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ASSESSMENT OF HEAVY METALS CONTAMINATION IN RECREATIONAL PARKS OF POZNAN

OCENA STANU ZANIECZYSZCZENIA METALAMI CIĘŻKIMI W REKREACYJNYCH PARKACH POZNANIA (POLSKA)

Abstract: City Recreational Parks (RP) exert important functions for inhabitants of great agglomerations. They create peculiar ecosystem subjected to high pressure of anthropogenic factors (ie, motorization, maintenance, dusts), which may be a source of heavy metal contamination. Four parks located within the city Poznan have been: RP Marcinkowski (RPM), RP Solacki (RPS), RP Wodziczko (RPW) and RP Piatkowo (RPP). The aim of the work was to apply different quantitative methods for assessing heavy metal contamination state of these parks and to outline the encountered difficulties in the choice of the appropriate method.

On the basis of the assessment made by the IUNG suggestion [16], it appeared, that soils of all Recreational Parks may be considered as not contaminated by Pb, Cu and Zn. Cadmium was the main contaminant of RPM, RPS and RPW soils. The use of data representing the geochemical background [17], classifies soils of all parks as contaminated to polluted, even, whereas the evaluation made on the basis of mean heavy metal contents of Polish soils [18], stated that cadmium solely exceeded the reference value. Criteria reported in the Minister of Environment Directive [19] dealing with heavy metal thresholds seem to be less restrictive. The resulting assessment revealed that soils of investigated parks are free of any contamination.

Keywords: recreational parks, Poznan, soil, Pb, Cd, Cu, Zn, assessment methods, geochemical background

The development of city infrastructures along with transportation activities and heating systems generates a bulk of harmful by-products of which heavy metals are nowadays one of the most threatening pollutants. This is of great concern since heavy metals are not biodegradable in soils, so they tend to accumulate and persist in urban soils for a very long time [1, 2]. Lead, cadmium, nickel, copper and zinc are among others reported to cause the highest impact on living organisms, humans particularly [3, 4]. City dwellers, including a large number of children, most frequently spend their

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leisure time in green areas commonly termed as recreational parks, which are strictly under anthropogenic pressure (conservation, incorporation of composts before laying lawns, dry as well as wet dusts deposition). Assessment of the level of contamination or pollution has been made on the basis of several approaches dealing with the application of (phyto)biological methods [5, 6], chemical tests, whose data are confronted with broadly suggested and implemented guidelines (ie, background values, threshold values). The most frequently encountered difficulty relies in the choice of convincing and *site-adapted* guidelines [7–9], especially for city recreational parks.

The purpose of the study was to evaluate the level of heavy metals contamination of selected Poznan recreational parks by applying some implemented guidelines. The targeted approach is to outline the disparity and divergence in the elaboration of final decisions over the contamination or pollution state of a given environment.

Materials and methods

Short description of Recreational Parks (RP)

The investigated four *recreational parks* (RP) are located within the city-agglomeration Poznan and consist of: *Recreational Park Marcinkowski* (RPM, 52°24'15"N, 16°55'4"E), *Recreational Park Wodziczko* (RPW; 52°25'11"N, 16°54'56"E), *Recreational Park Solacki* (RPS; 52°25'17"N, 16°54'15"E) and *Recreational Park Piatkowo* (RPP; 52°27'27"N, 16°55'48"E). The RPM, formerly Frederic Schiller, was created during the period 1905–1906 and occupies currently an area of 9.4 hectares. It is located in the center of Poznan and surrounded by streets of heavy daily traffic. Trees and grasses form quite a similar area, which is yearly subjected to several maintenance activities. The Recreational Park Solacki (RPS) is one of the most beautiful leisure places and highly attended by Poznan dwellers. It was established within years 1907–1913 and actually its area spans to ca 14.63 hectares. The RPW occupies currently an area of 7.06 hectares. This park was decidedly set up in 1971–1972 and is laying close to the RPS. Recreational Park Piatkowo (RPP) was the widest investigated area consisting of ca 55.0 hectares. This complex (Park/Forest) was created in 1959 and involves a Reserve – Zurawiniec of 1.27 hectare. The site is located close to a housing estate Batory.

Soil sampling and chemical analyses

Soil samples were collected at two depths, 0–10 and 10–20 cm in October, 2009. This sampling procedure was adopted in order to outline the possible effect of conservation practices, lawn laying and other anthropogenic factors on metals levels. The amounts of samples are as follows: RPM – 36 samples, RPS – 52 samples, RPW – 32 samples and RPP – 34 samples.

Prior to chemical analyses, soils were air-dried and crushed to pass a 1.0 mm screen. Particle size composition was determined according to the aerometric method of Bouyoucos-Casagrande [10] and organic carbon ($C_{org.}$) by the Walkley-Black method as reported by Nelson and Sommers [11]. The pH was determined potentiometrically (w/v ,

1:5) according to Polish Standard [12] in $0.010 \text{ mol CaCl}_2 \cdot \text{dm}^{-3}$. *Cation exchange capacity* (CEC) was obtained by the summation of exchangeable alkaline cations extracted by $1 \text{ mol CH}_3\text{COONH}_4 \cdot \text{dm}^{-3}$, pH 7.0 according to Thomas [13]. The *electrical conductivity* (EC) was determined conductometrically as described by Jackson [14]. Total contents of lead (Pb), cadmium (Cd), copper (Cu) and zinc (Zn) were assayed by hot-digestion in *aqua regia* chemical test [15]. The quantitative-based assessment of heavy metals contamination (means of the layers 0–10 and 10–20 cm) was undertaken throughout:

- IUNG suggestion of soil contamination by heavy metals according to Kabata-Pendias et al [16],
- geochemical background values [17],
- mean heavy metal contents for Polish soils [18],
- Directive of the Minister of Environment for soil quality [19].

Computations were made by using the Excel[®] Sheet and simple statistical analysis by the Statgraphics Software facilities.

Results and discussion

Short overview

The last 15 years have been marked by significant trials and efforts aiming at implementing operational [16–18] and administrative [19] guidelines for the evaluation of heavy metal levels in Polish soils. The last ones concern in bulk, agricultural lands, forest environments, industrial areas, urban zones at large and specific ecosystems designated as protected zones. Most of the suggested guidelines were elaborated to be applied for broad soil characteristics and environmental conditions and are based on the total content of a given metal. Soil chemists and environmentalists frequently face the problem, which guideline(s) to use for a best estimation of the investigated site.

Data reported in Table 1 (mean of 0–10 and 10–20 cm) outline the specific characteristics of four recreational parks (RP) located within the city Poznan.

Table 1

Selected physical and chemical characteristics of soils within investigated Recreational Parks (RP) of the city Poznan (mean of 0–10 and 10–20 cm)

Parameter		RPM (n = 36) ^a	RPS (n = 52) ^b	RPW (n = 32) ^c	RPP (n = 34) ^d
Silt (0.002–0.05 mm)	[g · kg ⁻¹]	397.2 ^α ± 139.3 ^β	425.5 ± 143.2	227.5 ± 57.2	244.9 ± 129.9
Clay (< 0.002 mm)		136.8 ± 56.8	175.3 ± 79.6	111.9 ± 43.1	186.1 ± 59.0
C _{org.} ^c		24.0 ± 5.5	25.0 ± 6.9	22.7 ± 4.1	17.5 ± 4.4
pH _{CaCl2}		7.9 ± 0.13	7.2 ± 0.7	7.9 ± 0.07	6.8 ± 1.4
EC [μS · cm ⁻¹]		111.7 ± 28.2	125.9 ± 72.3	141.3 ± 72.9	67.2 ± 30.7
CEC [mmol(+) · kg ⁻¹]		107 ± 22.7	139 ± 79	125 ± 48	43 ± 31

^{a, b, c, d} – Recreational Parks: Marcinkowski, Solacki, Wodziczko, Piatkowo, respectively; ^α – Mean value ± ^β – Standard Deviation; ^c – C_{org.} · 1.724 = *organic matter* (OM).

It should be mentioned the significantly low clay and silt content observed for the RPP (Recreational Park Piatkowo) site. The same was applied for the *cation exchange capacity* (CEC) amounting $43 \text{ mmol}(+) \cdot \text{kg}^{-1}$. In the case of the three other parks, ie, RPM (Recreational Park Marcinkowski), RPS (Recreational Park Solacki) and RPW (Recreational Park Wodziczki), the reported physical and chemical properties appear to be at levels, which may efficiently control the geochemistry of heavy metals.

Quantitative-based assessment of heavy metals contamination

The IUNG suggestion [16]. A step to improve the interpretation of soil heavy metal contamination level was made in Poland, by distinguishing 6 contamination degrees, taking into account soil texture, organic matter content and *soil reaction* (pH). For the purpose of the current study, only the first degree, ie not contaminated (designated as natural content) was considered. Mean Cu, Zn, Pb and Cd contents are listed in Table 2 were used for assessing the contamination state of recreational parks.

Table 2

Total heavy metal content of soils within investigated Recreational Parks of the city Poznan (mean of 0–10 and 10–20 cm)

Metal	RPM (n = 36) ^a	RPS (n = 52) ^b	RPW (n = 32) ^c	RPP (n = 34) ^d
	[mg · kg ⁻¹]			
Cu	23.3 ^α ± 12.1 ^β	19.4 ± 32.0	17.0 ± 10.2	10.5 ± 19.1
Zn	102.8 ± 47.4	58.6 ± 51.7	67.1 ± 63.6	41.8 ± 90.2
Pb	56.4 ± 25.0	32.0 ± 20.6	40.1 ± 18.2	13.0 ± 15.3
Cd	1.58 ± 0.42	2.12 ± 1.57	2.42 ± 1.58	0.87 ± 1.20

^{a, b, c, d} – Recreational Parks: Marcinkowski, Solacki, Wodziczko, Piatkowo, respectively; ^α – Mean value ± ^β – Standard Deviation.

Data reported in Table 3 revealed, that in any of the parks, the natural contents of Cu and Pb were not exceeded, except in the case of Zn, where its content in the RPM was higher *ca* 2.8 % as compared with the natural content.

Table 3

Heavy metal content used as “References” for the evaluation of contamination level of investigated Recreational Parks of the city Poznan

Metal	IUNG [16] ¹	Czarnowska [17]	Kabata-Pendias and Pendias [18]	Minister of Environment Directive [19] ²
	[mg · kg ⁻¹]			
Cu	40.0	7.1	10.4	150
Zn	100.0	30.0	41.7	300
Pb	70.0	9.8	14.2	100
Cd	1.0	0.18	0.29	4.0

¹ – 0⁰ contamination suggested as natural content for: share of particle fraction < 0.02 mm (range: 35–60 %), pH > 6.5, organic matter < 60 g · kg⁻¹, ² – group B, soil sampling depth 0–0.3 m.

Most specifically is the contamination state related to Cd. It appears, that three (ie RPM, RPS, and RPW) of all parks exhibited a slightly high Cd contamination. The natural content ($1.0 \text{ mg} \cdot \text{kg}^{-1}$) was exceeded ca 38, 53 and 59 %, respectively, which implies, that additional care should be given to this metal. Practically, on the basis of the IUNG suggestion [16], the Recreational Park Piatkowo may be considered as not contaminated by all heavy metals.

The Geochemical background basis [17]. Strikingly interesting is the metal contamination state evaluated by applying the geochemical background as reported by Czarnowska [17]. On the basis of this evaluation it appeared, that all soils within the Recreational Parks were contaminated to even severely contaminated by investigated metals. Hence the reference geochemical background was exceeded for Cu from 48 to 228 %; Zn: 39–243 %; Pb: 33–476 % and Cd, incredibly from 383 to 1244 %! In other terms, it means from *ca* 1.5 to 3.3 times, 1.5 to 3.5 times, 1.3 to 5.8 times and 4.8 to 13.4 times, for Cu, Zn, Pb and Cd, respectively. Of all studied parks, it was found that the RPM was the most threatened by quite all metals, except Cd, whose levels were higher in RPS and RPW, confirming then the reported contamination state. Therefore, with respect to the current assessment, it may “roughly” be concluded, that investigated parks are not suitable for recreational purposes and should be disqualified, practically.

Mean heavy metal contents for Polish soils [18]. Data listed in Table 3 resume the content of heavy metals at surface soil layers for the whole Polish area, ie all ecosystems included. The levels of heavy metals as reported in Table 2 explicitly reveal, that of all investigated parks, only the Recreational Park Piatkowo (RPP) may be classified as not threatened by Cu, Zn, Pb, but by Cd, significantly, since the reference value was exceeded 3 times (in relative number 200 %). On the basis of metal contents, two parks ie RPS and RPW may be grouped in the same range of contamination state. The level of metals in these parks exceeded the reference values *ca* 1.8, 1.5, 2.5 and 15.7 times for Cu, Zn, Pb and Cd, respectively. This aspect may be partly explained by a relatively low content of metals in Polish soils, which implies that anthropogenic and mainly metallurgical site-specific contamination were not decisive in shaping mean heavy metal contents for Polish soils [18]. Furthermore, it may be mentioned that these values are much more close to geochemical backgrounds [17] as compared with metal contents according to IUNG suggestion [16].

Directive of the Minister of Environment for soil quality [19]. Criteria related to this Directive are formulated on the basis of permissible values of metals and chemicals according to functions or destiny of a given environment. Three groups have been set:

- A – protected lands on the basis of water legislative regulations and environmental protection,
- B – agricultural and forest lands, urban and inhabited zones,
- C – industrial, mining and communication areas.

Recreational Parks are classified in the group B and reference metal values used for contamination evaluation reported in Table 3. These limits seem to be exceptionally “less restrictive” as compared particularly to the IUNG suggestion [16] and mean heavy metal contents for Polish soils [18]. On this basis it may be observed, that investigated

parks are all “free” of any threat related to these heavy metals! If we assume, that only 10 % of these references occur in readily active forms (ie water extractable) [20], therefore it should be expected the emergence of a potential concern related to specific contamination of attendees.

This is particularly probable for sandy soils, characterized most generally by low organic matter content. Such cases are often met under conditions of city recreational parks, for instance the Recreational Park Wodziczki (RPW) and Recreational Park Piatkowo (RPP). The applicability of the Directive of the Minister of Environment for soil quality [19] criteria for evaluating in-city contamination status must be supplemented by additional chemical soil tests in order to specify the fraction of the easily mobile (or labile) metals fractions.

Conclusions

1. On the basis of the IUNG suggestion [16], the soils of all Recreational Park may be considered as not contaminated by Pb, Cu and Zn. Cadmium was the main contaminant of RPM, RPS and RPW soils.

2. Contamination evaluation made on the basis of the Geochemical Background [17] revealed that all studied soils within the Recreational Parks were contaminated by all metals. Therefore, it may “roughly” be concluded, that investigated parks are not suitable for recreational purposes and should be disqualified, practically.

3. The levels of heavy metals in soils of investigated parks explicitly reveal, that only the Recreational Park Piatkowo (RPP) may be classified as not threatened by Cu, Zn, Pb, but by Cd, significantly, since the reference value (mean heavy metal contents for Polish soils [18]) was exceeded 3 times.

4. The Directive of the Minister of Environment for soil quality [19] seems to be “less restrictive” as compared particularly with the IUNG suggestion [16] and mean heavy metal contents for Polish soils [18]. On this basis it may be stated, that soils of investigated parks are all “free” of any threat related to these heavy metals.

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Abstrakt: Rekreacyjne Parki (RP) miejskie spełniają ważne funkcje dla mieszkańców wielkich aglomeracji. Tworzą swoisty ekosystem, który jest poddany silnej presji czynników antropogenicznych (motoryzacja, prace pielęgnacyjne, pyły) mogących być źródłem zanieczyszczenia metali ciężkimi. Badaniami objęto cztery parki mieszczące się w mieście Poznań: RP Marcinkowskiego (RPM), RP Sołacki (RPS), RP Wodzicki (RPW) i RP Piątkowo (RPP). Celem pracy było zastosowanie różnych metod ilościowej oceny stanu zanieczyszczenia gleb tych parków metalami ciężkimi oraz wskazanie na trudności wyboru odpowiedniej metody.

Z oceny przeprowadzonej metodą zaproponowaną przez IUNG [16] wynika, że gleby wszystkich parków są niezanieczyszczone Cu, Zn i Pb. Kadm był głównym czynnikiem zanieczyszczającym gleby RPM, RPS i RPW. Gdy zastosowano jako kryterium tło geochemiczne [17], gleby parków zaliczono do grup od zanieczyszczonych do skażonych, natomiast według oceny dokonanej w oparciu o średnie zawartości metali ciężkich dla gleb polskich [18], tylko zawartość kadmu znacznie przekraczała wartość referencyjną. Kryteria zamieszczone w Rozporządzeniu Ministra Środowiska [19] odnośnie progowych zawartości metali ciężkich wydają się być „mniej restrykcyjne”. Ocena przeprowadzona w oparciu o te wartości progowe wykazała, że gleby badanych parków są wolne od zanieczyszczeń.

Słowa kluczowe: parki rekreacyjne, Poznań, gleba, Pb, Cd, Cu, Zn, metody oceny, tło geochemiczne