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The content of selected heavy metals in the willow and in the soil from the Hel Peninsula

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Abstract: *The content of selected heavy metals in the willow and in the soil from the Hel Peninsula.* The content of copper, zinc, lead and cadmium were determined in rods of a one year old *Salix acutifolia* which grew on the Hel Peninsula near the towns of Władysławowo, Kuznica and Hel. Sampling sites were chosen both from the side of the sea and from the side of the bay. It was found that the content of heavy metals in wood and bark differ depending on the growth site of the willows.

Keywords: heavy metals, Hel Peninsula, willow *Salix acutifolia*

INTRODUCTION

Changes in the environment resulting from human activity can take diverse forms starting from slight changes in small ecosystems, to total destruction of the flora and fauna of the area. Since many years effective ways of preventing the destructive impact on the environment have been searched. The plants are one of the main factors influencing the maintenance of the ecological balance in the natural environment. One of the key environmental issues is the protection of waters and watercourses. Thanks to the wide possibilities of adaptation to environmental conditions the willow has found wide appliance, for example, in strengthening the banks of water reservoirs, creating buffer zones by sewage treatment plants and landfills as well as for the regeneration of sewege from sewage treatment plants and reclamation of degraded lands (Waliszewska, Podobiński, Bobkiewicz 1999; Waliszewska 2002; Waliszewska and Prądzyński 2002; Vandecasteele et al. 2005). One of the major ecological problems is the contamination of soils with heavy metals. They pose a risk to aquatic and terrestrial ecosystems as well as to human health. One of the methods of soil reclamation is planting plants which through an efficient transport system of heavy metals from the root zone, carry them to the aboveground parts. Such plants are called hyperaccumulators (Evangelou et al. 2007).

Exposed to water and wind erosion areas of the coastline require special protection. In case of land management and protection against erosion, willow is credited with the highest expectations, due to its increased degree of tolerance to poor habitat conditions as well as to air and soil pollution. Willow which is responsible for stabilization functions is the plant with highest resistance to root exposure caused by erosion (Jeż 1995). Additionally, it demonstrates extraordinary phytoremediation abilities. Obarska-Pempkowiak et al. (2010) showed that the willow can act as a filter to eliminate cadmium from reclaimed land irrigated with sewage sludge.

One of the unique nature's creations in terms of nature and geography is the Hel Peninsula. The narrow strip of land is exposed to continuous and intense abrasion. Additional threats posed to the Peninsula are water pollution and high anthropogenic pressure associated with recreation and tourism. From the side of the sea and the bay, the Peninsula is mostly covered with a strip of sand dunes, which are an extremely poor habitat for plants. One of the ways of protecting the coast is by planting willow trees on the sand dunes. Being an expansive

species, the *Salix acutifolia* Wild. is commonly used for planting thanks to its ease in adapting to extreme habitat conditions of the Hel Peninsula.

The aim of the study was to examine the contents of selected heavy metals in the wood and bark of one year old *Salix acutifolia* rods from the Hel Peninsula as well as in the soil where the willow grew.

MATERIAL AND METHODS

The content of heavy metals was determined by atomic absorption method with the use of a Spectr AA - 20 device from Varian.

Samples consisted of one year old *Salix acutifolia* rods collected from towns located in the beginning (Władysławowo), the middle (Kuźnica) and the end of the peninsula (Hel). Wood and bark were analysed separately. Rods, after a full growing season, were taken from both sides of the peninsula - from the side of the sea and from the side of the bay. Samples were collected from ten randomly selected willow stumps. The rods were deprived of small offshoots. Next, they were seasoned, cut and grounded with a Fritsch Pulverisette 15 laboratory knife mill.

Soil samples were taken from three depth levels: 0 cm, 30 cm and 100 cm from the surface in the willow samples collection sites.

The mineralization of plant material was carried out in dry conditions according to PN-91/ R-04014. Determination of selected elements in the soil was made according to the methodology presented by Ostrowska et al. (1991) by using nitric acid and perchloric acid.

RESULTS

The natural content of heavy metals in the wood is said to be low and depends on several factors, for example, the cleanliness of the environment in which it grows. The toxicity of elements depends not only on their concentration in the environment, but primarily on the biochemical role which they play in metabolic processes. The concentration of heavy metals in wood depends also on their content in the soil of the habitat (Kozłowska 2008, Krzesłowska 2004, Szpakowska et al. 2010, Michelinia et al. 2014).

Table 1. Content of selected heavy metals in willow samples from the side of the Baltic Sea

Analyzed element	Sample collection site					
	Władysławowo		Kuźnica		Hel	
	wood	bark	wood	bark	wood	bark
	[ppm]					
Cu	9.56	32.03	14.73	50.27	10.29	29.65
Pb	6.71	60.39	4.55	46.42	5.90	54.52
Cd	0.14	0.31	0.09	0.84	0.22	0.62
Zn	77.32	86.25	76.92	85.68	79.68	84.97

Based on the study, in all cases, a higher content of heavy metals was observed in the rods growing from the side of the sea than in those growing from the side of the bay (Table 1 and 2).

The highest copper content was observed in one year old *Salix acutifolia* rods from Kuźnica. The amount was 14.73 ppm for wood and 50.27 ppm for bark from the side of the sea and 12.80 ppm for wood and 40.84 ppm for bark from the side of the bay. The content of copper in the bark of the willow rods was three times higher than in the wood of the willow

rods. The rods from the town of Hel from the side of the bay had the lowest content of copper out of all tested samples - 7.68 ppm for wood and 28.64 ppm for bark (Table 2).

Table 2. Content of selected heavy metals in willow samples from the side of the Puck Bay

Analyzed element	Sample collection site					
	Władysławowo		Kuźnica		Hel	
	wood	bark	wood	bark	wood	bark
	[ppm]					
Cu	8.66	30.42	12.80	40.84	7.68	28.64
Pb	5.67	53.41	3.96	38.72	5.02	46.88
Cd	0.09	0.25	0.09	0.82	0.16	0.62
Zn	31.68	52.31	62.05	73.43	76.95	84.89

The content of lead in the analyzed willows is shown in Table 1 and 2. The rods taken from the beginning of the peninsula from Władysławowo showed the highest lead content for both sides, from the sea and from the bay. Lead content values for wood ranged from 5.67 ppm to 6.71 ppm and for bark from 53.41ppm to 60.39 ppm. The lowest content of this element was observed in willow rods from Kuźnica from the side of the bay. After one growing season in this location the *Salix acutifolia* wood contained 3.96 ppm and *Salix acutifolia* bark 38.72 ppm (Table 2).

According to Kabata - Pendias and Pendias (1999) cadmium content in aerial parts of the plant is 0.05 - 0.2 ppm. In case of the bark of the willow rods, the upper limit was exceeded in all analyzed samples. The amount of this toxic element ranged from 0.31 ppm in the bark of rods taken from the side of the sea from Władysławowo to 0.84 ppm in the bark of the rods from Kuźnica. Bark from rods taken from the side of the Puck Bay contained from 0.25 ppm in the case of rods from Władysławowo to 0.82 ppm in the case of rods from Kuźnica (Table 2). When analyzing the cadmium content it can be observed that higher amount of this element was found in the bark of one year old *Salix acutifolia* rods growing from the sea side than from the bay side (Table. 1). The greatest accumulation of this toxic element in the wood of the rods was found in *Salix acutifolia* from Kuźnica, growing both from the side of the sea and from the side of the bay. Wood from rods taken from both the sea and the bay side contained 0.09 ppm of cadmium (Table 1 and 2).

Salix acutifolia rods from the Hel Peninsula growing in Władysławowo from the side of the bay had the lowest amount of zinc content in both the wood - 31.68 ppm and in the bark - 52, 31 ppm. *Salix acutifolia* rods from the Hel Peninsula growing from the side of the Baltic Sea, at the beginning, the middle, and the end of the peninsula, showed higher zinc content than the analyzed rods growing from the side of the bay. Zinc content in wood of one-year willow rods growing from the side of the sea accounted for 77.32 ppm in Władysławowo, 76.92 ppm in Kuźnica and 79.68 ppm in Hel, while in those growing from the side of the bay the zinc content was 31.68 ppm, 62.05 ppm and 76.95 ppm (Table 1 and 2). Elevated levels of zinc were found in the annual *Salix acutifolia* rods growing in Hel from both sides of the peninsula. For wood, this content was 79.68 and 76.95 ppm from the side of the bay, and for bark 84.97 ppm from the side of the sea and 84.89 ppm from the side of the bay, respectively.

To summarize the contents of heavy metals (Σ Pb, Cu, Cd) in the willow rods from the Hel Peninsula, it was found that the one year old *Salix acutifolia* rods from Kuźnica had an increased content of toxic elements reaching a total of 19.37 ppm, and had the highest amount of these elements in wood.

Tab. 3 Content of selected heavy metals in the soil

Metal	Sampling depth [cm]	Heavy metal content [ppm]					
		Wladyslawowo		Kuznica		Hel	
		sea	bay	sea	bay	sea	bay
Cu	0	3.49	1.47	1.57	1.43	1.60	1.11
	30	2.21	1.06	1.96	1.53	1.36	1.04
	100	1.91	1.05	1.25	1.16	1.14	0.95
Pb	0	4.52	4.21	5.66	5.33	5.61	4.47
	30	5.03	4.10	5.68	5.03	5.48	4.50
	100	5.15	4.49	5.84	5.28	4.89	4.53
Cd	0	0.12	0.04	0.13	0.24	0.52	0.48
	30	0.13	0.02	0.13	0.22	0.60	0.59
	100	0.10	0.01	0.18	0.21	0.63	0.66
Zn	0	4.53	3.54	4.04	3.07	1.30	1.09
	30	3.55	1.36	2.16	1.31	1.61	1.17
	100	4.49	2.26	3.30	3.09	1.44	1.37

Based on the conducted research, the content of heavy metals in the soil, in all cases, was higher in the soil taken from the side of the sea compared to that taken from the side of the bay (Table 3).

According to Kabata-Pendias and Pendias (1999), the copper content in the soil ranges from 1ppm - 140 ppm. The highest amount of this element at all studied depth levels was found in soil samples from Władysławowo from the side of the sea. For the depth level 0 cm, the copper content was 3.49 ppm, for 30 cm - 2.21 ppm, whereas for the depth of 100 cm - 1.91 ppm. The lowest copper content, however, was observed in the soil from the town Hel taken from the side of the bay. The content of this element amounted to 1.11 ppm, 1.04 ppm and 0.95 ppm in the depth level of 100 cm.

In data published by Kabata- Pendias and Pendias (1999), the average natural content of lead in national soils is 18 ppm. None of the analyzed soil samples exceeded or came close to this level. The lowest lead content was found in the soil from Władysławowo from the side of the bay and ranged from 4.10 ppm to 4.49 ppm depending on the sampling depth. The content of this element in the soil from Kuźnica and Hel was at a very similar level ranging from 4.47 ppm to 5.84 ppm regardless of the depth of sampling and the side of the peninsula.

In the case of soil from the town Hel the acceptable range for cadmium content was exceeded in samples from both sides of the peninsula. Kabata-Pendias and Pendias (1999) reported the amount of 0.2 ppm as a limit value. Cadmium content in the soil from this sampling site ranged from 0.48 ppm to 0.66 ppm. The lowest cadmium content in all three sampling depths was observed in the soil taken from Władysławowo from the side of the bay ranging from 0.01 ppm to 0.04 ppm.

According to Alloway (1999), the average zinc content of the national soils is 33 ppm. In the studied soil samples from the Hel Peninsula it was found that irrespectively of the location, the zinc content was similar and far from the average content of this element in the Polish soils. The lowest content was found in the soil from the end of the peninsula from the town Hel, both from the side of the bay and from the side of the sea. The highest content of this element was observed in soil samples from Władysławowo in which at 0 cm, 30 cm and 100 cm depth levels the element content was 4.53 ppm, 3.55 ppm and 4.49 ppm, respectively.

CONCLUSIONS

1. A higher content of heavy metals was observed in rods growing from the side of the sea than from the side of the bay.
2. Soil from the side of the sea contained a higher amount of the analyzed heavy metals than soil from the side of the bay.
3. Despite the low zinc content in the soil a much higher amount of this element was found in the wood and bark of the willow rods, regardless of the side of the peninsula and the growth site.

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Streszczenie: *Zawartość wybranych metali ciężkich w wierzbach i glebie z Półwyspu Helskiego.* Jednym z głównych problemów ekologicznych jest zanieczyszczenie gleb metalami ciężkimi, które mogą wpływać toksycznie na rośliny oraz powodować zmiany w łańcuchu troficznym. Unikatowy twór przyrody, jakim jest Półwysep Helski, jest obszarem chronionym pod względem przyrodniczym i geograficznym. Głównym zagrożeniem Półwyspu są zanieczyszczenia wód oraz duża presja turystyczna i rekreacyjna. Chroniąc brzegi półwyspu przed erozją, nasadza się rośliny, które zatrzymują przemieszczanie się wydm. Wierzba *Salix acutifolia* Wild. pełni funkcje stabilizacyjne i ekologiczne. Celem pracy było zbadanie zawartość miedzi, cynku, ołowiu i kadmu w jednorocznych prętach (w korze i w drewnie) wierzby *S. acutifolia* rosnącej na Półwyspie Helskim w pobliżu miejscowości Władysławowo, Kuźnica i Hel. Oznaczono również zawartość tych pierwiastków w glebie. Wytypowano miejsca pobrania materiału od strony morza i od strony zatoki. Stwierdzono zróżnicowanie w zawartości metali ciężkich w drewnie i korze w zależności od miejsca wzrastania wierzb. Kora zawierała kilkakrotnie więcej metali ciężkich, niż drewno prętów wierzbowych rosnących zarówno od strony morza, jak i od strony zatoki.

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