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CONTENT OF HEAVY METALS IN SOIL TOP LAYERS FROM DISTRICT PLAYGROUNDS OF SOUTHERN AREAS OF KRAKOW

METALE CIĘŻKIE W WIERZCHNIEJ WARSTWIE GLEB OSIEDLOWYCH PLACÓW ZABAW POŁUDNIOWYCH REJONÓW KRAKOWA

Abstract: Excessive amounts of heavy metals can occur in the natural environment especially in urban areas. In big cities district playgrounds are very often the only places for rest and recreation. Children playing on playgrounds can be exposed to the negative impact of the chemical soil contamination. The object of the work was the evaluation of the level of pollution with heavy metals: Cd, Pb, Cu, Zn, Cr and Ni in top soil layers of playgrounds situated in southern Krakow districts and the estimation of the potential risk resulting from the excessive amounts of these elements. The analyzed playground soils were characterized in the straight majority of cases by natural contents of cadmium, nickel, chromium, lead and copper. The only heavy metal whose content was in general higher than natural was zinc.

Keywords: urban soils, playgrounds, heavy metals, Krakow

In big cities district playgrounds are very often the only places for rest and recreation. They play an important role as they influence the physical and emotional development of children [1]. Excessive accumulation of harmful substances in the environment results in the progress of diseases associated with civilization, thus in bad conditions for physical and mental development [2]. The studies carried out in urban [3–7] and industrial areas or located in the vicinity of roads [8] show that soils of these terrains are often characterized by an elevated level of heavy metals. The metals belong to the group of mineral pollutants of the environment the most dangerous for people, animals and plants. Therefore children, regular customers of playgrounds, can be particularly exposed to the negative impact of the chemical soil transformation. Up to now studies

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concerning heavy metal contents in playground soils have been carried out, among others, in Uppsala [9] and Madrid [10].

The present study aimed at the evaluation of the contamination with Cd, Pb, Cu, Zn, Cr and Ni of the top layers of soils in district playgrounds situated in southern parts of Krakow and the estimation of the potential risk, resulting from the excessive amounts of these elements, for children staying there.

Material and methods

Soil material for laboratory analyses was sampled from 9 playgrounds located in southern parts of Krakow (Fig. 1). From the selected playgrounds, depending on their area one or two soil samples were taken, in each case from the layer 0–1 cm (surface layer) and 0–20 cm (deeper layer). Such proceedings aimed at the determination of the impact of the depth from which the sample was taken on the content of heavy metals. It was guided also by the fact that children staying on playgrounds have a direct contact with the surface soil layer. The deeper soil layer was treated as a kind of a background for the surface layer.

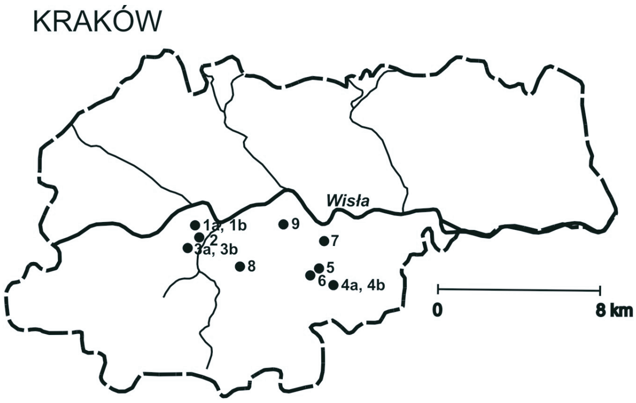

Fig. 1. Location of playgrounds in southern parts of Krakow: **1a, 1b – Debniki**; between Praska St. and Pietrasinskiego St., **2 – Debniki**; between Slomiana St. and Szwedzka St., **3a, 3b – Debniki**; between Slomiana and Szwedzka St., **4a, 4b – Prokocim**; J. Kurczaba St., **5 – Prokocim**; P. Sciegiennego St., **6 – Prokocim**; P. Sciegiennego St., **7 – Prokocim**; Klodzka St., **8 – Osiedle na Kozlowce**; Spoldzielcow St., **9 – Plaszow**; Krzywda St.

In the sampled soil material, after its drying and sieving through a plastic sieve with 1 mm mesh, the following analyses were performed: pH in 1 mol · dm^{-3} KCl [11], soil texture [12], organic carbon [13] and a level of total forms of: cadmium, lead, copper, zinc and chromium by the AAS method and nickel by the atomic emission spectrometry with inductively coupled plasma (ICP-AES), after previous digestion in the mixture of nitric(V) and chloric(VII) concentrated acids [14].

The results were subjected to statistical analysis. Simple correlation coefficients (r) between contents of heavy metals and selected soil properties were calculated.

A significance of correlation coefficients was estimated with the use of the t-Student's test. A significance of differences between mean contents of studied heavy metals in the layer 0–1 cm and 0–20 cm was evaluated by Tukey's test for the reasonable significant difference (RIR) at the significance level 0.05. The calculations were made using the STATISTICA program version 8.

Results and discussion

Heavy metal bounding in soil results mainly from its clay content, humus and soil reaction [15, 16]. The studied soils had sand texture in 3/4 cases, both in samples taken from the layer 0–1 cm and from the layer 0–20 cm. The remaining soils were light loams. Usually in soils from the deeper layer there were more fractions with ∅ < 0.002 mm (Table 1).

Table 1

Soil reaction and contents of fraction ∅ < 0.002 mm, organic carbon and heavy metals

Point No.	Layer [cm]	pH_{KCl}	Fraction ∅< 0.002 mm [%]	$C_{org.}$ [$g \cdot kg^{-1}$]	Cd	Pb	Cu	Zn	Cr	Ni
					$mg \cdot kg^{-1}$					
1a	0–1	6.6	0	35.4	0.06	45.7	23.2	171.3	17.9	9.1
	0–20	7.0	1	33.8	0.40	60.8	39.0	245.2	20.3	12.4
1b	0–1	6.5	1	18.1	0.00	10.9	6.0	71.5	10.1	2.9
	0–20	6.9	2	10.3	0.00	25.9	12.0	113.9	15.5	5.8
2	0–1	7.2	3	14.3	0.25	24.5	12.3	124.8	19.7	8.6
	0–20	7.3	5	10.9	0.14	26.8	11.5	111.4	14.2	9.8
3a	0–1	7.2	8	17.3	0.10	36.8	18.3	129.2	32.3	16.3
	0–20	7.0	8	19.4	0.19	38.5	20.5	135.6	27.3	14.6
3b	0–1	6.8	5	33.3	0.13	41.6	19.3	156.4	31.9	15.3
	0–20	7.1	6	22.3	0.11	60.4	26.8	181.2	28.4	17.1
4a	0–1	7.2	4	8.7	0.00	9.7	5.2	56.8	16.7	6.0
	0–20	6.9	4	5.4	0.00	10.2	6.5	55.9	14.2	7.1
4b	0–1	5.7	4	6.9	0.00	12.4	5.2	70.8	14.3	5.0
	0–20	6.7	2	5.9	0.07	17.4	5.2	69.6	13.3	5.8
5	0–1	6.4	1	10.2	0.00	9.6	4.0	71.3	7.7	3.0
	0–20	6.5	3	4.8	0.01	12.0	5.8	75.6	8.8	5.6
6	0–1	7.1	3	5.9	0.00	16.6	4.2	101.3	9.7	3.9
	0–20	7.1	3	8.0	0.00	10.6	5.9	80.0	11.5	5.5
7	0–1	7.4	4	29.3	0.01	36.2	22.8	126.8	31.1	9.4
	0–20	6.8	5	19.6	0.05	43.6	25.7	132.7	28.8	10.0
8	0–1	6.6	10	7.3	0.00	13.2	7.2	98.5	21.1	9.2
	0–20	7.3	9	5.4	0.00	15.2	7.8	94.7	20.1	9.7
9	0–1	6.8	1	9.7	0.00	5.8	2.4	33.5	10.1	2.6
	0–20	7.5	3	4.4	0.00	6.3	3.3	32.8	12.7	4.8

The majority of the studied soils, regardless of the depth from which they were taken, was characterized by a neutral reaction, even though there occurred also alkaline or slightly acid soils, and even acid in one case (a playground in Prokocim, point 4b, layer 0–1 cm). In the studied soils the organic carbon content ranged in large limits from 4.4 to 35.4 g · kg^{-1}, and the depth from which the soil was sampled influenced its content and in consequence the content of humus. The highest levels of organic carbon were determined usually in the surface layer (0–1 cm). The exceptions were constituted by soils from research points 3a and 6, where in the layer 0–20 cm a slightly higher level of organic carbon was ascertained. Playground soils located in the western part of the studied area (Fig. 1) were characterized by a distinctly higher organic carbon content than those in the eastern part, except for the soil taken from the playground in Prokocim in Klodzka Street (point 7).

Anthropopressure and natural processes going on in the nature did not contribute, apart from a few exceptions, to the pollution of the analyzed soils with cadmium, lead, copper, chromium and nickel. Their content is presented in Table 1. On the basis of the division serving for the evaluation of the level of the soil pollution with heavy metals, proposed by IUNG [17], it can be ascertained that in almost all playground soils regardless of the sampling depth a natural content of Cd, Pb, Cu and Ni occurred. The chromium content in the studied soils is comparable with that determined in unpolluted soils with this element [16]. Also, according to the Directive of the Environment Ministry regarding soil quality standards and ground quality standards, issued on 9 September 2002 [18], amounts of heavy metals determined and named in this paper did not exceed the acceptable values of the concentration of these elements. It was only the soil taken from point 1a (playground between Praska Street and Pietrasinskiego Street) which was characterized by small enrichment in heavy metals. In a deeper layer of this soil elevated Cd and Ni contents were determined when in both layers elevated Pb contents with elevated Cu content in the surface layer and slight pollution with this element in the layer 0–20 cm were noticed. Among other soils, only in point 7 (in Prokocim) in the layer 0–20 cm, elevated content of copper occurred [17].

In the case of Zn whose content ranged from 32.8 to 245.2 (105.9 on average) mg · kg^{-1} (Table 1), the largest contribution among the studied soils had those with its elevated content. Soils sampled from both layers in points 4a, 8 and 9 as well as from the layer 0–20 cm in point 4b revealed a natural content of zinc [17]. The highest content of Zn (as it was in the case of Pb and Cu) occurred in both soil layers from the playground in Debniki in point 1a. According to IUNG criteria [17] it was, comparably to the soil in point 1b from the layer 0–20 cm and in point 6 from the layer 0–1 cm, slightly polluted with this element (II degree of pollution). However due to the Directive of the Environment Ministry from 9 September 2002 [18] in none of the studied soils was the acceptable level of zinc concentration exceeded.

Among analyzed soil properties, organic carbon content had the strongest impact on heavy metal bounding in studied soils, which confirms the calculated correlation coefficients (Table 2). In playground soils in Uppsala [9] the most important soil property influencing the amount of heavy metals was clay content, which in the case of Cr and Ni was also noticed in the present study (Table 2).

Table 2

Simple correlation coefficients (r) determining relations between total contents of Cd, Pb, Cu, Zn, Cr, Ni and selected physicochemical properties of studied soils

Soil properties	Heavy metals					
	Cd	Pb	Cu	Cr	Zn	Ni
pH_{KCl}	0.219	0.181	0.194	0.293	0.131	0.300
$C_{org.}$	0.553**	0.830***	0.851***	0.622**	0.813***	0.590**
Fraction ∅ < 0.002	–0.011	0.109	0.080	0.575**	0.085	0.583**

** $p \le 0.01$, *** $p \le 0.001$.

Soils sampled from the deeper layer were usually characterized by a higher content of heavy metals than those taken from the surface layer, even though statistical analysis performed using the reasonable significant difference (RIR) of Tukey did not reveal any significant differences among the mean contents of studied heavy metals in layers 0–1 cm and 0–20 cm (Table 3).

Table 3

Differences between mean contents of heavy metals in layers 0–1 i 0–20 cm in studied playground soils from southern parts of Krakow

Heavy metals	Layer 0–1 cm	Layer 0–20 cm
Pb	21.92[a]	27.31[a]
Cd	0.045[a]	0.081[a]
Cu	10.84[a]	14.17[a]
Zn	101.02[a]	110.72[a]
Ni	7.60[a]	9.02[a]
Cr	18.55[a]	17.93[a]

Differences between means marked in superscripts by the same letter are statistically insignificant.

Alloway and Ayres [15] as well as Kabata-Pendias and Pendias [16] attributed the increase of the heavy metal content in soils mainly to the industrial activity and motorization. However, it seems that in the case of playground soils of southern parts of Krakow they have a minimal significance. Heavy metal contents determined in the studied soils are generally much lower than in soils in Krakow with a different way of use: allotments [3], convent gardens [6], or a city park [7]. The only heavy metal that occurred in higher amounts was zinc. Metal devices, especially covered by an anticorrosive layer could be one of the reasons for its considerable accumulation in the analyzed soils. As a result of corrosion and stripping zinc together with other heavy metals can find its way to soils. Nevertheless its content is lower than maximal found in city soils in Krakow which, as Pasieczna reports [19], can amount to 612.0 mg $\cdot$ kg^{-1} in the layer 0–20 cm. In the studied soils the determined contents of heavy metals are, except for zinc, at the similar level to those determined in the surface layer of playground soils in Madrid [10].

Small enrichment in heavy metals which occurred in some studied soils could have different sources that are difficult to establish. Regarding heavy metal contents, playground soils in southern parts of Krakow should not pose any serious danger to children playing on them but other risks must not be forgotten, among others those related with the technical condition of outdoor game devices.

Conclusions

1. The straight majority of playground soils in southern parts of Krakow was not polluted with cadmium, nickel, lead, copper and chromium.
2. Zinc was the only heavy metal whose content was generally higher than natural. The majority of soils revealed its elevated content.
3. The studied soils should not pose any danger regarding their contamination with heavy metals for children playing on playgrounds.

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METALE CIĘŻKIE W WIERZCHNIEJ WARSTWIE GLEB OSIEDLOWYCH PLACÓW ZABAW POŁUDNIOWYCH REJONÓW KRAKOWA

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Abstrakt: Nadmierne ilości metali ciężkich mogą występować w środowisku przyrodniczym zwłaszcza w obszarach miejskich. W wielkich miastach, bardzo często jedynym miejscem wypoczynku i rekreacji są osiedlowe place zabaw. Dzieci bawiące się na tych placach mogą być narażone na negatywne oddziaływania chemicznego skażenia gleb. Celem pracy była ocena stopnia zanieczyszczenia metalami ciężkimi: Cd, Pb, Cu, Zn, Cr i Ni wierzchnich warstw gleb placów zabaw położonych w południowych dzielnicach Krakowa oraz oszacowanie ewentualnego zagrożenia wynikającego z nadmiernej zawartości tych pierwiastków. Analizowane gleby placów zabaw charakteryzowały się, w zdecydowanej większości przypadków, naturalną zawartością kadmu, niklu, chromu, ołowiu i miedzi. Jedynym metalem ciężkim, którego zawartość była na ogół większa od naturalnej, był cynk.

Słowa kluczowe: gleby miejskie, place zabaw, metale ciężkie, Kraków