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CONTENT OF HEAVY METALS IN MEADOW SOILS IN DIFFERENT SEASONS

ZAWARTOŚĆ METALI CIĘŻKICH W GLEBACH ŁĄKOWYCH W RÓŻNYCH PORACH ROKU

Abstract: The content of heavy metals like cadmium (Cd), lead (Pb), zinc (Zn), copper (Cu) and nickel (Ni) was investigated in the meadow soils in the district of Bochnia in autumn and winter season 2010/2011. The meadows were located at different distances from the road 2 m, 100 m and 200 m. The soils tested showed an average pH of acidic to nearly neutral and humidity in autumn 17.17–29.53 % and in winter season within 24.68–37.59 %. Statistically significant showed differences in the content of Zn, Cu, Ni and Pb between stations in the autumn and winter seasons. In relation to cadmium did not show such dependence. The content of this element (0.6–0.88 ppm) is similar occurred at all stations, regardless of the season. The number and diversity of pedofauna were also analyzed, which was higher in the winter season in the studied meadow soils. It has been found, however, that significant differences in metal content did not affect the abundance of soil fauna at different stations in the studied seasons.

Keywords: heavy metals, meadow soils, pedofauna, density, diversity.

Processes in the soil are essential for the sustainability and productivity of terrestrial ecosystems. Anthropogenic activity causes major changes in the circulation of elements in the environment, leading to contamination of its individual components. The problem of soil pollution is very significant as it may indirectly or directly affect adversely the human health. Particularly serious is heavy metal soil contamination due to the occurrence of their migration and accumulation, also in plants of permanent farmland situated along traffic routes, which is exacerbated with growing numbers of internal combustion vehicles [1]. The soil pollutants may enter the human body indirectly through ingestion of plants that were taking up harmful components from the polluted soil or were contaminated by atmospheric deposition of particles from industrial

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emissions or from wind or rainwash erosion. Physical and chemical properties of the soil affect the take-up of elements by plants and their absorption into the food chain system. Among them, it is the pH value that matters most for the accumulation of heavy metals in plants. In an acidic environment, plants may take up great amounts of these elements, particularly Cd, Zn and Ni, even from lightly polluted soils [2, 3]. In the soil environment, heavy metals are characterised by varying mobility. Lead and nickel are less mobile, while Cd and Zn are the most mobile.

Lead is strongly bound by the organic matter of the surface soil layer and slightly migrates deeper into the profile. The mobility of nickel in soils depends on the granulometric and mineralogical structure of the soil. Nickel is strongly bound by mineral colloids and iron hydroxides, and therefore its movement is limited. Cadmium displays high mobility in the environment and is easily taken up by plants. The total content of metals in the soil is determined, next to the size of the deposition, by the humification conditions of the plant material and the balance of accumulation and leaching processes of the metals [3, 4].

The goal of the performed investigations was to determine the heavy metal (Pb, Cd, Ni, Zn and Cu) content of the soil at three meadow sites located at the distance from 2 to 200 m from a main traffic route in the autumn and winter seasons, as well as to determine the effect of the studied metals on the density of soil fauna found there.

Materials and methods

Cadmium, lead, zinc, copper and nickel contents of meadow soils were investigated in Bochnia County in the autumn and winter seasons of 2010/2011. The meadows were situated at various distances, 2 m, 100 m and 200 m from a busy county road No. 1444 k. The contents of selected heavy metals in the soil were determined by FAAS (after prior mineralisation of the tested soil material). Soil samples were taken from the test sites by means of a 25 cm × 25 cm soil frame from a surface of 1 m^2 and then, mesofauna were flushed out by a dynamic method in a modified Tullgren apparatus. The effect of the heavy metal content on the pedofauna population numbers was also analysed. The moisture content and the pH value of the investigated soil was also determined.

The results were analysed using a unifactorial ANOVA variance procedure. The *post hoc analysis* was performed by means of the Tukey's HSD test. Furthermore, Pearson's and r^2 coefficients of correlation between the heavy metal concentration and the population of the studied fauna were analysed. The differences were statistically significant at $p < 0.05$.

Results and discussion

The soils were characterised by weak acidic to almost neutral pH values (5.3–6.8) and moisture content ranging from 16.48 % to 30.5 % in the autumn, and higher, 21.46–42.37 % in the winter (Table 1).

Table 1

Characteristics of soil in the studied localities

Selected parameters	Site I autumn	Site II autumn	Site III autumn	Site I winter	Site II winter	Site III winter
Soil pH	5.49 5.34 ± 5.71	6.04 5.87 ± 6.27	5.37 5.16 ± 5.65	6.66 6.49 ± 6.8	5.94 5.93 ± 5.95	5.3 5.16 ± 5.44
Dampness of soil [%]	17.17 16.48 ± 18.11	25.56 24.17 ± 27.32	29.53 28.85 ± 30.55	24.68 21.46 ± 27.19	29.7 28.96 ± 30.42	37.59 32.8 ± 42.37

Locality I – meadow 200 m away from the road.
Locality II – meadow 2 m away from the road.
Locality III – meadow 100 m away from the road.

Pedofauna population at the test sites varied in the period of investigations, it was significantly higher in the winter season. The highest value of 21216 specimen per square meter was noted at Site III, about 200 m away from the road, in the winter. The lowest density of 10176 specimen per square meter was found in the meadow 200 m away from the road in the autumn, where the moisture content was at its lowest (Table 1, Fig. 1).

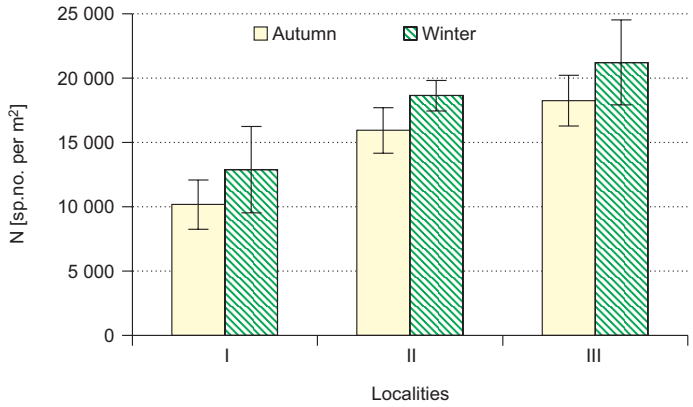

Fig. 1. Density of the soil fauna in the studied localities

The assessment of the level of pollution by Cu, Cd, Zn, Ni and Pb in the investigated meadow soils was carried out by the use of limit values for the heavy metal content set out in the Minister of Environment Regulation on the soil quality and farmland quality standards (Polish Journal of Laws Dz.U. 2002 No. 165, item 1359 of 4 October 2002). No cases of exceeding the limit values for metals were found for Group B soils (a group covering the land rated as farmland excluding the land under ponds and the land under ditches, the woodland and tree- and bush-covered land, wasteland, as well as built-up and urban areas, excluding industrial areas, mine lands and transport areas). In the investigated soils, these elements occurred in the amounts defined as permissible for this soil group [5] (Table 2).

Table 2

Content of heavy metals in meadow soils in the autumn and winter [mg · kg^{-1}]

Metal [mg/kg]		Site I autumn	Site II autumn	Site III autumn	Site I winter	Site II winter	Site III winter	The limit values*
Cu	mean range	9.88 9.54 ± 10.2	6.53 6.39 ± 6.59	11.43 10.3 ± 12.3	10.43 9.24 ± 11.8	11.3 9.92 ± 12.3	10.27 8.58 ± 13.2	150
Pb	mean range	18.81 18.2 ± 19.79	18.41 16.35 ± 20.0	40.13 38.35 ± 41.7	16.43 13.72 ± 18.3	18.62 18.08 ± 22.0	45.62 44.12 ± 47.4	100
Zn	mean range	27.97 24.39 ± 30.5	29.43 27.7 ± 30.96	30.45 27.32 ± 33.6	33.58 31.45 ± 37.9	33.51 33.61 ± 36.5	42.91 41.7 ± 44.58	300
Cd	mean range	0.69 0.55 ± 0.79	0.62 0.36 ± 0.8	0.69 0.63 ± 0.82	0.8 0.63 ± 0.93	0.6 0.52 ± 0.73	0.88 0.79 ± 0.89	4
Ni	mean range	13.72 12.86 ± 14.4	10.02 9.59 ± 10.18	8.04 8.88 ± 10.86	14.52 11.91 ± 18.4	15.29 12.33 ± 16.6	9.58 8.32 ± 15.29	100

* The limit values for the heavy metal content set out in the Minister of Environment Regulation on the soil quality and farmland quality standards for Group B soils (Polish Journal of Laws Dz.U. 2002 No. 165, item 1359 of 4 October 2002).

Cadmium is relatively easily taken up by plants, generally proportionally to its concentration in the environment. The concentration of cadmium at the test sites ranged between 0.36 to 0.93 mg per kg of dry matter and stayed within the range specified for the soil in its natural state (degree 0) according to Kabaty-Pendias [6] (Fig. 2).

There was no statistically significant correlation found between the season and the Cd content in the soil ($F = 1.32$; $p = 0.29$).

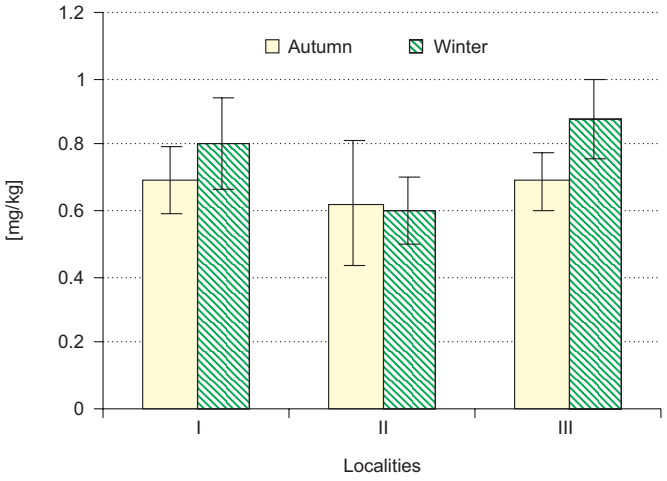

Fig. 2. The concentration of cadmium at the test sites

However, statistically significant differences were found between the content of other metals in the soil at the test site in the autumn and winter season (Table 3).

Table 3

Comparison of metal content in soil in autumn and winter – ANOVA test results

	Cu	Pb	Zn	Cd	Ni
F	14.39	11.42	71.47	1.32	6.96
p	0.0002	0.0006	0.0000	0.29	0.006

The concentration of Zn rises in the areas of increased industrial dust deposition, in the areas of intensive agricultural production and in the period of wearing out of automobile tyres. The studies carried out showed the zinc content at the level of 27.97 to 30.45 mg per kg of dry matter in the autumn. Higher levels of this element occurred in the winter at all test sites (Fig. 3).

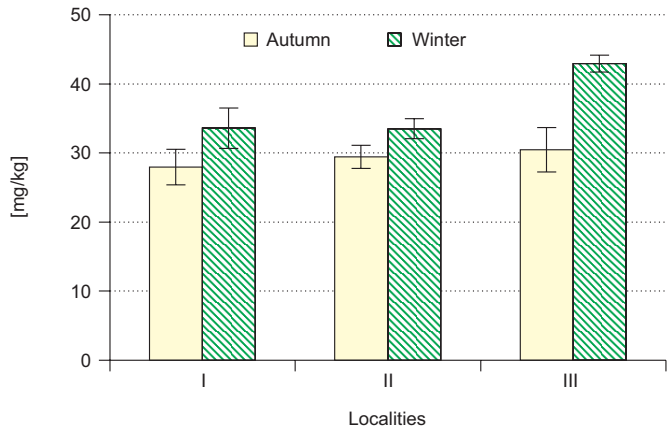

Fig. 3. The concentration of zinc at the test sites

Substantially lower Zn contents in the vicinity of the test sites (Bochnia and its surroundings), on average 7.2 mg per kg, were found by Zychowski [7]. It results from the studies that the highest Zn content in the soil occurs right next to the roadway. Some authors think that an increased Zn content occurs even 100 m from the roadway edge. It depends on the wind direction and on the traffic flow [8, 9]. This has been confirmed by the results of the present work, the highest Zn level of 42.91 mg per kg of dry matter was noted at the distance of 100 m from the road in the winter season (Site III).

The content of Cu in the studied soils ranged from 6.53 mg per kg of dry matter to 11.43 mg per kg of dry matter (Fig. 4).

The source of the soil pollution by Cu are, above all, plant pesticides, mineral fertilizers, and the application of organic wastes as fertilizers. Statistical analysis showed that the season affects the content of this element in the soil (Table 3).

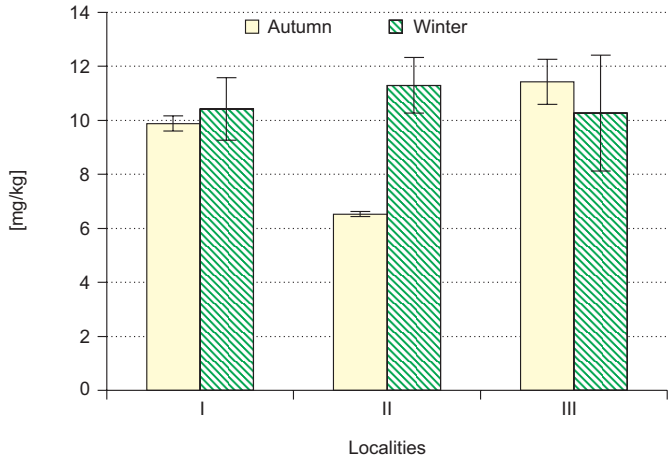

Fig. 4. The concentration of copper at the test sites

Significant differences were demonstrated in the Cu content at Site II, as well as between Cu content at Site II in the autumn, where its level was the lowest, and its content at the other sites both in the autumn (I/II $p = 0.007$, II/III $p = 0.0002$), and in the winter ($p = 0.002$).

Lead and all its compounds are strong poisons, harmful to humans. The source of lead pollution of the soil are motorization, non-ferrous metal industry and the sewage sludge used for soil fertilization. Pb and Cd are accumulated in the upper soil horizons. Pb concentrations indicate a significant enrichment in surface horizons from various soils in areas which receive significant acid atmospheric pollution [10]. The content of Pb at the test sites ranged between 18.41 and 45.62 mg per kg, moreover, at Site III it was over twice as high as at the other sites, both in the autumn and in the winter (Fig. 5).

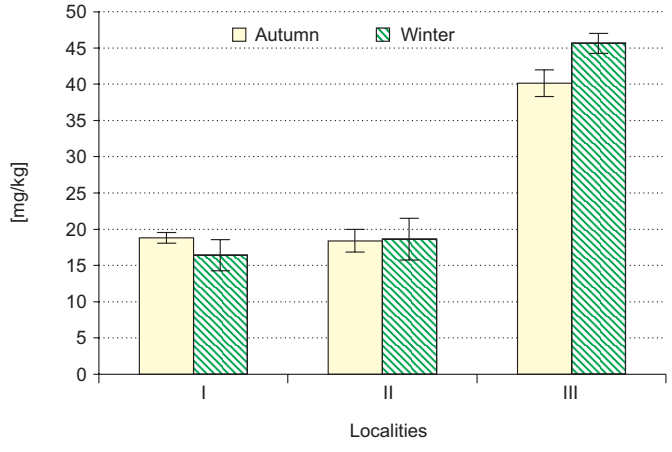

Fig. 5. The concentration of lead at the test sites

It might be associated with the position of this meadow below the road and the farmland, where from the sediments were flowing down. Significant differences were found between the Pb level at the test sites in the analysed seasons. The highest differences between the content of this metal occurred between Site III and the other meadows both in the autumn and in the winter (Table 4).

Table 4

Level of significance of differences calculated in the Tukey HSD test between studied localities

Sites	Site I autumn	Site II autumn	Site III autumn	Site I winter	Site II winter	Site III winter
Site I autumn		0.999317	0,000157	0.362651	0.997005	0.000157
Site II autumn	0.999317		0.000157	0.552970	0.963602	0.000157
Site III autumn	0.000157	0.000157		0.000157	0.000157	0.002210
Site I winter	0.362651	0.552970	0.000157		0.177510	0.000157
Site II winter	0.997005	0.963602	0.000157	0.177510		0.000157
Site III winter	0.000157	0.000157	0.002210	0.000157	0.000157	

Similarly, differences in the nickel content at the sites occurred between autumn and winter. The Ni level in the studied soil samples varied in the range from 8.04 to 15.29 mg per kg. In the winter season it was slightly higher than in the autumn, the highest at Site II situated closest to the roadway (Fig. 6).

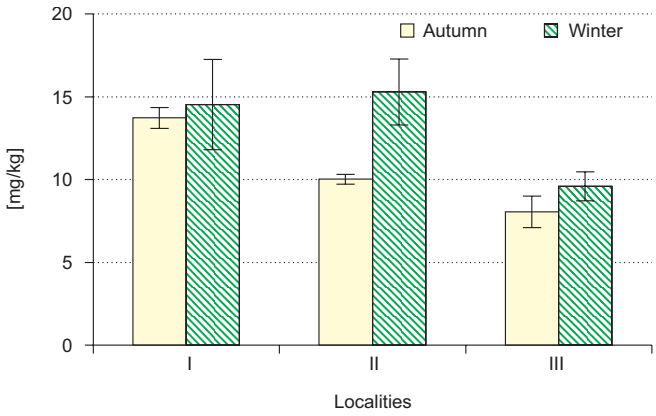

Fig. 6. The concentration of nickel at the test sites

The occurrence of nickel in the soil is determined by its presence in the parent rock, as well as the pollution, particularly with sludge sediments. Significant differences were found in the Ni content at Sites I and III in the autumn and in the winter, as well as between the seasons at the sites (I winter/ II autumn, I winter/ III autumn, II autumn/ II winter, III autumn/ II winter) (Table 5).

Table 5

Nickel of significance of differences calculated in the Tukey HSD test between studied localities

Sites	Site I autumn	Site II autumn	Site III autumn	Site I winter	Site II winter	Site III winter
Site I autumn		0.026807	0.009039	0.973872	0.683192	0.011498
Site II autumn	0.026807		0.994464	0.005760	0.001308	0.998302
Site III autumn	0.009039	0.994464		0.001967	0.000522	0.999997
Site I winter	0.973872	0.005760	0.001967		0.974922	0.002480
Site II winter	0.683192	0.001308	0.000522	0.974922		0.000626
Site III winter	0.011498	0.998302	0.999997	0.002480	0.000626	

However, despite the shown differences in Pb, Ni, Zn and Cu contents of the soil in the autumn and the winter seasons, no effect was found on the population of the soil fauna inhabiting it ($p < 0.05$).

Conclusions

1. No cases of exceeding the limit values for metals – Cd, Pb, Ni, Cu and Zn were found for Group B soils (a group covering the land rated as farmland excluding the land under ponds and the land under ditches, the woodland and tree- and bush-covered land, wasteland, as well as built-up and urban areas, excluding industrial areas, mine lands and transport areas) set out in the Minister of Environment Regulation on the soil quality and farmland quality standards (Polish Journal of Laws Dz.U. 2002 No. 165, item 1359 of 4 October 2002).

2. Statistically significant correlations were found between the Pb, Ni, Cu and Zn contents of the soil in the autumn and winter seasons at the individual sites. Higher levels occurred in the winter.

3. Such a correlation was not demonstrated for cadmium, the level of which in the soil was similar regardless of the season.

4. Despite differences in the content of the studied metals in meadow soils in the autumn and winter seasons, no effect was found on the population of the soil fauna inhabiting it.

5. Higher soil fauna density was noted in the winter season, when the moisture content of the soil was higher.

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ZAWARTOŚĆ METALI CIĘŻKICH W GLEBACH ŁĄKOWYCH W RÓŻNYCH PORACH ROKU

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Abstrakt: Badano zawartość Cd, Pb, Zn, Cu i Ni w glebach łąkowych w powiecie bocheńskim w sezonie jesiennym i zimowym 2010/2011. Łąki usytuowane były w różnej odległości od drogi: 2, 100 i 200 m. Gleby na badanych stanowiskach wykazywały odczyn od średnio kwaśnego do prawie obojętnego i wilgotność jesienią 17.17–29.53 %, natomiast w zimie 24.68–37.59 %. Wykazano istotne statystycznie różnice w zawartości Zn, Cu, Ni, Pb na poszczególnych stanowiskach w badanych sezonach. W stosunku do kadmu nie wykazano takich zależności. Pierwiastek ten w podobnym stężeniu (0.6; 0.88 ppm) występował na wszystkich stanowiskach bez względu na porę roku. Analizowano również liczebność i różnorodność pedofauny, która była większa w sezonie zimowym w glebach badanych łąk. Stwierdzono jednak, że znaczne różnice w zawartości metali nie miały wpływu na liczebność fauny glebowej na poszczególnych stanowiskach w badanych porach roku.

Słowa kluczowe: metale ciężkie, gleby łąkowe, pedofauna, zagęszczenie, różnorodność