceeds their physiological needs, with the result that excess of these elements in soils can act phytotoxic. A biological consequence of the accumulation of these pollutants in soils and plants is their transition to higher links of the trophic chain, including the human being [5].

Road transport is a major source of heavy metal pollution of soils adjacent to transport routes. They originate, among others, from greenhouse gases from internal combustion engines, as well as the abrasion of tires, brake facings, heavy

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metal additives to oils as means of refining, etc. This is particularly important within the cities where the traffic is not smooth and is characterized by high density, moreover, there is a lot of dust and disturbed air transport. Automotive impurities are more severe than industrial ones since they are spread in relatively high concentrations, at low heights, in the immediate breathing zone of humans, animals and plants [1, 8]. The content of heavy metals (particularly of elements such as lead, copper, zinc or cadmium) in the soil can be taken as an indication of the adverse impact of road on the natural environment [2, 10, 15].

The aim of the study has been to determine the impact of motor transport on heavy metal content in the soil - the total and bioavailable form and the content of heavy metals in grass vegetation. For this purpose, indicators of heavy metal migration between the soil and the plant were calculated.

STUDY AREA AND METHODS

18 locations characterized by high traffic density were chosen. In each of the locations, two representative surface soil samples (up to 30 cm from the edge of the road and within 2 m) were taken. At the same time plant samples were collected. In total, 36 soil samples and 36 samples of plant were collected.

In this paper, data on the physical and chemical characteristics of soils (pH, organic carbon, hydrogen replaceable, the sum of base cations) and bioavailable forms of content and total Pb, Cu, Cr, Cd, and Zn in soils was taken from the previous paper by Plak *et al*. [13]. In respect of the samples basic physicochemical properties of soil were determined as well as the plant-available form of Pb, Cu, Cr, Cd, and Zn extracted by Lindsey and Norvell [9]. Digestion of the samples in order to obtain total content of heavy metals was performed using *aqua regia*, and the metals were determined by the AAS technique [6]. The plant samples were rinsed three times in distilled water, and then dried at 65 °C and homogenized in an agate mill. Plant samples were mineralized with *aqua regia* according to ISO 11466 [6]. The heavy metal content was determined using the AAS technique. In this paper, the data on the content of heavy metals in plant samples was taken from the publication of Plak *et al*. [12].

In order to determine the phytotoxicity of the heavy metals, bioaccumulation factors were calculated. Statistical relationships between the content of bioavailable form and total heavy metals concentration in soils and their content in analysed grass material were also analysed using Statistica software.

RESULTS AND DISCUSSION

The element with the highest average total content in the tested locations is zinc, followed by copper, lead, chromium and cadmium. A similar sequence occurs in the case of heavy metals in the studied grass sward. In the case of bioavailable forms the highest average content was determined for copper and Cu > Pb > Zn > Cd> Cr. There was a small variation in the concentration of elements in forms available to plants at points located at the edge of the road and about 2 m away. The effect of the distance from the source of emission is negligible. In a different manner, with a clear differentiation of the determined concentrations of heavy metals, the total content was shaped. Similarly, as the majority of authors pointed out, the content of heavy metals decreases the farther the distance from the communication path is [7, 8, 11]. Similar patterns were found for heavy metals determined in the grassy sward.

The percentage share of the available forms for plants in the total pool of heavy metals accounted for copper ranging from 6.7 to 35.3%, for lead ranging from 7.4 to 36.2%, for cadmium ranging from 3.3 to 90.1 %, for chromium ranging 0, 22 to 0.94 % and for zinc ranging from 1.7 to 10.7%.

On the basis of the results for the individual elements, enrichment factors were calculated using the equation formula (e.g., Zn in grass):

$$Wz(Zn) = Th(Zn)/C(Zn) \quad (1)$$

where: Wz(Zn) – enrichment factor for zinc, Th(Zn) – zinc content in the grass, C(Zn) – zinc content in the soil at the same location.

Grass sward located by Lublin roadways with the highest traffic cumulated mostly cadmium. The average enrichment factor was 3.44 (Fig. 1). To a lesser extent zinc was cumulated where the average enrichment factor was 1.63, and followed by chrome (average Wz 1.18), copper (average Wz 0.66). The least cumulated metal by grass sward was lead. The average enrichment factor was 0.255.

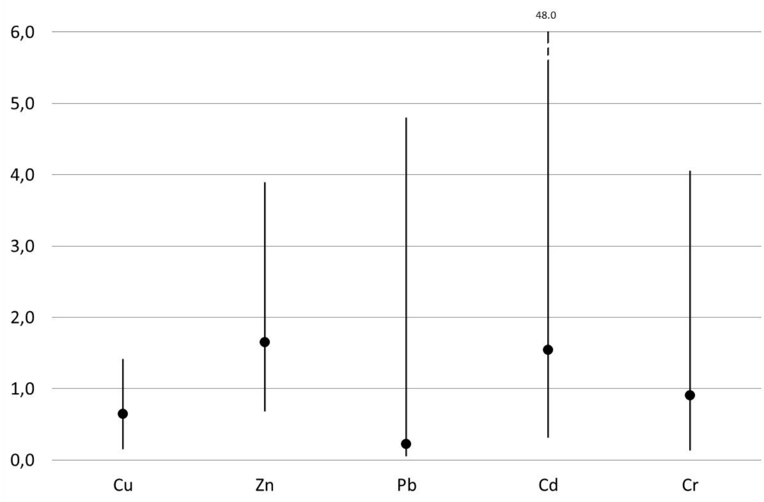

Fig. 1. Enrichment coefficients (maximums, minimums and medians) of particular heavy metals (total forms and plants).

The aassessment of the level of contamination by Cu, Cd , Pb and Zn in the soils was based on the permissible limits of heavy metals listed in the Regulation of the Ministry of Environment on soil quality standards and earth quality standards [14]. The permissible limit of the content of copper, lead, cadmium, and zinc for the land belonging to group C, including industrial areas, farmland, fossil and communication areas was not exceeded. The tested soils contained these elements in the amounts defined as permissible for this group of soils.

The assessment of the level of contamination of plants by metals mentioned above was made using the limits of metals in plants' feed provided by different authors [3, 4]. It was assumed that the feed from grasslands should contain 50–100 mg Zn ; 7.1–10 mg Cu <20 mg Cr ; ≤ 0.5 mg Cd ; ≤ 10 mg Pb kg $^{-1}$ d.m.

Zn content in the grass sward in almost all points exceeded the permissible limits for fodder plants. Similar phenomenon was found in all tested profiles for copper. For lead it was found in nearly half of the experimental group. In the case of cadmium, the permissible limit for fodder plants was not exceeded and chromium concentration in the grass sward exceeded the permissible limit in six profiles (Nos 4, 8, 9, 10 , 12, 18).

TABLE 1. CORRELATIONS BETWEEN THE TOTAL AMOUNT OF PARTICULAR HEAVY METALS IN SOILS AND PLANTS. MARKED VALUES ARE SIGNIFICANT AT $p<0.5$

	Cu (total)	Cu (plants)	Zn (total)	Zn (plants)	Pb (total)	Pb (plants)	Cd (total)	Cd (plants)	Cr (total)
Cu (plants)	**0.64**								
Zn (total)	**0.70**	0.30							
Zn (plants)	0.22	0.25	**0.45**						
Pb (total)	**0.43**	0.17	**0.40**	0.25					
Pb (plants)	-0.08	-0.02	0.01	0.27	-0.03				
Cd (total)	**0.54**	0.16	**0.84**	**0.39**	0.20	0.17			
Cd (plants)	0.12	**0.41**	0.22	**0.57**	0.24	0.20	0.19		
Cr (total)	**0.67**	0.29	**0.91**	0.25	0.18	-0.07	**0.74**	0.00	
Cr (plants)	**0.36**	0.29	**0.38**	0.30	0.19	0.23	**0.35**	0.15	**0.36**

TABLE 2. CORRELATIONS BETWEEN THE CONTENT OF PARTICULAR HEAVY METALS (AVAILABLE FORM) IN SOILS AND PLANTS. MARKED VALUES ARE SIGNIFICANT AT p<0.5

	Cu (available)	Cu (plants)	Zn (available)	Zn (plants)	Pb (available)	Pb (plants)	Cd (available)	Cd (plants)	Cr (available)
Cu (plants)	**0.68**								
Zn (available)	**0.54**	0.28							
Zn (plants)	0.20	0.25	**0.21**						
Pb (available)	**0.37**	0.09	**0.09**	0.01					
Pb (plants)	-0.10	-0.02	-0.02	0.27	0.02				
Cd (available)	**0.03**	-0.09	**0.25**	**0.12**	0.52	0.01			
Cd (plants)	0.25	**0.41**	0.22	**0.57**	0.17	0.20	0.23		
Cr (available)	**0.63**	0.36	**0.38**	0.14	0.18	-0.03	**0.08**	0.04	
Cr (plants)	**0.19**	0.29	**-0.18**	0.30	0.10	0.23	**-0.14**	0.15	**0.15**

The resulting values of bioaccumulation indicators showed that plants in the vicinity of the busiest streets of Lublin accumulated Cd, Zn and Cr (highest value Wz > 1) easier than Cu and Pb. This also proves the high mobility of Cd, Zn and Cr as compared to other metals and relatively easy uptake of these elements by plants . The resulting figures confirmed that the Cd and Zn are metals very easily accumulating in plant tissues, ipso facto coming into trophic chain [5, 7].

The statistical analysis of the concentration of heavy metals in the grass sward, on the background of the content of bioavailable form and the total concentration in soils directly adjacent to roads showed statistically significant correlations for copper, zinc and chromium, and the lack of correlation for lead and cadmium (Table 1, 2).

CONCLUSIONS

1. Considerable impact of transport pollution on heavy metal content in the grass sward taken from selected roadways of Lublin has been assessed. After

determining the enrichment factors it was found that cadmium was the most cumulated by grass sward and lead was the least.

2. Accumulation of heavy metals in the grass sward and soils have developed in the following sequence Zn > Cu > Pb > Cr> Cd. In the case of bioavailable forms, the highest average content was determined for copper and Pb > Zn > Cd> Cr .

3. The content of Zn and Cu in grass sward in almost all points exceeded the permissible content limits for fodder plants.

4. The total concentrations of Cu, Cd, Cr, Pb, and Zn in soils did not exceed the permissible limits for the lands belonging to group C, including industrial areas, farmland, fossil and communication areas governed by the Regulation of the Minister of the Environment on soil quality and earth quality standards; however, high concentrations of these elements indicate that the studied areas are under the strong anthropogenic impact .

5. Statistical analysis showed significant correlations for the content of copper, zinc and chromium in the grass sward and soils, and the lack of correlation for lead and cadmium.

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AKUMULACJA METALI CIĘŻKICH W GLEBACH I DARNI WZDŁUŻ ARTERII KOMUNIKACYJNYCH LUBLINA

W pracy podjęto próbę oceny stopnia zanieczyszczenia metalami ciężkimi Cu, Cd, Cr, Pb, Zn gleb i roślinności trawiastej sąsiadujących z wybranymi ciągami komunikacyjnymi Lublina o największym natężeniu. Pobrano 36 glebowych prób powierzchniowych (0–20 cm) oraz roślinność trawiastą (część korzeniową i nadziemną). Celem pracy było określenie wpływu komunikacji samochodowej na zawartość metali ciężkich i wyznaczenie wskaźników migracji pomiędzy glebą a rośliną na podstawie współczynnika wzbogacenia. Badane gleby charakteryzowały się wysoką zawartością metali ciężkich, średnio: Cu 80.14 mg kg^{-1}, Cd 0.97 mg kg^{-1}, Cr 12.80 mg kg^{-1}, Pb 56.89 mg kg^{-1}, Zn 87.31 mg kg^{-1}. W roślinności trawiastej rosnącej w bezpośrednim sąsiedztwie badanych dróg średnia zawartość metali ciężkich kształtowała się następująco: Cu 46.91 mg kg^{-1}, Cd 1.41 mg kg^{-1}, Cr 16.36 mg kg^{-1}, Pb 15.05 mg kg^{-1}, Zn 129.01 mg kg^{-1}. Akumulacja metali ciężkich w badanych glebach i roślinach była zróżnicowana. Stwierdzono znaczący wpływ zawartości metali ciężkich oznaczonych w glebach na ich koncentrację w roślinności trawiastej pobranej z ciągów komunikacyjnych Lublina o największym natężeniu ruchu.