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# HEAVY METALS IN SOILS FROM DISTRICT PLAYGROUNDS IN THE NORTHERN PART OF KRAKOW

## METALE CIĘŻKIE W GLEBACH OSIEDLOWYCH PLACÓW ZABAW PÓŁNOCNEJ CZĘŚCI KRAKOWA

**Abstract:** The research was conducted to assess the degree of pollution with Cd, Pb, Zn, Cu, Cr and Ni in the top layer of soils from district playgrounds in the northern part of Krakow. The analyses were conducted on soil material collected from 12 objects.

Determined values of chromium and nickel were similar to the values noted in soils unpolluted with these elements. The most of analyzed soils were classified to the soil with the natural contents of cadmium, lead and copper, although in some of them elevated contents of Cd, Pb or Cu were assessed and a slight pollution with Pb or Cu. A majority of the studied soils revealed elevated contents or a slight pollution with zinc. Dependence between Ni content and the amount of $\varnothing < 0.002$ mm fraction was highly significant. Slight relationship between Cd and Cu content and organic carbon content was also registered in the analyzed soils.

**Keywords:** playgrounds, urban soils, heavy metals, Krakow

In the urbanized areas soil plays a different role than in the natural environment. Among others it forms a substratum of recreational areas. District playgrounds provide opportunities for active spending of pass time. They differ with their sizes or the number and state of playground equipment anyway, all should be places of safe and healthy rest, which ought to be ensured by unpolluted soil. Therefore, the playground soil environmental monitoring is necessary and should involve also determining heavy metal content. Urban soil pollution with heavy metals was a subject of numerous investigations, however a definitely lesser number of those focused on playgrounds [1–3]. Soil affects human health directly or indirectly. The direct influence involves ingestion of soil, inhaling of soil dust and contact through the skin [4]. Especially young children, curious about the surrounding world and exploring the environment are exposed to the contact with contaminated soil. The examples are provided for

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lead polluted soils, where this element accumulation was observed in children's organisms [5].

The research was undertaken to assess the degree of pollution with heavy metals: Cd, Pb, Zn, Cu, Cr and Ni in the top layer of district playground soils located in the northern, left-bank side of Krakow.

## Material and methods

Twelve playgrounds located in the northern part of Krakow: in Bronowice, Krowodrza, Srodmiescie and Nowa Huta districts were considered in the investigations (Fig. 1). They differed with their sizes, state in which playground equipment was maintained and turfing. Among the analyzed objects were small ones (eg the playground at Zwirki i Wigury Street) and very big ones (at Lotnicza Street). Depending on the size and spatial differentiation of the playgrounds, between 1 and 3 representative collective samples were taken from individual objects. A single collective sample consisted of 5 primary samples collected from the 0–20 cm soil layer using soil stick. In the laboratory the soil material was dried at room temperature and sifted through a plastic sieve with 2 mm mesh. Subsequently, soil texture [6], pH in 1 mol · $dm^{-3}$ KCl solution, hydrolytic acidity [7] and the sum of exchangeable bases [8] was determined, organic carbon content was assessed with Tiurin method and total heavy metal contents using atomic absorption spectrometry after mineralization in concentrated nitric(V) and chloric(VII) acids [9].

The results were verified statistically. The interdependence between the contents of the analyzed heavy metal form and selected soil properties was determined by computing Spearman's rank correlation coefficient.

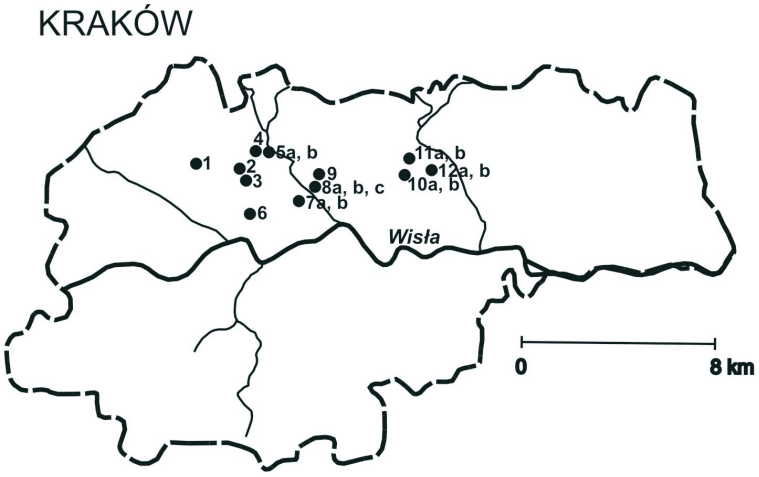


Fig. 1. Localisation of investigated playgrounds in the northern part of Krakow: 1 – Bronowicka St., 2 – Mazowiecka St., 3 – Grottgera Av., 4 – Fieldorfa-Nila St., 5a, 5b – Zdrowa St., 6 – Sikorskiego Sq., 7a, 7b – Kielecka St., 8a, 8b, 8c – Lotnicza St., 9 – Zwirki i Wigury St., 10a, 10b – Niepodleglosci housing estate, 11a, 11b – Kazimierzowskie housing estate, 12a, 12b – Gorali housing estate

## Results and discussion

Results of basic soil properties assessments which affect heavy metal mobility and the contents of Cd, Pb, Zn, Cu, Cr and Ni were presented in Table 1.

Table 1

Basic properties and heavy metal contents in soils of the analyzed playgrounds

| Point No. | $pH_{KCl}$ | BS [%] | org. C [g · kg$^{-1}$] | Fraction ∅ < 0.002 mm [%] | Cd | Pb | Zn | Cu | Cr | Ni |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | [mg · kg$^{-1}$] | | | | | |
| 1 | 6.5 | 83.0 | 16.6 | 1 | 1.14 | 50.5 | 126.1 | 18.4 | 11.9 | 5.2 |
| 2 | 6.2 | 97.3 | 13.7 | 2 | 0.46 | 50.6 | 136.5 | 40.6 | 14.7 | 6.7 |
| 3 | 7.2 | 87.7 | 21.8 | 2 | 0.94 | 73.9 | 203.4 | 37.1 | 20.0 | 7.6 |
| 4 | 7.4 | 95.8 | 10.8 | 5 | 0.22 | 12.8 | 61.7 | 9.1 | 13.0 | 6.4 |
| 5a | 7.2 | 94.8 | 14.5 | 3 | 0.47 | 46.0 | 144.5 | 25.9 | 10.7 | 6.7 |
| b | 7.2 | 95.8 | 11.1 | 5 | 0.47 | 31.6 | 185.6 | 13.9 | 11.4 | 6.5 |
| 6 | 6.8 | 90.5 | 12.8 | 6 | 0.55 | 106.0 | 214.1 | 20.8 | 12.7 | 8.1 |
| 7a | 7.5 | 97.0 | 11.6 | 3 | 0.56 | 53.1 | 252.5 | 14.2 | 13.2 | 8.4 |
| b | 6.9 | 96.7 | 15.0 | 7 | 0.54 | 23.4 | 201.7 | 12.9 | 15.6 | 12.4 |
| 8a | 7.1 | 96.7 | 12.3 | 10 | 0.30 | 3.0 | 68.2 | 9.1 | 10.6 | 10.7 |
| b | 7.3 | 98.1 | 13.4 | 9 | 0.25 | 8.9 | 104.1 | 10.8 | 12.9 | 10.7 |
| c | 7.2 | 97.8 | 11.9 | 13 | 0.09 | 9.1 | 69.0 | 10.0 | 17.2 | 11.9 |
| 9 | 7.1 | 97.2 | 25.1 | 6 | 0.29 | 13.7 | 131.6 | 13.6 | 17.2 | 9.1 |
| 10a | 7.5 | 96.2 | 13.4 | 10 | 0.34 | 15.1 | 135.3 | 9.4 | 18.2 | 10.2 |
| b | 7.1 | 98.7 | 8.0 | 9 | 0.21 | 19.1 | 105.1 | 9.6 | 16.5 | 8.7 |
| 11a | 6.2 | 87.6 | 13.8 | 13 | 0.35 | 15.6 | 104.2 | 10.0 | 19.3 | 11.9 |
| b | 7.1 | 92.7 | 15.9 | 10 | 0.46 | 24.5 | 119.6 | 10.5 | 17.8 | 11.0 |
| 12a | 7.4 | 97.0 | 14.9 | 8 | 0.88 | 30.1 | 266.3 | 12.8 | 21.2 | 10.5 |
| b | 5.9 | 97.7 | 7.2 | 11 | 0.35 | 17.7 | 108.0 | 8.9 | 13.9 | 8.2 |

Texture of the analyzed playground soils depended on the parent rock, but was also the result of anthropogenic effect. The area of Krakow situated north of the Vistula River is composed of loesses and non-loess deposits [10]. The influence of natural factors on the soil texture is most clearly visible on the playgrounds in Nowa Huta (objects 10–12) where soils, similarly as loess, used to be silts. However, in the past these playgrounds used to be construction sites or were located in their vicinity, which resulted in introducing gravel, sand or more finely granulated fraction into the soils. It is evidenced by diversified texture on the playgrounds from which more than one soil sample was taken (eg objects 5 and 8). Beside silts or loamy silts the investigated soils revealed the texture of strong loamy silty sands, strong loamy sands, light loamy sands and light silty loams. They also considerably differed with the content of ∅ < 0.002 mm fraction; the soils located in the western part of the studied area contained apparently

smaller quantities of clay than the ones in the eastern part (Fig. 1). The investigated soils were characterized by pH between 5.9 and 7.5 but generally higher than 7.0. It allowed to classify a majority of them to alkaline or neutral soils, and only four were counted among slightly acid soils. A substantial share of alkaline or neutral soils in cities, particularly in Krakow, was also reported by Pasieczna [11]. A considerable diversification in pH was observed among the soil samples collected from the playgrounds at Kazimierzowskie and particularly at Gorali housing estates (objects 11 and 12), which evidences a point introduction of materials containing alkaline components. The obtained values of base saturation [BS] also assume very high values, approximate to or exceeding 90 %. Organic carbon contents in the analyzed soils was diversified and fluctuated from 7.2 to 25.1 g · $kg^{-1}$ (on average 13.9 g · $kg^{-1}$).

Anthropogenic effect either had no effect or only to a slight degree influenced the contents of chromium and nickel in the top soil layer of playgrounds located in the northern part of Krakow. These elements content oscillated within a relatively narrow range, ie from 10.6 and 21.2 mg Cr · $kg^{-1}$ (on average 15.1 mg · $kg^{-1}$) and 5.2–12.4 mg · $kg^{-1}$ Ni (on average 9.0 mg · $kg^{-1}$). These amounts are similar to registered in soil unpolluted with these elements [12]. Also soil contents of cadmium, lead and copper, assessed according to heavy metal soil pollution classification suggested by ISSPC (IUNG) [13], allow to count most of the analyzed soils to the class with natural contents ($0^o$ of pollution) of these elements. However, soils from the playgrounds at Bronowicka and Mazowiecka Streets, Grottgera Avenue, Sikorskiego Square or Kielecka Street revealed elevated content of cadmium ($I^o$ of pollution). Elevated lead contents ($I^o$ of pollution) occurred in the soils of the playgrounds at Mazowiecka and Kielecka Streets (point 7a), whereas slight Pb pollution ($II^o$ of pollution) was detected in soil of the playground at Sikorskiego Square. Copper contents were elevated ($I^o$ of pollution) only in soils of the playgrounds situated at Grottgera Avenue and Zdrowa Street on the point 5a, whereas the playground soil at Mazowiecka Street was slightly polluted. Zinc was the only metal whose content (except for soil from points 4, 8a and 8c) was higher than considered normal [13] and reached 266.3 mg · $kg^{-1}$. In most of the analyzed soils elevated zinc content was noted or a slight pollution was observed in the soils from playgrounds located at Mazowiecka Street, Grottgera Avenue, Sikorskiego Square and Kielecka Street. According to the Regulation of Minister of the Environment on the soil quality standards and earth quality standards [14] the admissible contents of Cd, Pb, Zn, Cu, Cr or Ni were not exceeded in any of the investigated playground soils.

Conducted statistical analysis revealed weak relationships between organic carbon content and the quantity of cadmium and copper (Table 2). The dependence between the content of $\varnothing < 0.002$ mm fraction and nickel content was highly significant. Also significant dependencies occurred between this fraction content and contents of the other heavy metals (except chromium), however, due to a negative value of correlation coefficient these should be considered accidental. It evidences human impact on the texture of the analyzed soils and is contrary to fixed opinions on the relationship between clay fraction content and amount of heavy metals [12]. The other relationships were statistically insignificant (Table 2).

Table 2

Spearman's rank correlation coefficients (r) between heavy metal contents and selected properties of the analyzed soils (n = 19)

| Property | Cd | Pb | Zn | Cu | Cr | Ni |
|---|---|---|---|---|---|---|
| pH KCl | –0.068 | –0.117 | 0.152 | –0.061 | 0.078 | –0.065 |
| Org. C | 0.479* | 0.239 | 0.326 | 0.526* | 0.358 | 0.153 |
| ∅ < 0.002 | –0.582** | –0.679** | –0.508* | –0.790*** | 0.313 | 0.764*** |

* $p \leq 0.05$, ** $p \leq 0.01$, *** $p \leq 0.001$.

The content of the analyzed heavy metals in playground soils located in the northern part of Krakow usually remains on an approximate or even lower level than in the variously used soils of Krakow [11, 15, 16]. Higher contents of particularly zinc and lead occurred in the areas earlier and more intensively urbanized, as eg Sikorskiego Square, which corroborates the research of Ljung et al [1]. Generally, the determined heavy metal contents are not alarming. Slight pollution of the soils with zinc and lead may seem disturbing. It was registered on the playgrounds poorly turfed or practically devoid of vegetation, such as the ones at Grottgera Avenue or Kielecka Street. Children while playing there may carry soil particles to alimentary tract because of dirty hands [2, 4]. They may be also more exposed to inhaling soil dust due to their low height. Therefore it is so important to maintain greenery, particularly lawns on playgrounds, in good condition because of their isolating function. It also affects humus content in soil, the soil structure and therefore the air-water relationships.

## Conclusions

1. Soils of district playgrounds in the northern part of Krakow were not polluted with chromium or nickel.

2. Most of the analyzed soils revealed natural ($0^o$ of pollution) contents of cadmium, lead and copper acc. to ISSPC criteria, but soils with elevated ($I^o$ of pollution) contents of Cd, Pb and Cu were also registered, as well as single soils slightly polluted ($II^o$ of pollution) with Pb or Cu each.

3. Elevated contents of zinc were found in most soils, whereas in several also slight pollution with this element was observed.

4. Highly significant relationship was noted between the nickel content and share of ∅ < 0.002 mm fraction and weak relationship between cadmium and copper contents and organic carbon content.

5. Greenery on playgrounds, especially lawns should be maintained in good condition, since in the event of elevated heavy metal contents they will limit the direct contact between soil and child's organism.

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## METALE CIĘŻKIE W GLEBACH OSIEDLOWYCH PLACÓW ZABAW PÓŁNOCNEJ CZĘŚCI KRAKOWA

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**Abstrakt:** Przeprowadzone badania miały na celu ocenę stopnia zanieczyszczenia Cd, Pb, Zn, Cu, Cr i Ni wierzchniej warstwy gleb osiedlowych placów zabaw północnej części Krakowa. Badania przeprowadzono na materiale glebowym pobranym z 12 obiektów.

Oznaczone zawartości chromu i niklu były podobne do występujących w glebach niezanieczyszczonych tymi pierwiastkami. W przypadku kadmu, ołowiu i miedzi większość badanych gleb zaliczono wg kryteriów IUNG do gleb o naturalnej ich zawartości ($0^o$ zanieczyszczenia), chociaż w kilku z nich wystąpiła podwyższona zawartości Cd, Pb lub Cu ($I^o$ zanieczyszczenia) oraz słabe zanieczyszczenie Pb lub Cu ($II^o$ zanieczyszczenia). Większość badanych gleb charakteryzowała się zwiększoną zawartością lub słabym zanieczyszczeniem cynkiem. Stwierdzono statystycznie istotną zależność między zawartością Ni a ilością frakcji $\varnothing < 0.002$ mm. Wystąpiła również słaba zależność między zawartością Cd i Cu a zawartością węgla organicznego w analizowanych glebach.

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