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TRACE ELEMENT CONTENT IN CEREAL WEEDS AGAINST THE BACKGROUND OF THEIR SOIL CONTENTS PART 2. CHROMIUM AND LEAD CONTENTS IN SOIL AND WEEDS*

ZAWARTOŚĆ PIERWIASTKÓW ŚLADOWYCH W CHWASTACH ROŚLIN ZBOŻOWYCH NA TLE ICH ZAWARTOŚCI W GLEBIE Cz. 2. ZAWARTOŚĆ CHROMU ORAZ OŁOWIU W GLEBIE I CHWASTACH

Abstract: The investigations aimed at determining the contents of chromium and lead in weeds occurring in cereal crops, *ie* cornflower – *Centaurea cyanus* L., poppy – *Papaver rhoeas* L., corn chamomile – *Anthemis arvensis* L. and thistle – *Cirsium arvense* (L.) Scop. against the background of their soil contents. The soils, from which the materials for analyses were gathered, revealed a considerable diversification in these element contents, both in soluble forms assessed in 0.1 mol · dm^{-3} HCl solution and in approximate to total contents.

Total chromium and nickel contents in the studied soils ranged widely (14.44–58.30) mgCr · kg^{-1}, at geometric mean 24.72 mgCr · kg^{-1}, and from 17.34 mgPb · kg^{-1} to 30.44 mgPb · kg^{-1}, at geometric mean 25.53 mgPb · kg^{-1} of soil. Contents of chromium and lead soluble forms fluctuated from 0.11 mgCr · kg^{-1} to 0.39 mgCr · kg^{-1}, at geometric mean 0.21 mgCr · kg^{-1}, and from 3.88 mgPb · kg^{-1} to 10.11 mgPb · kg^{-1}, at geometric mean 7.25 mgPb · kg^{-1} of soil.

Chromium and lead contents in the studied weeds ranged widely depending on weed species, analyzed plant part, soil reaction and these elements concentrations in soil. Statistical analysis of the obtained results revealed that physicochemical properties of the analyzed soils not unanimously affected chromium and lead contents in the researched weeds.

Lead content was decreasing in the aboveground parts of the analyzed weeds with pH_{KCl} value increasing over 5.5, whereas in roots its contents changed irregularly. No unanimous influence of the soil reaction on chromium accumulation in the studied weeds was observed. In all analyzed weeds much higher contents of the discussed metals were assessed in roots than in the aboveground parts.

Keywords: weeds, chromium and lead concentrations, soil pH_{KCl}

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The natural environment pollution with trace metals leads to their increased contents in all biotic elements of ecosystems. The agroecosystems occurring in polluted areas face a hazard of excessive concentrations of heavy metals in plants designed for animal fodder or human food. Beside other quality parameters the excess of these metals in plants determines the quality of animal feeds or food products [1, 2].

Determining the level of heavy metals in crops cultivated in the areas threatened with anthropogenic pollution allows to organize farming in these areas towards diminishing negative effect of these elements through various agrotechnological measures, such as liming or increasing the contents of organic matter and proper selection of plants [1, 3]. The most frequently mentioned factors affecting heavy metal salts solubility in soil comprise: organic matter contents, soil granulometric composition, sorption capacity and soil pH [1, 4–7].

The investigations aimed at determining the contents of chromium and lead in weeds growing in cereal crops against the background of their soil concentrations.

Material and methods

Thirty soil samples were collected from the 0–25 cm layer of arable land on which cereal crops were cultivated in the Brzeznica commune in the first decade of June 2007. Each soil sample (0.5; 1.0) kg of soil was an average sample of individual ones. Basic physical and chemical properties were determined in the collected soil samples using agricultural chemistry standard methods [8]: granulometric composition was determined using Bouyoucose-Casagrande aerometric method modified by Proszyński, pH by potentiometric method in soil suspension in H_2O and 1 mol · dm^{-3} KCl solution, hydrolytic acidity by means of Kappen method and organic carbon content using Tiurin method.

Weeds growing in cereal crops, *ie* cornflower – *Centaurea cyanus* L., poppy – *Papaver rhoeas* L., corn chamomile – *Anthemis arvensis* L. and thistle – *Cirsium arvense* (L.) Scop. were collected from the same sites. The site where both soil and plant samples were collected was described in the "Materials and methods" section in the first part of the previous article [9].

Total contents of trace elements in the analyzed soils were determined following their mineralization at the temperature of 450 ^{o}C. Next, they were digested in a mixture of perchloric(VIII) and nitric(V) acid mixture (2 : 3, v/v). Mineralized soil material was dissolved in HCl [8]. The contents of trace elements in soluble forms were determined in 0.1 mol · dm^{-3} HCl solution, and the soil to extraction solution ratio was 1 : 10.

Collected plant material was washed, the samples were divided into the aerial parts and roots, dried, crushed and dry mineralized. The ash was dissolved in nitric acid (1 : 2). In the obtained solutions of the soil and plant samples chromium and lead contents were assessed using *atomic absorption spectrophotometry* (AAS). Obtained results of these elements contents in soil and analyzed weeds were elaborated statistically, *ie* arithmetic and geometric mean were calculated, as well as standard deviation and simple correlation coefficients.

Results and discussion

Characteristics of collected soil material

The analyzed soils were greatly diversified concerning their granulometric composition, soil pH, organic carbon content and the analyzed elements, both their soluble forms and approximate to total contents. The value of soil pH assessed in water suspension ranged from 4.81 to 7.68, whereas in 1 mol KCl · dm^{-3} solution from 3.95 to 6.64. The results of analyses of physicochemical soil properties were presented in the first part of the previous article [9].

Soil pH is one of the factors determining solubility of mineral compounds and therefore their availability to plants. Total chromium and nickel contents in the studied soils ranged widely from 14.44 mgCr · kg^{-1} to 58.30 mgCr · kg^{-1}, at geometric mean 24.72 mgCr · kg^{-1}, and from 17.34 mgPb · kg^{-1} to 30.44 mgPb · kg^{-1}, at geometric mean 25.53 mgPb · kg^{-1} (Table 1). In slightly acid and neutral soils total contents of chromium and lead were by 10 % lower in comparison with chromium and lead contents in soil with pH lower than 5.5.

Table 1

Chromium and lead content in soil, depending on soil reaction

Specification	Total content		Soluble forms content	
	[mg · kg^{-1}]			
	Cr	Pb	Cr	Pb
pH in 1 mol KCl · dm^{-3} ≤ 5.5				
Arithmetic mean	27.77	26.64	0.211	7.95
Geometric mean	**25.85**	**26.45**	**0.197**	**7.86**
Range	(14.44–58.30)	(17.30–30.44)	(0.11–0.391)	(5.80–10.11)
Relative standard deviation [%]	42	12	40	15
pH in 1 mol KCl · dm^{-3} from 5.5 to 6.5				
Arithmetic mean	23.22	24.63	0.238	6.38
Geometric mean	**22.90**	**24.34**	**0.234**	**6.21**
Range	(18.11–25.25)	(17.63–27.65)	(0.16–0.33)	(3.88–9.31)
Relative standard deviation [%]	17	15	20	15
pH in 1 mol KCl · dm^{-3} ≥ 6.6				
Arithmetic mean	22.19	24.66	0.257	7.21
Geometric mean	**22.18**	**24.52**	**0.236**	**7.13**
Range	(21.48–23.33)	(21.99–27.15)	(0.14–0.39)	(5.71–7.98)
Relative standard deviation [%]	5	13	70	18

The contents of soluble chromium and lead forms ranged widely: for chromium from 0.11 mgCr · kg^{-1} to 0.39 mgCr · kg^{-1}, at geometric mean 0.21 mgCr · kg^{-1}, whereas for lead from 3.88 mgPb · kg^{-1} to 10.11 mgPb · kg^{-1}, at geometric mean 7.25 mgPb · kg^{-1} (Table 1). The share of chromium and lead soluble forms in their total contents in the studied soils ranged from 0.52 % to 3.72 % for chromium and from 15 % to 39 % for lead.

Gasior et al [10] stated that the content of soluble element forms in soil after flood depended on percentage of floatable particles, soil pH and humus content.

It was revealed that at $pH_{KCl} > 5.5$ the amount of soluble lead forms diminished in the analyzed soils but opposite effect was observed for chromium which soluble forms contents increased under those conditions. In slightly acid and neutral soils soluble chromium content was by 19 % higher than in very acid soils with $pH_{KCl} \leq 5.5$. Wisniowska-Kielian [11] revealed that mountain soils with higher sum of total precipitation (Tymbark commune) contained twice larger amounts of Pb, Cd and Cr but 20 % less of Ni in soluble forms than weakly acid soils from the lowland areas (Przemysl commune). Statistical analysis showed that physical, physicochemical and chemical properties of the studied soils not unanimously affected the contents of analyzed elements and their soluble forms, as evidenced by simple correlation coefficients (Table 2).

Table 2

Simple correlation coefficients (r) between chromium and lead contents in soil and selected soil properties

Soil properties n = 30	Total forms		Soluble forms	
	Cr	Pb	Cr	Pb
pH_{KCl} value	–0.129	–0.418*	0.419*	–0.457**
Content of C_{org} [%]	0.146	0.504**	0.183	0.318
Share of fraction with diameter:				
< 0.02 mm	0.354*	0.302	0.025	–0.060
< 0.002 mm	0.322	0.384*	–0.358*	0.037

n = number of samples 30; r significant at: *p = 0.05; **p = 0.01.

A significant positive dependence was demonstrated between soil pH assessed in KCl solution and soluble chromium form content, where the value of simple correlation coefficient for these parameters was r = 0.419; (p < 0.01), whereas a significantly negative dependence was registered for lead; r = –0.425; (p < 0.01). A significant positive relationship was revealed between organic carbon content and total lead content but also between the content of floatable particles and total content of analyzed cations (Table 2). Kalembasa et al [12] demonstrated significant positive dependencies between the contents of heavy metals and organic C content, sorption capacity (T) and the content of floatable particles in alluvial soils.

On the basis of obtained results the analyzed soils in which cereals were cultivated were assessed concerning the degree of pollution with lead and chromium according to the guidelines suggested by Kabata-Pendias et al [13]. It was revealed that all soil samples showed natural contents of these metals (0^o).

Contents of chromium and lead in plants

Contents of Cr and Pb in collected weeds from cereal crops ranged widely depending on: the species, analyzed plant part and soil reaction, contents of total and available forms of these elements in soil. The relationships were confirmed by numerous experiments [1, 14–16].

Chromium is an element necessary for growth and development of living organisms. The element is absorbed by plants passively, so its concentration in the individual plant parts is a derivative of its concentrations in the soil solution. It is the element responsible for many physiological processes and for activation of some enzymes in plants, particularly from the oxyreductase group.

Geometric mean contents of chromium in the roots of studied weeds from cereal crops was put in the following order according to increasing contents: poppy – 2.39 mgCr $\cdot$ kg^{-1}, thistle – 2.56 mgCr $\cdot$ kg^{-1}, corn chamomile – 3.66 mgCr $\cdot$ kg^{-1} and cornflower – 5.42 mgCr $\cdot$ kg^{-1}, whereas for the aboveground parts the order was as follows: thistle 1.95 mgCr $\cdot$ kg^{-1}, corn chamomile – 1.99 mgCr $\cdot$ kg^{-1}, poppy – 2.06 mgCr $\cdot$ kg^{-1} and cornflower – 2.94 mgCr $\cdot$ kg^{-1} (Table 3).

Table 3

Chromium and lead contents [mg $\cdot$ kg^{-1} d.m.] in cereal crop weeds depending on soil reaction

Mean content	Roots		Aboveground parts	
	Cr	Pb	Cr	Pb
Cornflower – *Centaurea Cyanus* L.; n = 30				
pH in 1 mol KCl $\cdot$ dm^{-3} $\leq$ 5.5				
Arithmetic mean	6.61	3.09	3.64	1.30
Geometric mean	**5.87**	**2.99**	**3.13**	**1.22**
Range	(3.52–19.70)	(1.85–4.85)	(1.49–7.84)	(0.68–2.75)
pH in 1 mol KCl $\cdot$ dm^{-3} from 5.5 to 6.5				
Arithmetic mean	5.14	2.31	3.37	1.44
Geometric mean	**4.79**	**2.09**	**2.79**	**1.16**
Range	(2.89–10.25)	(1.24–5.33)	(1.16–2.46)	(0.59–3.51)
pH in 1 mol KCl $\cdot$ dm^{-3} $\geq$ 6.5				
Arithmetic mean	7.09	2.69	3.37	1.28
Geometric mean	**6.99**	**2.64**	**2.79**	**1.22**
Range	(6.18–8.84)	(1.88–3.09)	(1.16–7.94)	(0.89–1.85)
Poppy – *Papaver rhoeas* L.; n = 30				
pH in 1 mol KCl $\cdot$ dm^{-3} $\leq$ 5.5				
Arithmetic mean	2.79	1.47	2.64	1.18
Geometric mean	**2.65**	**1.37**	**2.37**	**1.04**
Range	(1.41–4.14)	(0.56–2.45)	(0.93–6.04)	(0.48–2.59)

Table 3 contd.

Mean content	Roots		Aboveground parts	
	Cr	Pb	Cr	Pb
pH in 1 mol KCl · dm^{-3} from 5.5 to 6.5				
Arithmetic mean	1.87	0.87	1.88	0.85
Geometric mean	**1.75**	**0.82**	**1.79**	**0.75**
Range	(1.12–4.22)	(0.52–1.30)	(1.31–3.50)	(0.28–1.37)
pH in 1 mol KCl · dm^{-3} from 5.5 to 6.5				
Arithmetic mean	2.58	1.05	1.73	0.87
Geometric mean	**2.56**	**1.00**	**1.70**	**0.83**
Range	(2.12–2.28)	(0.64–1.39)	(1.31–2.07)	(0.59–1.17)
Corn chamomile – *Anthemis arvensis* L.; n = 30				
pH in 1 mol KCl · dm^{-3} ≤ 5.5				
Arithmetic mean	4.79	2.90	2.53	1.28
Geometric mean	**4.41**	**2.04**	**2.35**	**1.18**
Range	(2.12–9.98)	(0.45–7.64)	(1.18–5.07)	(0.61–1.17)
pH in 1 mol KCl · dm^{-3} from 5.5 to 6.5				
Arithmetic mean	3.46	1.29	1.86	0.99
Geometric mean	**3.13**	**1.16**	**1.70**	**0.89**
Range	(1.79–7.25)	(0.45–2.07)	(0.87–3.04)	(0.46–2.14)
pH in 1 mol KCl · dm^{-3} from 5.5 to 6.5				
Arithmetic mean	2.36	1.96	1.52	0.76
Geometric mean	**2.32**	**1.35**	**1.49**	**0.74**
Range	(2.01–3.01)	(1.21–1.69)	(1.21–1.96)	(0.56–1.35)
Thistle – *Cirsium arvense* (L.) Scop.; n = 30				
pH in 1 mol KCl · dm^{-3} ≤ 5.5				
Arithmetic mean	2.74	2.26	1.92	1.53
Geometric mean	**2.59**	**1.91**	**1.75**	**1.31**
Range	(1.61–5.79)	(0.88–5.89)	(0.97–4.09)	(0.56–4.01)
pH in 1 mol KCl · dm^{-3} from 5.5 to 6.5				
Arithmetic mean	2.56	0.96	3.00	1.20
Geometric mean	**2.39**	**0.88**	**2.54**	**1.16**
Range	(1.39–4.06)	(0.35–1.42)	(1.27–7.14)	(0.71–1.66)
pH in 1 mol KCl · dm^{-3} ≥ 6.5				
Arithmetic mean	3.10	1.30	1.81	0.93
Geometric mean	**2.89**	**1.16**	**1.73**	**0.92**
Range	(1.65–3.83)	(0.72–2.16)	(1.15–2.39)	(0.77–1.07)

Lead uptake by plant roots is a passive process and proportional to the occurrence of its soluble forms in the substratum. Generally higher contents are assessed in plant roots than in the aerial parts. Geometric mean content of lead in the roots of the analyzed weeds from cereal crops was ordered according to increasing contents: poppy – 1.14 mgPb · kg^{-1}, thistle 1.34 mgPb · kg^{-1}, corn chamomile – 1.62 mgPb · kg^{-1} and cornflower – 2.62 mgPb · kg^{-1}, whereas in the aboveground parts respectively: poppy 0.91 mgPb · kg^{-1}, corn chamomile 1.02 mgPb · kg^{-1}, thistle 1.17 mgPb · kg^{-1} and cornflower 1.19 mgPb · kg^{-1}.

No unanimous effect of the studied soils reaction on chromium or lead contents in weeds from cereal crops was observed, except corn chamomile. Geometric mean contents of chromium and lead in the roots of corn chamomile from slightly acid and neutral soils was lower for chromium by 24 and 29 % and for lead by 44 and 8 %, respectively, in relation to geometric mean contents of these metals in corn chamomile roots from the soils with $pH_{KCl} \leq 5.5$ (Table 3). In the roots of cornflower growing in slightly acid soils chromium content was smaller by 19 %, whereas this metal contents in cornflower roots from neutral soils with $pH_{KCl} \geq 6.6$ was 19 % higher in comparison with cornflower roots gathered from very acid soils (Table 3). Wisniowska-Kielian [11] demonstrated that wheat roots from strongly acid soils contained three times larger amounts of Cd and Ni and twice more of Pb and Cr than the roots from less acidified soils.

Table 4

Values of simple correlation coefficients (r) between chromium and lead contents in cereal weeds and selected soil properties

Properties of soil	**Cornflower – *Centaurea Cyanus* L.**; n = 30			
	roots		aboveground parts	
	Cr	Pb	Cr	Pb
pH_{KCl} value	–0.1382	–0.5528*	–0.1558	0.0447
Total content	0.0563	0.3286	–0.0612	0.1623
Soluble forms	–0.1523	0.3683*	0.3081	0.0683
Poppy – *Papaver rhoeas* L.; n = 30				
pH_{KCl} value	–0.2528	–0.5428**	–0.3714*	–0.2299
Total content	0.0055	0.3133	–0.1288	–0.0058
Soluble forms	0.0597	0.5328**	0.3726*	0.1746
Corn chamomile – *Anthemis arvensis* L.; n = 30				
pH_{KCl} value	–0.4213*	–0.3417*	–0.3648*	–0.2063
Total content	0.1213	0.0103	0.1269	–0.1477
Soluble forms	–0.2763	0.0447	–0.3178	0.0664
Thistle – *Cirsium arvense* (L.) Scop.; n = 30				
pH_{KCl} value	0.0686	–0.3752*	0.1512	–0.0948
Total content	0.2720	0.3274	–0.3333	–0.2482
Soluble forms	0.1428	0.3303	0.0553	0.0767

n = number of plant samples 30; r significant at: *p = 0.05;**p = 0.01.

Statistical analysis of the obtained results showed that physicochemical properties of the analyzed soils not unanimously affected chromium and lead contents in weeds from cereal crops, as evidenced by simple correlation coefficients (Table 4). Significantly negative relationship was demonstrated between pH value of the studied soils and lead contents in the roots of the analyzed weeds (Table 4).

Chromium and lead contents both in roots and the aboveground parts of the analyzed weeds from cereal crops were small and no exceeded critical values of these elements concentrations were assessed in plants designed for animal feeds [13]. It suggests that no exceeded critical concentrations of these elements occur in the cultivated cereal crops.

Conclusions

1. Analyzed soils revealed a considerable diversification concerning their approximate to total contents of the studied elements and their soluble forms. In very acid soils higher contents of these elements were assessed in comparison with slightly acid and alkaline soils. All studied soils had natural contents of these elements.

2. The contents of chromium and lead in the researched weeds ranged widely depending on the weed species, analyzed plant part, soil pH and content of these elements soluble forms in soil. Much higher contents were assessed in the roots than in the aboveground parts.

3. No exceeded critical contents of chromium or lead were revealed in the roots or the aboveground parts of the analyzed weeds. It may suggest a good quality of cultivated cereals since no critical concentrations of these metals occurred.

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ZAWARTOŚĆ PIERWIASTKÓW ŚLADOWYCH W CHWASTACH ROŚLIN ZBOŻOWYCH NA TLE ICH ZAWARTOŚCI W GLEBIE
Cz. 2. ZAWARTOŚĆ CHROMU ORAZ OŁOWIU W GLEBIE I CHWASTACH

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Abstrakt: Celem badań było określenie zawartości chromu i ołowiu w chwastach występujących w uprawach roślin zbożowych, tj.: chaber bławatek – *Centaurea cyanus* L., mak polny – *Papaver rhoeas* L., rumian polny – *Anthemis arvensis* L. oraz ostrożeń polny – *Cirsium arvense* (L.) Scop. na tle ich zawartości w glebie. Gleby, na których zebrano materiał do badań, cechowały się znacznym zróżnicowaniem pod względem zawartości tych pierwiastków, zarówno w formach rozpuszczalnych oznaczonych w roztworze HCl o stężeniu 0,1 mol $\cdot$ dm^{-3}, jak i formach zbliżonych do całkowitych zawartości.

Całkowita zawartość chromu i ołowiu w badanych glebach wahała się w szerokim zakresie: dla chromu od 14,44 do 58,30 mgCr $\cdot$ kg^{-1}, ze średnią geometryczną 24,72 mgCr $\cdot$ kg^{-1}, natomiast dla ołowiu od 17,34 mgPb $\cdot$ kg^{-1} do 30,44 mgPb $\cdot$ kg^{-1}, ze średnią geometryczną 25,53 mgPb $\cdot$ kg^{-1}. Zawartość chromu i ołowiu w formach rozpuszczalnych wahała się w zakresie: dla chromu od 0,11 mgCr $\cdot$ kg^{-1} do 0,39 mgCr $\cdot$ kg^{-1}, ze średnią geometryczną 0,21 mgCr $\cdot$ kg^{-1}, natomiast dla ołowiu od 3,88 mgPb $\cdot$ kg^{-1} do 10,11 mgPb $\cdot$ kg^{-1}, ze średnią geometryczną 7,25 mgPb $\cdot$ kg^{-1}.

Zawartość chromu i ołowiu w zebranych chwastach wahała się w szerokim zakresie w zależności od: gatunku chwastu, analizowanej części rośliny, odczynu gleby i zawartości tych pierwiastków w glebie. Analiza statystyczna uzyskanych wyników wykazała, że właściwości fizykochemiczne badanych gleb w niejednakowym stopniu wpływały na zawartość chromu i ołowiu w badanych chwastach.

Wraz ze wzrostem wartości pH_{KCl} powyżej 5,5 zawartość ołowiu w częściach nadziemnych badanych chwastów zmniejszała się, natomiast w korzeniach jego zawartość zmieniała się w sposób nieregularny. Nie zaobserwowano jednoznacznego wpływu odczynu gleby na akumulację chromu w badanych chwastach. We wszystkich badanych chwastach stwierdzono znacznie wyższe zawartości badanych metali w korzeniach niż częściach nadziemnych.

Słowa kluczowe: chwasty, zawartość chromu i ołowiu, pH_{KCl} gleby