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Cumulation of Cu, Zn, Cd, and Mn in Plants of Gardno Lake

J. Trojanowski, C. Trojanowska and J. Antonowicz

Department of Environmental Chemistry, Pomeranian University in Słupsk, Arciszewskiego 22, 76-200 Słupsk, Poland, e-mail: trojsnowski@apsl.edu.pl

Abstract. In the present paper there have been shown the results of research on yhe content of Zn, Cd, Cu, Mn and Pb in chosen plants of Lake Gardno.The biggest concentration of those metals has been observed in *Potamogton natans* and *Elodea canadensis*, on average Zn – 34.9, Pb -2.77, Cd – 0.62, Cu – 3.24 and Mn – 257.4 µg g^{-1}. It has been found that the over-ground parts of the plants under analysis cumulate several times less of heavy metals than their roots. The determined enrichment factors enabled the researchers to state that Cu in the examined plants is of natural origin while Mn, Cd and Zn – of anthropogenic origin.

Key words: Heavy metals, aquatic plants, phytosorption

Introduction

Aquatic and rush vegetation constitutes an essential component of inland aquatic ecosystems. It is considered to be a significant biotope-forming factor [6] and, at the same time, a specific ecotone land/open water level [9, 16]. Concentrations of heavy metals in plants are frequently higher than in the water surrounding them. Andrzejewski [2] proved that the concentration of zinc in phytoplankton and zooplankton is 30 times higher than in water. Higher plants take a very important part in migration of those metals and they cumulate them in their tissues unevenly [5, 8]. A lot of heavy metals shows a high correlation between their content in the environment, including the aquatic environment, and the concentration in aquatic macrophytes [1, 4].

The purpose of this work was :

– to define participation and abilities of chosen aquatic plants in Lake Gardno to cumulate zinc, copper, lead, cadmium and manganese and to assess the correlation among metals in this process;

– to define to what degree sea water flows into the lake influence the content of heavy metals in plants.

Lake Gardno (54o79' N, 17o07' E) is a large (24.7 km2) and shallow (average depth 1.3 m) estuarine lake locatewd close to yhe Baltic Sea in middle part of the Polish coast (Fig.). The level of the water does not change considerably throughout the year; mean yearly amplitude of 0.32 m constitutesonly a quarter of the average depth.The waters of the lake exchange nine times throughout the year. The area of the direct drainage area of Lake Gardno equals, excluding the lake itself, 893 km2 and is 36 times greater than the surface area of the lake.

Material and Methods

Considering content differentiation of heavy metals due to the stage of plants development, the authors limited themselves only to taking samples in the summer vegetation period of 2009 and 2010. The plants under examination were taken from two characteristic places in the lake. Station 1 was situated near the place where the Łupawa River flows into the lake in its eastern part, station 2 – near the outflow of this river in the north-eastern part of the lake (Fig.).

Nine plant species characteristic for this lake were included in the research, namely : *Sparganium ramosum hudds, Elodea canadensis, Typha latifolia, Phragmites australlis, Potamogeton natans, Myriophyllum spicatum, Veronica anagallis, Acorus calamus, Nuphar lutea*. In the case of *Typha lafiolia, Acorus calamus, Phragmites australis, Veronica anagallis* and *Sparganium ramosum hudds* the over-ground portion and root part were examined separately, in the remaining plants no such distinction was made. Their appearance was defined as an average percentage of the total biomass of all plants in reference to the covered area. The range of appearance of particular macrophytes and their biomass were defined with the use of Traczyk's method [14]. After being collected, plant samples were washed with distilled water to remove bottoms and suspended solids, then dried in the temperature of 100^{o}C to get solid matter. The dried plant

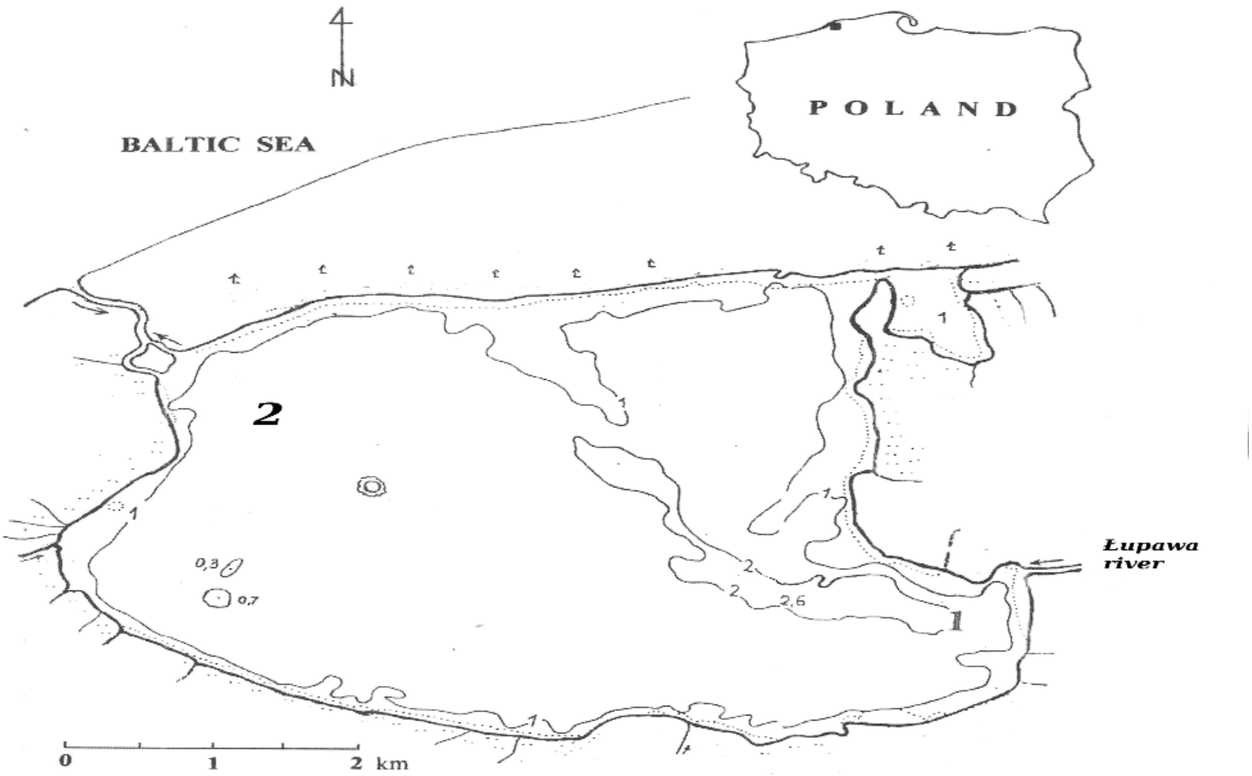

Fig. 1. Study Area. Location sampling stations in Lake Gardno.

material was mineralized with the use of mixture of HNO_3 and $HClO_4$. The content of heavy metals in the plant matter was defined with the use of a spectrophotometer of atomic absorption AAS.

Phytosorption was estimated as the content of a particular metal in the plant in the form of biomass expressed in mg m^{-2} [15]. The results were subject to statistic analysis according to test-t.

On the basis of knowledge of trace elements concentration in the plants under analysis, enrichment factors with those metals were calculated for them in order to define their origin in the ecosystem [13]. The enrichment factor is defined as a ratio of a particular metal concentration (me) in the organism under analysis $(C_{me})_S$ to its concentration in the lithosphere $(C_{me})_{EC}$ [13] :

$$EF = \frac{(C_{me}/C_{Fe})_S}{(C_{me}/C_{Fe})_{EC}},$$

where : C_{Fe} stands for the concentration of iron.

Results and Discussion

The content of zinc, lead, copper, manganese and cadmium in chosen plants of Lake Gardno (Tab. 1) is comparable with the average values observed for eutrophic lakes [3, 7, 10, 11, 12]. In those plants copper is of natural origin while zinc, manganese and cadmium are of anthropogenic origin (Tab. 4). However, the origin of lead depends on the place of plant appearance and its species. Unequal space concentration of metals in the examined plants indicates the source of water pollution with these metals in Lake Gardno. The plants under examination collected at the station 1 (at the outlet of the River Łupawa into the lake) were characterized by several times higher content of heavy metals under analysis, both in the over-ground part and in the roots, than the analogical plants collected at the station 2 (at the outlet of the River Łupawa from the lake) (tab. 2). It indicates a higher concentration of those metals in the region of the River Łupawa outlet into the lake than in the place of its outlet from the lake.

It has been found that in particular parts of the plants under examination the degree of metal accumulation is different. The over-ground parts of *Phragmites australis*, *Sparganium ramosum hudds, Acorus calamus, Veronica anagallis* and *Typha latifolia* were characterized by a much smaller content of the analyzed metals in comparison with the root part (Tab. 2). The over-ground part of *Phragmites australis* and *Acorus calamus* proved to be the part of the lowest concentrations of heavy metals with the narrowest range of their appearance. Particularly big differences between those two parts have been observed in the case of lead and cadmium in the plants from the region of the Łupawa outlet into Lake Gardno. The roots of *Typha latifolia* accumulate four times as much of lead as its over-ground portion whereas the roots of *Phragmites australis* – ten times more.

From among analyzed macrophytes *Elodea*

Table 1. Average content of heavy metals, in µg g^{-1} of dry mass, in the chosen plants of Lake Gardno in the years 2009 - 2010.

Species	Station	Cu	Zn	Pb	Cd	Mn
Patomogeton natanas	1	3.98	34.67	3.17	0.67	249.8
	2	3.48	31.20	2.54	0.50	238.0
Elodea canadensis	1	3.09	40.67	3.04	0.88	322.0
	2	2.45	33.07	2.34	0.43	219.7
Nuphar lutea	1	2.15	22.35	2.03	0.43	169.7
	2	1.22	13.98	1.65	0.25	173.9
Myriophyllum spicatun	1	1.78	18.54	1.94	0.32	276.1
	2	1.12	11.89	1.58	0.14	187.4
Sparganium ramosum hudds	1	2.09	21.32	2.83	0.31	143.7
(over-ground part)	2	1.32	13.87	1.13	0.21	159.0
Sparganium ramosum hudds	1	8.75	44.38	19.40	0.76	421.8
(root part)	2	2.09	28.60	4.79	0.27	198.5
Phragmites australis	1	1.13	17.07	1.14	0.12	159.8
(over-ground part)	2	0.65	10.76	0.62	0.07	95.3
Phragmites australis	1	3.21	48.25	11.65	0.68	465.7
(root part)	2	1.54	14.83	1.49	0.18	176.9
Acorus calamus	1	1.35	13.92	1.39	0.20	108.7
(over-ground part)	2	0.78	9.52	0.80	0.06	99.4
Acorus calamus	1	4.46	35.69	5.48	0.59	276.4
(root part)	2	1.93	15.40	2.77	0.20	181.5
Veronica anagallis	1	1.47	20.12	2.12	0.31	147.5
(over-ground part)	2	0.92	11.37	0.99	0.08	111.7
Veronica anagallis	1	5.38	37.87	14.51	1.87	498.6
(root part)	2	2.35	17.89	4.46	0.31	231.8
Typha latifolia	1	1.83	21.97	2.01	0.23	195.6
(over-ground part)	2	0.91	9.32	1.06	0.06	102.4
Typha latifolia	1	4.76	27.31	8.90	0.80	584.5
(root part)	2	2.29	16.74	3.74	0.20	247.0

canadensis and *Potamogeton natans* appeared to be the plants that cumulate the biggest amounts of metals under analysis. They were also characterized by the biggest abilities to cumulate heavy metals, therefore they can be used to assess the degree of aquatic environment contamination with heavy metals. Taking into consideration the area (Tab. 1) that the plants under analysis cover, their biomass and level of heavy metals phytosorption (Tab. 3), they play a vital role in drawing those metals from the ecosystem of Lake Gardno.

The content of analyzed metals in over-ground parts of the plants under examination appeared in the following sequence : Mn > Zn > Pb = Cu > Cd, and in the roots a little differently : Mn > Zn > Pb > Cu > Cd. From among those metals the biggest ability to cumulate in the examined plants showed manganese, zinc and cadmium (Table 4).

Conclusions

- From among analyzed macrophytes *Elodea canadensis* and *Potamogeton natans* appeared to be the plants that cumulate the biggest amounts of metals under analysis. They were also characterized by the biggest abilities to cumulate heavy metals, therefore they can be used to assess the degree of aquatic environment contamination with heavy metals.
- The over-ground part of study plants cumulated less heavy metals than root part.
- *Phragmites australis* showed highest the level of study metals phytosorption in Lake Gardno.
- In those plants copper is of natural origin while zinc, manganese and cadmium are of anthropogenic origin.

Table 2. Coefficients of heavy metals concentration in over- ground and root parts of the analyzed water plants in Lake Gardno (I- *Potamogeton natans, Elodea canadensis* II - *Nuphar lutea, Myriophyllum spicatun, Sparganium ramosum hudds*; III - *Phragmites australis*, *Acorus calamus, Veronica anagallis, Typha latifolia*).

Metals	Stations	Over-ground part*			Root**
		I	II	III	
Cu	1	2.14	0.40	0.29	0.52
	2	1.15	0.48	0.32	0.32
Zn	1	1.89	1.04	0.92	0.92
	2	3.58	1.48	1.14	0.71
Pb	1	0.28	0.21	0.15	0.37
	2	0.23	0.14	0.08	0.21
Cd	1	2.40	1.09	0.66	0.67
	2	3.07	1.33	0.47	0.37
Mn	1	2.68	1.84	1.43	1.27
	2	3.72	2.82	1.66	2.45

K = content of metal in the over-ground part * or in roots**/concentration of metal in water * (μg dm^{-3}) or bottoms**(μg g^{-1})

Table 3. Average phytosorption, in mg m^{-2}, of Cu, Zn, Pb, Cd and Mn in dominating plants of Lake Gardno in the years 2009 – 2010.

Plants	Dry plants biomass	Cu	Zn	Pb	Cd	Mn
	(g m^{-2})	(mg m^{-2})				
Patomogeton natanas	225.4	0.835	7.422	0.642	0.131	54.97
Elodea Canadensis	198.2	0.549	7.308	0.533	0.129	23.67
Nuphar lutea	123.4	0.208	2.240	0.227	0.043	21.20
Myriophyllum spicatun	344.2	0.499	5.239	0.606	0.079	79.70
Sparganium ramosum hudds	41.5	0.148	1.124	0.292	0.047	9.57
Phragmites australis	581.8	0.948	13.224	2.164	0.151	130.53
Acorus calamus	148.1	0.315	2.759	0.386	0.038	24.66
Veronica anagallis	72.2	0.183	1.575	0.398	0.046	17.86
Typha latifolia	170.1	0.415	3.203	0.668	0.054	48.04

Table 4. Enrichment factors in the chosen plants of Lake Gardno with heavy metals (**I**- *Potamogeton natans, Elodea canadensis;* **II** - *Nuphar lutea, Myriophyllum spicatun, Sparganium ramosum hudds;* **III** - *Phragmites australis., Acorus calamus, Veronica anagallis, Typha latifolia).*

Metals	Stations	Plants		
		I	II	III
Cu	1	2.73	1.79	1.25
	2	2.28	1.01	0.70
Zn	1	145.6	86.8	74.2
	2	124.7	55.5	44.4
Pb	1	9.8	8.5	5.3
	2	8.4	4.2	2.7
Cd	1	239.6	117.7	72.9
	2	142.7	67.2	23.9
Mn	1	52.3	38.9	31.2
	2	41.9	34.3	20.9

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