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CADMIUM AND LEAD ACCUMULATION PATTERNS IN ORGANS OF CHOSEN URBAN TREE SPECIES

AKUMULACJA KADMU I OŁOWIU W ORGANACH WYBRANYCH GATUNKÓW DRZEW MIEJSKICH

Abstract: The concentration of Cd and Pb in leaves/needles, twigs, seeds and fruit coverings of: horse-chestnut (*Aesculus hippocastanum* L.), yew-tree (*Taxus baccata* L.), European ash (*Fraxinus excelsior* L.), and in the soil at the base of the same trees was investigated. The ability of metal accumulation was determined in all investigated tree species as well as different partitioning in examined plant tissues. The lowest Pb concentration was found in fruit parts of all tree species: in seeds or fruit covering. The lowest Cd concentration in unpolluted regions was determined in leaves/needles or twigs.

The highest Cd and Pb concentration in investigated tissues depends on the species and the pollution level of the place where plants were growing. The obtained results could be used to determine the most suitable organs for Pb and Cd biomonitoring in the environment.

Keywords: heavy metals, *Aesculus hippocastanum*, *Taxus baccata*, *Fraxinus excelsior*

Still developing industrialization and urbanization, despite the increasing concern about the environment, causes many toxic emissions including heavy metals. The main source of the pollution are domestic heating systems, industry and traffic [1]. Among the non-essential heavy metals for living organisms, the most spread ones are lead and cadmium. These elements also have a highly toxic effect on living organisms, which can lead to intoxications, pathological changes and even increased mortality among people exposed to cadmium [2, 3]. Therefore, constant monitoring of Cd and Pb concentration in the environment is essential.

The use of plant tissues as heavy metal bioindicators is commonly known. As good Pb and Cd bioindicators were found: leaves of European ash (*Fraxinus excelsior* L.) [4], Norway maple (*Acer platanoides* L.) [5], white birch (*Betula pendula* Roth.), crack willow (*Salix fragilis* L.), broad-leaved linden (*Tilia platyphyllos* Scop.) [6], wood of water oak (*Quercus nigra* L.) and black oak (*Q. velutina* Lam.) [7].

In this project three common tree species were chosen: common yew (*Taxus baccata* L.), European ash (*Fraxinus excelsior* L.) and horse-chestnut (*Aesculus hippocastanum* L.)

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and the concentration of Cd and Pb in their leaves/needles, twigs, seeds and fruit coverings was investigated.

The aim of this paper was to determine the ability of the examined tree species to accumulate Cd and Pb, determine the accumulation pattern in the investigated organs and find the organs most suitable for Cd and Pb bioindication.

Material and methods

Leaves/needles, fruits, twigs and the upper 10 cm of soil at the base of the sampled trees were collected in early autumn 2004 and 2006. The sampling was carried out in heavily polluted cities of Upper Silesia Industrial District – southern Poland (Chorzow, Katowice, Myslowice, Siemianowice Slaskie, Sosnowiec, Gliwice). Sampling places located in the Beskid Slaski (south of Upper Silesia), which is comparatively unpolluted (Kety, Porabka, Slemien, Cieszyn, Ustron, Cisownica, Skoczow, Brenna), were chosen as control sites. In this part of Poland the dominant wind direction is south-west and the mean annual precipitation is 650–800 mm for the Upper Silesia Industrial District and 800–1000 mm for the Beskid Slaski [8].

The material was sampled in at least 5 replicates at each location. The soil was stored in linen bags until air dry. The soil samples were passed through a 1 mm mesh sieve. The 10 g soil samples were shaken with 100 cm^3 10 % HNO_3 for one hour.

The plant material was washed in tap and distilled water. The fruits were divided into seeds and fruit covering. The material was ground and dried at 105 ^oC for 24 h. 3 g samples were dry mineralized in a muffle oven at 460 ^oC and then digested in 25 cm^3 10 % HNO_3 and filtrated. The Cd and Pb concentration was measured using the method AAS. All the analyses were carried out in three replicates.

The accumulation factor was calculated as the element mean concentration ratio between the polluted sites and the control [9].

Results

The Pb and Cd accumulation level in the investigated tree organs reveal differences depending on tree species and the pollution level of the place where the plants were growing. The mean element concentrations in the investigated organs are presented in Table 1.

Cadmium. Cd concentrations in the organs of the examined tree species increased as follows:

	a) polluted sites	b) control sites
Ash tree	fruit covering < seeds < leaves < twigs	twigs < seeds < leaves < fruit covering
Yew-tree	seeds < needles < fruit covering < twigs	needles < seeds < fruit covering < twigs
Horse-chestnut	fruit covering < leaves < twigs < seed	leaves < fruit covering < twigs < seeds

Table 1

Mean metal concentrations in investigated tree organs [mg/kg d.m.]

Tree organ		Ash tree		Yew-tree		Horse-chestnut	
		Polluted site	Control site	Polluted site	Control site	Polluted site	Control site
Cd	seeds	0.98 ± 0.14	0.77 ± 0.22	0.80 ± 0.13	0.71 ± 0.11	2.64 ± 0.22	1.81 ± 0.19
	fruit covering	0.85 ± 0.11	0.95 ± 0.17	0.93 ± 0.22	0.79 ± 0.11	1.47 ± 0.20	1.03 ± 0.10
	leaves	1.02 ± 0.28	0.82 ± 0.20	0.83 ± 0.35	0.70 ± 0.21	1.74 ± 0.26	0.95 ± 0.14
	twigs	1.94 ± 2.31	0.46 ± 0.23	1.73 ± 0.48	0.96 ± 0.20	1.84 ± 0.52	1.15 ± 0.40
Pb	seeds	6.63 ± 3.33	4.98 ± 1.86	3.93 ± 1.29	4.69 ± 0.91	12.12 ± 4.22	2.37 ± 1.91
	fruit covering	10.80 ± 3.35	5.36 ± 4.49	8.35 ± 2.35	4.13 ± 1.99	7.04 ± 12.37	3.10 ± 1.65
	leaves	49.09 ± 73.39	11.40 ± 2.93	66.10 ± 112.85	6.96 ± 1.16	101.54 ± 194.99	7.68 ± 3.32
	twigs	225.73 ± 484.09	7.34 ± 2.00	164.45 ± 292.91	9.30 ± 2.95	63.08 ± 122.32	7.94 ± 2.93

The Cd accumulation factor was the highest for the ash tree twigs, the lowest for the fruit coverings of all examined tree species (Fig. 1).

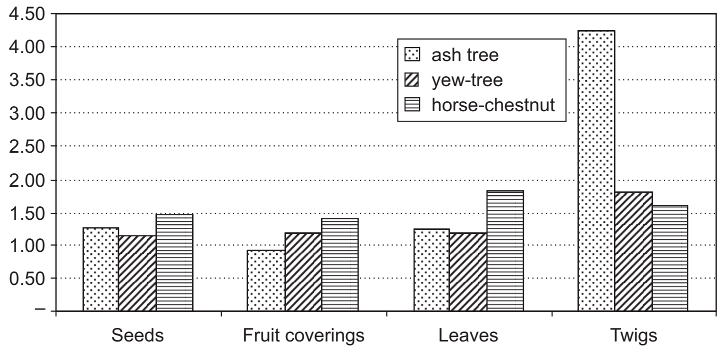

Fig. 1. The Cd accumulation factor for the investigated tree tissues

The Cd concentration among all investigated horse-chestnut organs was positively correlated and significant (Table 2). The correlation coefficient between the Cd level in tissue and in soil was significant except seeds and twigs. A significant correlation between the Cd concentration in yew organs was found between fruit covering and twigs, seeds and twigs, leaves and twigs. The Cd concentration in soil was significantly correlated only with Cd in twigs. The Cd concentration in ash tree was significantly correlated only between leaves and twigs and between soil and fruit covering.

Table 2

The correlation coefficient between the metal concentration in soil and in investigated tree organ and between tree organs

	Ash tree		Yew-tree		Horse-chestnut	
	Cd	Pb	Cd	Pb	Cd	Pb
Fruit covering/seeds	–0.36	0.58***	0.68***	0.38	0.09	–0.13
Fruit covering/leaves	–0.02	0.38	0.94****	0.98****	0.42	–0.70****
Fruit covering/twigs	0.07	0.41	0.53**	0.98****	0.66***	–0.68****
Fruit covering/soil	0.55**	–0.11	0.39	0.97****	0.22	0.07
Seeds/leaves	–0.28	0.50*	0.77****	0.47*	0.60***	0.03
Seed/twigs	–0.24	0.47*	0.62***	0.47*	0.40	0.03
Seeds/soil	0.00	0.24	0.62***	0.49*	0.29	0.42
Leaves/twigs	0.80****	1.00****	0.65***	1.00****	0.49*	1.00****
Leaves/soil	0.07	0.09	0.55**	0.99****	0.05	0.35
Twigs/soil	0.04	0.03	0.26	0.98****	0.65***	0.40

r-correlation significance *p = 0.05; **p = 0.02; ***p = 0,01; ****p = 0.001.

Lead. Pb concentrations in the organs of the examined tree species increased as follows (Table 1):

	a) polluted sites	b) control sites
Ash tree	seeds < fruit covering < leaves < twigs	seeds < fruit covering < twigs < leaves
Yew-tree	seeds < fruit covering < needles < twigs	fruit covering < seeds < needles < twigs
Horse--chestnut	fruit covering < seeds < twigs < leaves	seeds < fruit covering < leaves < twigs

The highest Pb accumulation factor was calculated for ash tree and yew-tree twigs and horse-chestnut leaves, the lowest for the ash tree and yew-tree seeds and for the fruit covering of all investigated species (Fig. 2).

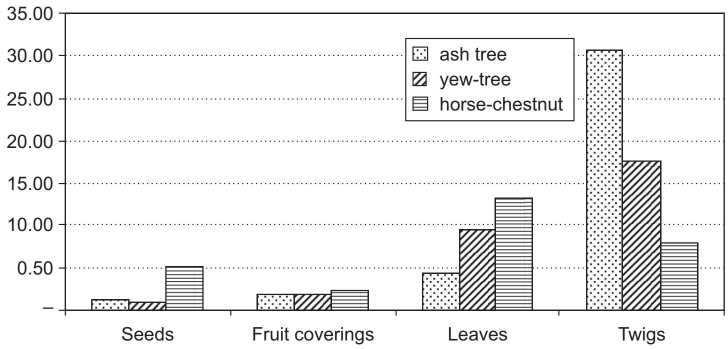

Fig. 2. The Pb accumulation factor for the investigated tree tissues

A strong positive correlation was observed between Pb soil concentration and the level of Pb in the fruit covering, leaves and twigs of yew-tree (Table 2). Insignificant was only the correlation between the Pb concentration in fruit covering and seeds. In ash tree and horse-chestnut the concentration of Pb in leaves and twigs was also strongly correlated. The Pb level in horse-chestnut fruit covering shows a significantly negative correlation between leaves and twigs.

Discussion

The accumulation of Cd and Pb in ash tree twigs was predominant in the whole analyzed plant material. The Cd and Pb concentration in yew-tree twigs was the highest in all analyzed organs of this plant species. Similarly, Rossbach and Jayasekera [10] measured higher Pb concentration in pine twigs than in needles. The highest accumulation factor for the horse-chestnut was calculated for the leaves. Such high metal concentration in twigs may be a result of incorporation of elements in the bark tissues during the perennial deposition [11]. The large surface and the umbrella-like shape of horse-chestnut leaves may protect the twigs against dust deposition in an efficient way and could uptake a majority of dry and wet precipitation. Additionally, the deposition increases with the appearance of necrotic lesions on leaves [12], caused by feeding of horse-chestnut leaf miner (*Cameraria ohidella*) larva.

The analyses revealed different partitioning of Cd and Pb not only in the examined plant species, but also among organs of the plants and it strongly depends on the pollution level of the environment where the trees were growing. The differences were visible usually in pairs such as twigs and leaves as well as fruit coverings and seeds.

It is considered that heavy metal concentration in plant organs increases with the pattern: seeds < inflorescence < stems < leaves, however this order sometimes varies with plant species [13, 14]. Seeds seem to be the organ best protected from heavy metal infiltration [15, 16]. This thesis finds confirmation in the results of Pb concentrations with an exception of the yew-tree samples from the control sites and horse-chestnut samples from the polluted sites. However, the lower values of Pb were observed only in fruit coverings.

The accumulation pattern observed for Cd was different, eg abnormal results were obtained for the horse-chestnut seeds, in which the Cd concentrations were the highest in both locations. The determined concentrations, even at the comparatively unpolluted stands, were repeatedly higher than results obtained by Lukasiewicz [17] in the horse-chestnut seeds from Poznan. The accumulation factor for both investigated metals in horse-chestnut seeds was higher than in yew-tree and ash-tree.

The correlation coefficient was statistically significant for Cd concentrations in soil and seeds, leaves/twigs and seeds ($p < 0.01$). It may suggest the soil origin and relocation of Cd between organs, because of its high mobility in plant organism [18].

The seeds, fruit coverings and leaves of the horse-chestnut showed a higher Cd accumulation factor than in the comparable organs of ash tree and yew-tree. This points to the suitability of horse-chestnut in environmental biomonitoring of this metal. Moreover, the highest Pb accumulation factor for horse-chestnut leaves and seeds shows that using these organs for monitoring the environment contamination with Pb is possible. Suitable for Cd and Pb biomonitoring are also ash tree twigs and as Pb bioindicators – yew-tree twigs. The statistically significant correlation factor of Pb and Cd concentration between leaves/needles and twigs of investigated tree species suggests their atmospheric origin, which confirms their bioindicative usability.

Conclusions

1. On the basis of the differences in Cd and Pb concentrations in tree tissues from the heavily polluted and comparatively unpolluted sites, the ability to accumulate these elements by the investigated tree species has been stated.

2. The Pb accumulation pattern in the examined plant organs does not essentially vary from the usually used patterns: the lowest concentrations were measured in seeds and fruit coverings and the highest in leaves and twigs. The differences are revealed between this pairs depending on the species and the location.

3. The Cd accumulation pattern in the plant organs shows greater divergences depending on the species. Exceptionally high was the Cd concentration in horse--chestnut seeds in relation to other investigated tree organs.

4. Ash tree twigs, horse-chestnut seeds, fruit covering and leaves could be suitable in the biomonitoring of Cd contamination of the environment and ash tree and yew-tree twigs, horse-chestnut leaves and seeds – in Pb biomonitorng.

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AKUMULACJA METALI CIĘŻKICH W ORGANACH WYBRANYCH GATUNKÓW DRZEW MIEJSKICH

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Abstrakt: Oznaczono stężenie Cd i Pb w liściach, pędach, nasionach oraz części płonej owocu trzech gatunków drzew popularnie nasadzanych w miastach: kasztanowcu zwyczajnym (*Aesculus hippocastanum* L.), cisie pospolitym (*Taxus baccata* L.) i jesionie wyniosłym (*Fraxinus excelsior* L.) oraz w materiale glebowym zebranym pod wybranymi osobnikami. Stwierdzono zdolność do akumulacji metali przez badane gatunki oraz zróżnicowane stężenie metali w poszczególnych organach. Najniższe stężenie Pb oznaczono u wszystkich trzech badanych gatunków w częściach owocu – nasionach lub części płonej, w przypadku Cd dla drzew z rejonów stosunkowo słabo zanieczyszczonych niższe zawartości kadmu notowano w liściach/szpilkach lub pędach.

Organy o najwyższym stopniu koncentracji Cd i Pb w tkankach różnią się w zależności od gatunku drzewa, badanego metalu oraz stopnia zanieczyszczenia środowiska, z którego pobierano próbki. Uzyskane dane mogą posłużyć do wytypowania organów przydatnych w biomonitoringu kadmu i ołowiu w środowisku.

Słowa kluczowe: metale ciężkie, *Aesculus hippocastanum*, *Taxus baccata*, *Fraxinus excelsior*