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BIOINDICATION OF HEAVY METALS POLLUTION IN THE TOWNS: BEDZIN AND CZELADZ

BIONDYKACJA ZANIECZYSZCZENIA METALAMI CIĘŻKIMI BĘDZINA I CZELADZI

Abstract: The analysis of heavy metals in plant leaves is suggested as a method for the identification of polluted areas. We determinted the following heavy metals: Zn, Pb and Cd concentrations in birch *Betula pendula* leaves, a common species found in urban parks and postindustrial areas in Poland. Samples of soil and birch leaves were collected in September 2007 from more and less polluted sites in Bedzin and Czeladz (Silesian province, southern Poland, 8 stands for each town). Concentrations of Zn, Pb and Cd in leaves and the upper layer of soil (0–10 cm) were determined. The heavy metal pollution of the investigated cities was on a comparable level. The obtained Cd and Pb concentrations in leaves were below the toxic range. Only Zn concentrations in some sites were higher than the level considered as toxic. Pb and Cd levels determined in the investigations exceed acceptable metal concentrations for soil in more stands in Bedzin.

Keywords: heavy metals, *Betula pendula* Roth., pollution

Foliage analysis has been used as a valid indicator of air pollution and in order to identify and possible polluted areas classification according to their pollution level [1–4]. Some investigations were performed on trees (common birch, *Betula pendula* Roth, Scots Pine, *Pinus sylvestris* L., Black Locust, *Robinia pseudoacacia* L., Sycamore Maple, *Acer pseudoplatanus* L., European Beech, *Fagus sylvatica* L., Norway Spruce, *Picea abies* (L.) Karst) and in the leaves of shrubs (Common Snowberry, *Symphoricarpos albus* (L.) Blake, Common Privet, *Ligustrum vulgare* L., White Syringa, *Philadelphus coronarius* L.) [5] in the Silesian towns, in Krakow, in municipal parks, in nature reserves and in the vicinity of industrial plants, to assess the heavy metal pollution level [4, 6–8]. Also the soil pollution with heavy metals such Zn, Cd, Pb, Cu and Cr was a concern. The soil contamination with metals results from local sources such as: industry, waste incineration, combustion of fossil fuels and traffic [9].

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Common birch, *Betula pendula* Roth. is a pioneering species on dumps and other postindustrial areas [9, 10]. It is a common plant in the cities too. It is postulated to plant it in a town green areas such as parks and squares and in larger distances from traffic routes [11, 12]. The investigations were performed in Czeladz and Bedzin, which are the oldest towns in the Zaglebie Dabrowskie region (Silesian province, southern part of Poland) [13]. The town Czeladz is exposed to low emission, ambient concentration from neighbouring towns and in Bedzin from emitters such as the power plant "Lagisza", heat and power plant, non-ferrous plant and others [14]. The aim of this study was to assess contamination of Bedzin and Czeladz by measuring zinc, lead and cadmium bioaccumulation in birch *Betula pendula* Roth. leaves and their content in soil samples from the upper layer (0–10 cm).

Material and methods

The *Betula pendula* Roth. leaves and soil samples from the upper layer (0–10 cm) were collected in September 2007. The birch (*Betula pendula* Roth.) leaves were collected randomly from ten trees situated in parks, plantings next to roads and in the vicinity of emitters. In each town 8 investigation sites were established. These sites exhibited varied heavy metal contamination level.

The air dried soil samples, sieved on a 1mm sieve was used to determine pH values in H_2O. 10 g soil samples were extracted with 10 % HNO_3. The concentration of metals Zn, Cd and Pb was measured with the flame Atomic Absorption Spectrometry (AAS) method [15]. Soil pH was measured in water (1: 2.5 soil:water ratio) using a pH meter, and organic matter content (expressed in %) was estimated by Ostrowska's methods [15]. In order to determine the heavy metal concentration, the plant material was washed in tap and distilled water, dried in 105 ^{o}C to constant weight and ground to fine powder, then mineralized and dissolved in 10 % HNO_3. After filtration Zn, Pb, and Cd content was measured using the flame Atomic Absorption Spectrometry (AAS) [mg/kg d.m.] [15, 16]. The quality of the analytical procedure was controlled by using samples of the reference material in each series of analysis. (Certified Reference material CTA-OTL-1 Oriental Tobacco Leaves) All plant and soil samples were studied in six replications. The data were processed using software Statistica to compute significant statistical differences between samples ($p < 0.05$) according to Tukey's multiple range test and to compute Pearson's correlation coefficients. Figures 1–6 were drawn with the use of Surfer 8 program.

Results and discussion

Zn concentration in the upper layer soil sample was higher in Czeladz than in Bedzin It ranged from 60.5 (power station "Lagisza") to 582.8 mg/kg (the park Zamkowa hill) in Bedzin and from 95.5 (Wiosenna (Staw) to 945.95 mg/kg (park Grabek) in Czeladz. Pb and Cd content in soil was on a comparable level in both towns. Pb content in soil sample varied from 61.5 (power plant) to 219.7 mg/kg (Sw. Dorota hill) in Bedzin and as 30 Wiosenna (Staw) to 283.2 mg/kg (Borzecha hill) in Czeladz. The highest

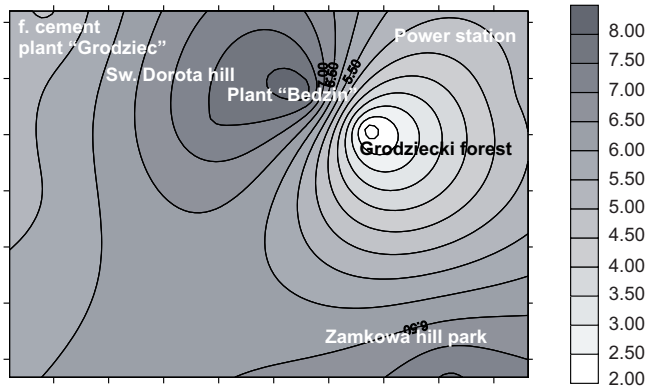

Fig. 1. Pb contamination in Bedzin based on metal content in birch leaves [mg/kg d.m.]

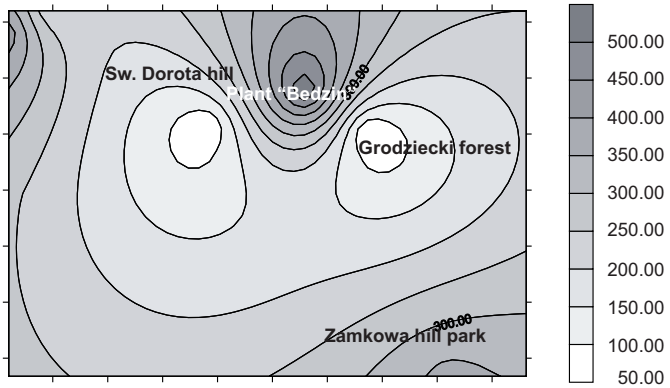

Fig. 2. Zn contamination in Bedzin based on metal content in birch leaves [mg/kg d.m.]

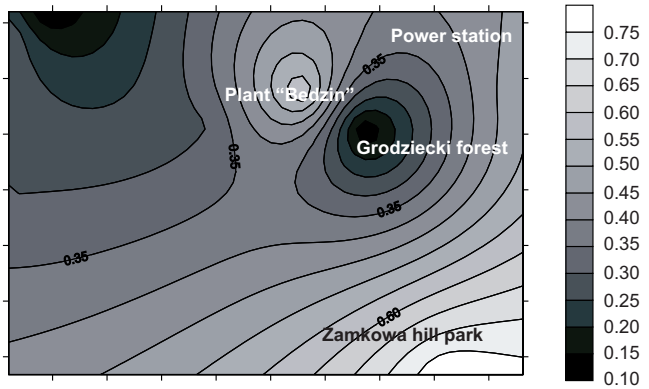

Fig. 3. Cd contamination in Bedzin based on metal content in birch leaves [mg/kg d.m.]

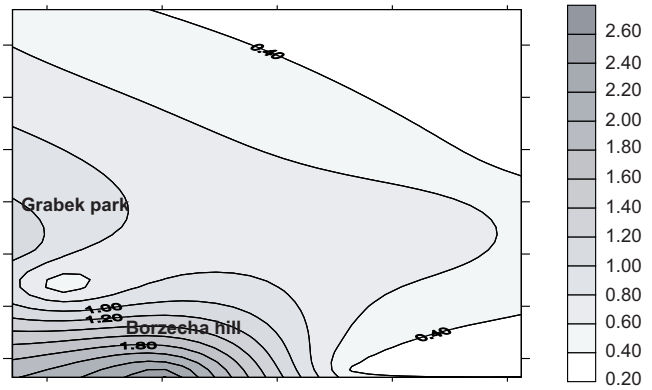

Fig. 4. Cd contamination in Czeladz based on metal content in leaves of birch [mg/kg d.m.]

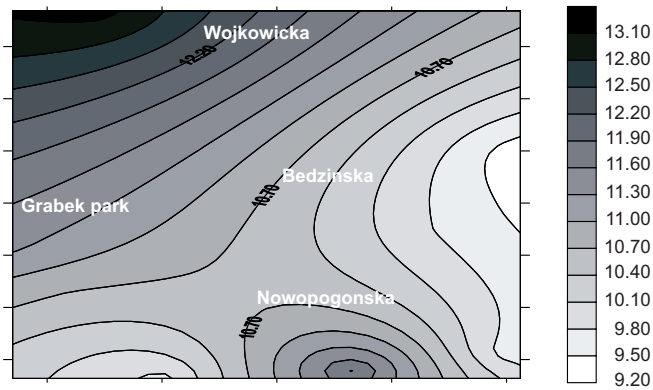

Fig. 5. Pb contamination in Czeladz based on metal content in leaves of birch [mg/kg d.m.]

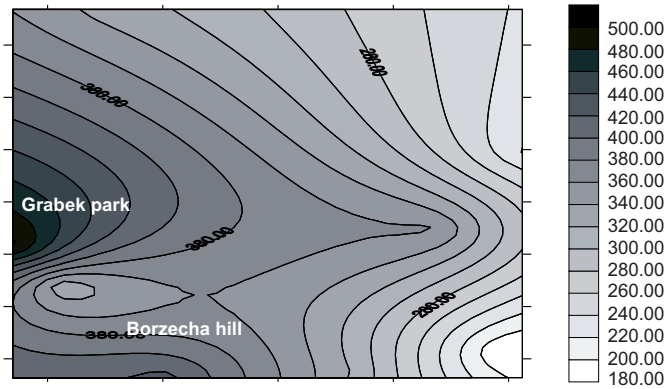

Fig. 6. Zn contamination in Czeladz based on metal content in leaves of birch [mg/kg d.m.]

concentration of Cd was found in Sw. Dorota hill (21.3 mg/kg) and the lowest 4.4 mg/kg (former cement plant) in Bedzin. Cd concentration in soil samples in Czeladz ranged from 14.1 (park Grabek) to 1.55 mg/kg Wiosenna (Staw) (Table 1, 2) [16, 17].

Table 1

Zn, Pb and Cd content, organic matter content and pH value in soil samples (upper layer) in Bedzin

	Zn	Pb	Cd	Organic matter content	pH value
Former mine Grodziec	184.1 ± 21 a	180.7 ± 17 a	11.9 ± 0.9 a	9.1 ±0.2 a	7.6 ± 0.02 a
Sw. Dorota hill	825.3 ± 32 b	219.7 ± 12 b	21.3 ± 0.3 b	4.1 ± 0.2 b	7.7 ± 0.03 b
Grodziecki forest	128.3 ± 26 c	179.9 ± 15 a	9.4 ± 0.5 c	3.6 ± 0.04 c	7.2 ± 0.04 c
Rozkowka park	149.2 ± 31 c	166.2 ± 16 ad	5.8 ± 0.9 d	7.1 ± 0.02 d	7.3 ± 0.01 c
Plant "Bedzin"	181.3 ± 36 a	181.6 ± 13 a	6.8 ± 0.8 de	4.8 ± 0.3 e	7.3 ± 0.05 c
Power plant "Lagisza"	60.5 ± 29 d	61.5 ± 12 c	12.4 ± 1 a	3 ± 0.09 f	6.8 ± 0.02 d
Former cement plant "Grodziec"	164.3 ± 21 b	149.2 ± 14 d	4.4 ± 1.5 d	6.4 ± 0.02 g	7.5 ± 0.01 a
Zamkowa hill park	582.8 ± 30 e	198.6 ± 17 a	4.6 ± 0.9 d	7 ± 0.04 d	7.3 ± 0.04 c

Values with the same letter are statistically the same for $p < 0.05$.

Table 2

Zn, Pb, Cd content, organic matter content and pH value in soil samples (upper layer) in Czeladz

	Zn	Pb	Cd	Organic matter content	pH value
Wojkowicka	257.4 ± 0.12a	87.14 ± 6.25 a	3.78 ± 0.1a	4.4 ± 0.1 a	7.43 ± 0.03 a
Bedzinska	510.6 ± 1.6b	181.2 ± 5.51 b	6.6 ± 1.6 b	9.03 ± 1.02 b	7.56 ± 0.1ab
Park Kosciuszki near Katowicka street	353.95 ± 0.12 c	91.76 ± 18.51a	3.85 ± 0.12 a	5.45 ± 0.13 c	7.3 ± 0.05 a
Park Grabek	945.95 ± 0.16 d	280.2 ± 6.08 c	14.1 ± 0.16 c	7.65 ± 0.7 b	6.61 ± 0.1 c
Borzecha hill	731.55 ± 0.10 e	283.2 ± 5.38 c	8.56 ± 0.11 d	7.97 ± 0.22 b	7.03 ± 0.11 d
(Wiosenna) Staw	96.5 ± 0.17 f	30.025 ± 6.9 d	1.55 ± 0.17 e	3.12 ± 0.51d	7.26 ± 0.02 e
Nowopogonska	642.05 ± 0.32 g	119.85 ± 0.2 e	5.29 ± 0.32 b	5.31 ± 0.3 c	7.4 ± 0.1 ab
Park near Mickiewicza street	299.45 ± 0.04 h	86.88 ± 2.05 a	3.81 ± 0.043 a	3.06 ± 0.44 d	7.7 ± 0.1 b

Values with the same letter are statistically the same for $p < 0.05$.

The surface accumulation of heavy metals is characteristic of aerial deposition of metal particulates [7]. Heavy metal concentrations in the upper layer of soil which were much higher than the results obtained in this study were found in the soil samples from Piekary Slaskie (6–143 mg/kg Cd, 378–2465 mg/kg Pb, 2730–8725 mg/kg Zn). The loads of metals in the soils in Piekary Slaskie have increased during some decades because of the pollution from the mine and the lead zinc smelter. The obtained concentrations of Zn, Cd and Pb in the top soil were higher or on a comparable level to

the content, which were found around steelworks KH "Katowice" in Dabrowa Gornicza in the vicinity of the investigated cities (Zn 40–120 mg/kg, 2–3 mg/kg Cd, 38–62 mg/kg Pb) [5, 7]. Wyzgolik noted similar or higher soil contamination results in Dabrowa Gornicza for 100–1000 Zn mg/kg [18]. The results of the metal concentration in the nature reserves "Las Murckowski" and "Ochojec" in Katowice were similar to the results obtained in the previous study (144–230 Zn, 115–150 Pb, 5,5–10 Cd mg/kg) [8]. Zn content in soil upper layer in most investigated stands in Czeladz and Zamkowa hill park and Sw. Dorota hill in Bedzin were higher than the level considered as permitted (300 mg/kg). Pb and Cd concentrations determined in our investigations exceed the acceptable metal concentrations for soil (100 mg/kg Pb, 4 mg/kg Cd) in most stands in Bedzin and in a half of the investigated stands in Czeladz [19, 20]. The soil pH in the studied cities were above 7 (see Table 1, 2). The sorption of Pb, Cd and Zn increases with increasing alkaline value and pH > 6.5 influenced the immobilizing action of Pb and Cd on the forms weakly dissolvable [7]. At pH value about 7 the influence of pH on heavy metals binding by organic matter is very strong [21].

The content of heavy metals in the leaves of birch was presented by means of isolines in the Figures 1–6. The Zn content noted in birch, *Betula pendula* Roth leaves ranged from 49,4–556 mg/kg d.m. in Bedzin and 178–506.75 mg/kg d.m. in Czeladz (Fig. 1–6). The Pb content in birch leaves ranged from 4.9–7.6 in Bedzin and 9.7–13.21 mg/kg d.m. in Czeladz. The Cd content in birch leaves was below 0.5 in most investigated stands in Bedzin and Czeladz (Fig. 1–6) [16, 17]. This study showed that the Zn concentrations noted for birch leaves were in the range (100–400 mg/kg d.m.) considered as toxic [22]. The Pb and Cd concentrations observed for birch leaves did not exceed toxical levels for plant tissues (5–30 mg/kg d.m. Cd, 30–300 Pb). Lead, cadmium and zinc concentration in birch leaves was the highest in the places in the vicinity of the emitter (non-ferrous plant "Bedzin") 556.3 mg/kg d.m. Zn, 6.2 mg/kg d.m. Pb, 0.35 mg/kg d.m. Cd or in the places which are near the roads – Zamkowa hill park in Bedzin 371 mg/kg d.m. Zn, 7.6 mg/kg Pb, 0.8 mg/kg Cd and in Czeladz Wojkowicka street (332.9 Zn, 13.21 mg kg d.m. Pb, 0.43 mg/kg d.m. Cd, Nowo-pogonska street 178.7 mg/kg d.m Zn, 9.7 Pb, 0.35 mg/kg d.m. Cd). Elevated concentration of Zn (506.75 park Grabek in Czeladz and 435.2 mg kg d.m. former coal mine "Grodziec" in Bedzin) was observed in the vicinity of former coalmines. Reiman et al investigated Cd, Zn and Ni in the leaves of birch (the contents were 0.13, 88.9, 109 respectively). Baycu et al in leaves of the investigated trees in Istambul noted Cd concentration between 0–1.33, Zn concentration 17.47–592.6 and Pb 3.99–34.4 mg/kg d.m. [23]. Lukasik et al [6] observed that Pb concentrations ranged as 13 in Sycamore Maple (*Acer pseudoplatanus* L.) to 53 mg/kg d.m. in Black Locust (*Robinia pseudoacacia* L.), Zn concentration ranged from 141 to 275 mg/kg d.m. and Cd concentrations were below 1 mg/kg d.m. in the tree leaves in Piekary Slaskie. Zn contents in birch (*B. pendula* Roth.) leaves in this study were on a comparable level to the results for this plant leaves in the vicinity of steelwork HK "Huta Katowice" [5, 7].

Heavy metals may be accumulated by plants from the air and soil. Our study confirmed the statement that leaf tissues may reflect the input of elements near emission sources because plants interact with their local environment [23]. As reported by Ross,

aerial sources of metals can contribute > 90 % of Pb, > 80 % Zn present in the leaves of various plants [24]. A positive (not statistically significant) correlation between Zn, Cd and Pb content in soil and in leaves was found in Bedzin and Czeladz.

Conclusions

Biological responses (eg heavy metal bioaccumulation) allow for estimating the level of pollutants and their impact on biological receptors. It was shown that Pb in the plants and soil samples tends to increase as traffic density increases (eg Zamkowa hill park, Sw. Dorota hill; Wojkowicka, Nowopogonska streets). It was suggested that the concentrations of the investigated metals in plants and soils in the industrial regions depend on the traffic and on the pollutants coming from neighbouring industrial sources (eg non-ferrous plant ”Bedzin”, power station “Lagisza”, former mine, cement plant “Grodziec”).

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BIONDYKACJA ZANIECZYSZCZENIA METALAMI CIĘŻKIMI BĘDZINA I CZELADZI

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Abstrakt: Jako jedną z metod identyfikacji zanieczyszczonych powierzchni podaje się analizę koncentracji metali ciężkich w liściach roślin. Oznaczano zawartość metali ciężkich Zn, Pb i Cd w liściach brzozy brodawkowatej *Betula pendula* Roth. pospolitego gatunku występującego w parkach i terenach poprzemysłowych w Polsce. Próbki gleby i liści brzozy pobierano we wrześniu 2007 r. z mniej i bardziej zanieczyszczonych miejsc miasta Czeladzi i Bedzina (województwo śląskie, Polska południowa, 8 stanowisk dla każdego miasta). Mierzono zawartość Zn, Pb, Cd w liściach oraz wierzchniej warstwie gleby (0–10 cm). Stwierdzono podobne zanieczyszczenie Zn, Pb i Cd dla badanych miast. Zawartość Cd i Pb w liściach brzozy była poniżej zakresu stężeń uznawanego za toksyczny dla roślin. Tylko koncentracje Zn na kilku stanowiskach były większe od uznawanych za toksyczne. Dla większości stanowisk badawczych Bedzina stwierdzona w glebie zawartość Pb i Cd była powyżej stężeń uznanych za dopuszczalne.

Słowa kluczowe: metale ciężkie, *Betula pendula,* zanieczyszczenie