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Risk assessment of heavy metals in children's playgrounds in the Rabka Zdrój health resort[1]

Zagrożenie metalami ciężkimi na placach zabaw w uzdrowisku dziecięcym Rabka - Zdrój

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Abstract
The problem of exposing to toxins in places frequented by people (especially children) for a longer time is an important aspect of environmental studies. Therefore, in Rabka-Zdrój, one of children health resorts, the contents of nine heavy metals, with a special focus on Cd, Pb and Zn, were determined in soils, grass, sands and dusts. The highest concentrations of Cd, Pb and Zn occur in soil samples: 2–3, 32–48 and 33–291 mg·kg^{-1}, respectively. Slightly lower are the concentrations in the sands taken from sandboxes: 1–3, 25–36 and 7–20 mg·kg^{-1} of Cd, Pb and Zn, respectively. In the grass, commonly growing in playground areas, the average concentrations of the metals are: 1.8, 20 and 60 mg·kg^{-1} of Cd, Pb and Zn, respectively. While the contents of the three metals in soils and sands do not exceed natural concentrations, the contents of Cd and Pb in grass exceed the values considered natural. The urban atmospheric dusts, suspected to be the major source of pollution, were analysed for the three metals. Their ranges (in mg·kg^{-1}) are: 6–15 for Cd, 80–215 for Pb and 104–260 for Zn. The lowest effects of pollution characterise the playground in the park no. III located in Orkana Street, whereas the highest the playground in the park no. I located in Parkowa Street. However, in none of the locations, the levels of Cd, Pb and Zn exceed the potentially harmful elements (PHE) considered as threatening the health and even life of children.

Streszczenie
Ważnym aspektem badań środowiskowych jest problem oceny narażenia ludzi (a szczególne dzieci) na związki toksyczne, znajdujące się w miejscach ich częstego przebywania. Dlatego w uzdrowisku dziecięcym – Rabka Zdrój zbadano zawartość wybranych metali ciężkich w glebach, trawach, piaskach i pyłach znajdujących się na 3 placach zabaw. Najwięcej Cd, Pb i Zn stwierdzono w próbkach gleb, odpowiednio (mg·kg^{-1}): 2-3, 32-48 oraz 33-291. Nieco niższe koncentracje oznaczone zostały w piaskach pobranych z piaskownic (zawartości w mg·kg^{-1}): Cd od 1 do 3, Pb od 25 do 36 oraz Zn od 7 do 20. W trawach, pospolicie rosnących na placach zabaw średnie koncentracje metali wynosiły (w mg·kg^{-1}): Cd 1,8, Pb 20 oraz Zn 60. O ile zawartości badanych metali w glebach i piaskach nie wskazywały podwyższonych koncentracji, o tyle zawartości Cd i Pb w trawach przekraczały tzw. zawartości naturalne. Źródeł metali szukano w pyłach miejskich, w których oznaczona zawartość całkowita wahała się (w mg·kg^{-1}): Cd 6-15, Pb 104-260 oraz Zn 80-215. Miejscem o najniższym wpływie zanieczyszczeń okazał się być osiedlowy place zabaw, położony przy ul. Orkana (Fig. 1, park nr III). Najwyższe zawartości metali stwierdzono natomiast w próbkach pobranych na najpopularniejszym placu zabaw, położonym przy ul. Parkowej (Fig. 1, park nr I). Jednak w żadnym z analizowanych miejsc nie stwierdzono zawartości zagrażających życiu i zdrowiu dzieci.

1. INTRODUCTION

Heavy metals can profoundly endanger the health and lives of people, especially of the youngsters when they appear in excessive amounts in the surrounding environment [Kabata-Pendias, Piotrowska 1995; Kabata-Pendias, Pendias 1999; Kicińska-Świderska 2004]. The potentially harmful elements (PHE), to which most of heavy metals belong, may enter the human organism via respiratory and digestive tracts or skin [Ljung 2006; Nieć *et al*. 2013]. An exposure of children to the PHE in playground areas has already been described in several papers [Liung 2006; Liung *et al*. 2007; Miko *et al*. 2010; Sidmov *et al*. 2013; Wong, Mak 1997]. This problem has been examined in Poland mainly in the areas characterised by high environmental contamination, such as the city of Kraków or the Silesia region [Astel *et al*. 2007; Gasiorek 2011; Jasiewicz *et al*. 2009; Nieć *et al*. 2013; Szwalec, Mundała 2010]. For the children, especially those living in polluted regions, the common recommendations are to consume safe and natural products (i.e. those lacking PHE) and to stay as frequently as possible in places of low pollution or not polluted at all [WHO 1982; 1989; 1993; 2011]. Health resorts are commonly considered to be such environmental retreats because of their location and use of therapeutic facilities (i.e. healthy climate, balneological resources, etc.). They are common destinations of health tourism to improve health conditions of human beings. The authors aim at assessing the risk of the

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exposure of children to heavy metals in the playgrounds of Rabka-Zdrój, one of the health resorts in southern Poland. It should be stressed that Rabka-Zdrój is one of the best known Polish health resorts for children.

2. MATERIAL AND METHODS OF STUDY

Samples were collected in April 2014 in three municipal playgrounds in the Zdrojowy Park (park no. 1) and a housing estate (parks no. 2 and 3, see Fig. 1). In three sites of each of the parks (at a distance of several metres), 15 samples representing the above-ground parts of grass, soils (taken at a depth of 0–20 cm), sand from sandboxes and finally, urban dusts deposited on facilities and toys used by children while playing were taken. The total number of each kind of samples was 45.

The soil and sand samples were cleaned of the grain fraction > 2 mm and the plant fragments and then brought to the air-dry state. The grass samples were averaged, homogenised and dried at a temperature of 105°C following the standard procedure. Dust samples were obtained by rinsing with distilled water and brushing off dust into glass containers. From such prepared laboratory samples, the As, Be, Cd, Co, Cu, Cr, Ni, Pb, Sn, Zn cations were extracted into the solutions using the mixture of concentrated acids (HNO_3 $HClO_4$ and HCl). The concentrations of the metals selected were determined using an ICP-MS Elan 6100 (PerkinElmer) mass spectrometer at the detection limit $0.2 \cdot 10^{-5}$ $mg \cdot dm^{-3}$. The active (in H_2O) and potential (in 1M KCl) soil acidities were determined at the solid to liquid ratio 1:5.

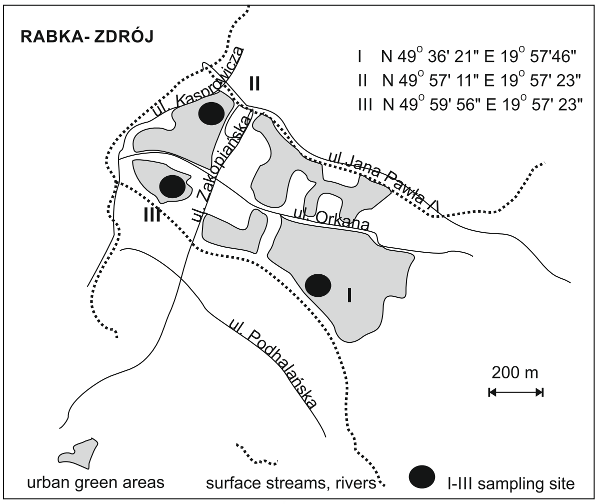

Fig. 1. Sampling site in the Rabka Zdrój

3. RESULTS AND DISCUSSIONS

The pH values in the range from 5.3 to 6.6 (Table 1) classify the soils as acidic or slightly acidic, which was expected for the soils developed on flysch strata. The concentrations of selected PHE in soils (Table 1) are the highest in case of Cd (2–3 $mg \cdot kg^{-1}$), Ni (12–18 $mg \cdot kg^{-1}$), Sn (0.9–3 $mg \cdot kg^{-1}$) and As (0.75–1.9 $mg \cdot kg^{-1}$), detected in the samples collected in the park no. I (Zdrojowy Park), whereas those of Pb (to 48 $mg \cdot kg^{-1}$), Cu (to 13 $mg \cdot kg^{-1}$) and Zn (to 291 $mg \cdot kg^{-1}$) in the samples collected in the park no. II (Sądecka Street). The lowest values of the selected PHE were found in the soils from the park no. III (Orkana Street).

If compared with the guidelines published by the Ministry of Environment [Regulation of 2002], most of the values contained in Table 1 do not exceed acceptable metal concentrations in soils of the protected areas (group A). The concentrations of Cd are the major exception as they exceed 1 ppm, which is the limit acceptable for the protected areas and this refers to cadmium in all the soils examined in the three parks. Fortunately, these Cd concentrations are below the upper limit for the soils of the group B areas, that is, the areas other than protected and industrial. The same is the situation with the concentrations of Zn in the soils of the park no. II: they also exceed the accepted soil limit for protected A-group areas, but are lower than the upper limit accepted for the group B soils.

In the same sites, samples of the above-ground parts of grass, which commonly grow around playgrounds, were taken. As in the case of soils, the same PHE were determined (Table 2), but their contents were significantly lower (about 50% in the average) in comparison with those found in the soils on which grass grow. There are no significant differences among the metal concentrations in the grass samples taken from different playgrounds. However, average contents of most of the elements measured (exceptions are Sn, Zn and Fe) are worrying as they are higher than the natural metal contents for grasses (*vide* Kabata-Pendias & Pendias 1999).

The next material tested as a carrier of the PHE risky for children is sand of sandboxes. As expected, in macroscopic observation quartz, being the mineral well known for its chemical inactivity, dominated among sand grains. Therefore, the PHE contents of the sand samples were generally lower than those determined in the soil samples (Table 3), which is clearly expressed for As, Be, Fe, Zn, Cu, Pb and Ni; only comparable were the contents of Cd and Co in sand and soil samples. The results (with an exception of cadmium) do not exceed the limit values of the PHE contained in the regulation of Ministry of Environment (op. cit).

The last material being a potential PHE source for children are urban atmospheric dusts, which accumulate on the playground facilities and toys (Table 4). According to earlier research [Kicińska-Świderska 2004] such dusts are major metal carriers. The highest metal concentrations occur in the samples from the Zdrojowy Park (park no. I, Fig. 1), with the average concentrations of Pb, Zn and Cd equal to 260, 215 and 13 in $mg \cdot kg^{-1}$, respectively, cadmium and lead concentrations in dusts are three times higher and beryllium even six times higher than in soils collected in the same areas. The concentrations of Cu and Zn in dusts and soils are comparable whereas the concentrations in dusts of Ni, Co and Fe were less than the soils collected in the same areas.

Therefore, it is seen that these are atmospheric urban dusts that are the main source introducing toxic and carcinogenic elements into the parks of Rabka-Zdrój. Cadmium causes kidney damage, deforms bones and is carcinogenic; lead damages liver, brain cells and bones; and beryllium causes inflammations of the respiratory system and skin [Kabata-Pendias, Pendias 1999].

Table 1. Average concentration of PHE and pH of soils from Rabka's Zdrój playgrounds

Sampling sites		pH_{H2O}	Cd	Ni	Co	Pb	Cu	Sn	Zn	Fe	Be
			mg·kg⁻¹								
I		6.02	3	18	11	40	7	1.9	4	10,657	2
II		6.13	2	14	12	48	13	1	291	10,784	2
III		6.03	2	12	7	32	4	1	33	4049	1
SD		-	*± 0.07*	*± 0.38*	*± 0.16*	*± 0.42*	*± 0.09*	*± 0.01*	*±.79*	*± 149*	*± 0.04*
min.–max.		5.3–6.6	2–3	12–18	7–12	32–48	4–13	0.9–3	33–291	4049–11,409	1–2
Average for *n = 45*		6.03	2.3	15.5	10	40	7.75	1.5	104.7	9225	1.75
Accepted values*	**A**	-	**1**	**35**	**20**	**50**	**30**	**20**	**100**	-	-
	B	-	**4**	**100**	**20**	**100**	**150**	**20**	**300**	-	-

*Due to Regulation of … [2002], group A - protected areas, group B - other areas but not industries

Table 2. Average content (mg·kg⁻¹) of elements in grasses form Rabka's Zdrój playgrounds

Sampling sites	Cd	Ni	Co	Pb	Cu	Sn	Zn	Fe	Be	As
	mg·kg⁻¹									
I	2	8	4	20	11	3	51	299	0.8	0.11
II	1	5	3	20	10	0	82	357	1	0.15
III	2	8	3	21	12	0.6	63	239	0.3	0.08
SD	*± 0.07*	*± 0.16*	*± 0.45*	*± 0.23*	*± 0.14*	*± 0.03*	*± 0.85*	*± 7.61*	*± 0.01*	*± 0.04*
min–max.	1–2	5–8	3–5	19–21	9–14	0–3	39–82	149–544	0.3–1	0.07–0.18
Average for *n = 45*	1.8	7	3.6	20	11	0.8	66	298	0.7	0.11
natural content*	**0.6**	**1.7**	**0.1**	**4.5**	**10**	**7**	**72**	**375**	**0.4**	**0.03**

*due to Kabata-Pendias, Pendias [1999]

Table 3. Average content (mg·kg⁻¹) of elements in sands from Rabka's Zdrój playgrounds

Sampling sites	Cd	Ni	Co	Pb	Cu	Sn	Zn	Fe	Be	As
	mg·kg⁻¹									
I	2	8	12	31	0.7	2.3	12.3	783	1	0,.5
II	2	6	9	28	0.3	2	9	618	0.01	0.17
III	2	4	9	34	0.4	2	10	584	1	0.16
SD	*± 0.07*	*± 0.15*	*± 0.16*	*± 0.37*	*± 0.01*	*± 0.01*	*± 0.15*	*± 6.31*	*± 0.02*	*± 0.04*
min.–max.	1–3	4–9	9–14	25–36	0.3–1	1–4	7–20	451–1316	0.01–1	0.16–0.35
Average for *n=45*	2	6.8	11	30.8	0.6	2.2	11.2	710.4	0.75	0.24

Table 4. Average content (mg·kg⁻¹) of elements in dusts from Rabka's Zdrój playgrounds

Sampling sites	Cd	Ni	Co	Pb	Cu	Zn	Fe	Be
	mg·kg^{-1}							
I	13.3	27	12	260	20	215	4404	33
II	12	15	1	128	4	128	944	3
III	6	5	7	104	6	80	1902	5
SD	*± 0.4*	*± 0.1*	*± 0.1*	*± 1*	*± 0.3*	*± 2.8*	*± 13*	*± 0.08*
Average for *n = 45*	6.6	11	6.4	122	9	99	2106	13

4. CONCLUSIONS

Therapeutic longer visits in health resorts are usually associated with some hours spent outdoors. In the case of children, it mainly means staying at playgrounds. The authors have demonstrated that the playgrounds located in the Rabka-Zdrój health resort are affected by anthropogenic pollutants to a various degree, which is reflected in variable metal contents in all the examined components of the environment, that is, in soils, grass and sand. The upper limits of the acceptable metal contents in soils located in protected areas were not exceeded for most of the elements analysed, except for Cd and Zn. Cadmium and zinc contents in soils of Rabka-Zdrój, a relatively small spa, are comparable with those found in soils from urban parks of the Krakow agglomeration [Szwalec, Mundała 2012]. It is a sign of a significant anthropogenic pressure in Rabka-Zdrój.

The contents of metals in sand from sandboxes in Rabka-Zdrój are for most elements (except for Cd) lower than the ones determined in parks of Krakow [Jasiewicz *et al*. 2009]. It is a positive observation, but one must remember that quartz, predominant sand component, is chemically almost inert and thus, does not accumulate elements.

The authors have shown that urban dusts are the significant source of the PHE. The most dangerous are toxic and carcinogenic elements, particularly Cd, Pb and Be. Their high concentrations have been found in the dusts taken from the playground of the largest and most popular Zdrojowy Park. These dusts, undoubtedly associated with the Rabka network of roads and streets, are generated by moving vehicles (burning of fuels and attrition of car parts and road surface).

Unfortunately, within the framework of the environment monitoring programme in Poland, there is no station measuring the air quality in Rabka-Zdrój. It would have enabled to have an insight into an annual changes of air pollution, especially during the winter season.

Air quality and the influence of the pollutants transported by air, particularly considering PHE - potentially harmful elements, is currently the most common problem faced in big towns and for protected areas [Wong, Mak 1997]. The authors have shown that it is also the problem affecting health resorts, even those dedicated for children.

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