



DETERMINATION OF THE ACCUMULATION OF HEAVY METALS OF RIVER SEDIMENT BY PLANTS

Éva KOVÁCS-BOKOR¹, Endre DOMOKOS², Endre KISS³

^{1,3} University of Dunaújváros

² University of Pannonia

Abstract

*Danube is the main river of Hungary. Danube and its floodplains and oxbow lakes are operating as ecological corridors, although their industrial, logistic and touristic role is not negligible. It is well known, that from the source to the estuary of the river Danube there are many industrial facilities. This heavy industrial pollution had effected on the water quality. The most dangerous components of the sewage water of these facilities are heavy metals, which can be found in the water as well as in the sediment. These toxic elements can cause significant health risks, because they can accumulate in the food-chain. The main aim of our research is to investigate the accumulation rate of the heavy metal content of the river sediment in the different parts of the test plants. The main sampling place of our research was a sediment dump was created by excavation from the Open Beach of Dunaújváros in 2009. During our measurements we analysed the cadmium, nickel, lead, chromium, copper and zinc concentration of the sediment and the plants. The test plants, which are growing on this sampling place, were parella (*Rumex patientia*), perennial rye-grass (*Lolium perenne*), sedge (*Carex riparia*), bistort (*Persicaria maculosa*). The extraction of the heavy metal content of the samples was made according to the MSZ Hungarian standard. The concentration of heavy metals were analysed with AAS (atom absorption spectrometer). According to our results we determined that parella could accumulate cadmium, nickel, chromium and zinc in its upper stem, on the other hand bistort could accumulate these elements mainly in its leaves. This information will be important in the case of the in-situ remediation of a polluted area in the future.*

Keywords: heavy metals, sediment, phytoaccumulation, remediation

1. INTRODUCTION

It is well known that the industrial and communal pollution along banks of the river Danube has affected on the water quality of the Hungarian surface and groundwaters. The conservation or the rehabilitation of the environmental state of these areas means huge tasks and high costs for the governments. Between the inorganic pollutants of the waters heavy metals can be very harmful. These elements can be found both in the sediment and the water furthermore they can accumulate in the food-chain and cause toxic, mutagenic, carcinogenic or teratogenic effects. Between the heavy metals, some chemical elements (zinc, copper) are essentials, but their high concentrations can be harmful for the health. The toxicity of the heavy metals can depend on the presence or the absence of the other elements which also appear in the environment [1]. Nowadays many physical, chemical and biological methods are available for the decontamination of the polluted areas. During our research work our main aim was to confirm the positive effect of the phytoremediation. We analysed the heavy metal content of different kinds of plants which are growing on the river sediment.

2. MATERIALS AND METHODS

The first sampling area (M1-M3, T) was the sediment dump of Dunaújváros (Figure 1/a.), which is located on the northern part of the town. This dump was made in 2009, when the local municipality wanted to rehabilitate this old Open Beach area of the town, therefore the sludge of this beach was dredged out onto the floodplain which is located on the right side of the river Danube. In the southern part of the dump a stream flows, which flows into the river Danube. In addition, a water channel surrounds the whole dump. The second sampling area was the estuary of the Felső-Foki-streamlet (FFS) (Figure 1/a.). This streamlet is flowing through many agricultural fields before its end. The third sampling area is an oxbow lake (OL) (Figure 1/b.) which is located on the southern part of Dunaújváros. Between the four oxbow lakes the sediment and plant samples were taken from the second lake.



Figure 1 The sampling points of the sediment dump (a) and the oxbow lakes (b) (Source: Google Earth)

The area of the sampling points was 1 m². The sediment samples were collected from the depths of 0-10 with a standard soil sampler. Five sediment samples were taken from every place.

The parella (*Rumex patientia*) (Figure 2/a) samples were collected from the M1, M2, M3 and T points of the sediment dump. The bistort (*Persicaria maculosa*) samples (Figure 2/d) were taken from the T point of the sediment dump. The perennial rye-grass (*Lolium perenne*) samples (Figure 2/b) were taken from the estuary of Felső-Foki-streamlet (FFS), and the riparian sedges (*Carex riparia*) samples (Figure 2/c) were taken from the oxbow lake (OL) place.



Figure 2. The photos of the test plants

The extraction of the heavy metal content of the river sediment was made with acidic destruction according to the MSZ 12739/4-78 Hungarian Standard. Following the directions of the Standard, firstly the organic parts were removed and the samples were dried. Thereafter, during the destruction process, the heavy metal content was extracted with concentrated nitric

acid and hydrogen-peroxide in a rotating evaporator (Heidolph Laborota 400). After filtration, the concentration of the heavy metals was analysed with an atomic absorption spectrometer (AAS, Perkin Elmer AAnalyst 400). Among the heavy metals, cadmium, nickel, lead, chromium, copper and zinc were measured [2].

For the determination of the heavy metal content of the plants the samples were also destructed with concentrated nitric acid and hydrogen peroxide. During the preparation process the main parts of the plants were washed with deionised water, and then they were dried. After that the plants were cut into pieces and these parts were treated with concentrated nitric acid for 12 hours and with hydrogen peroxide for additional 3 hours.

After filtration the heavy metal concentration of the samples was also measured by atomic absorption spectrometer (AAS) [3].

Our results were compared to the limit values of the heavy metals which can be found in the appendix of the 6/2009. (IV. 14.) KvVM-EüM-FVM law.

The sufferable levels of the element in plants were determined in the Hungarian Forage Codex (2003) and the related literatures [4-7].

3. RESULTS AND DISCUSSION

3.1. The cadmium content of the sediment and plant samples

Based on Figure 3 it was determined that the cadmium content of the sediment of the parella, sedge and bistort exceeded the Hungarian standard level (1 mg/kg).

Among the four test plants cadmium was detected in the leaves of sedge and perennial ryegrass, and the upper stem of the parella. The cadmium concentration was higher in the test plants than the tolerable limit, 0.5 mg/kg.

When the concentrations of the sediment and the parts of the plants were summarized, it is determined that cadmium remained mainly in the sediment, only 30-40% of the total cadmium content could accumulate in the plants [4-9].

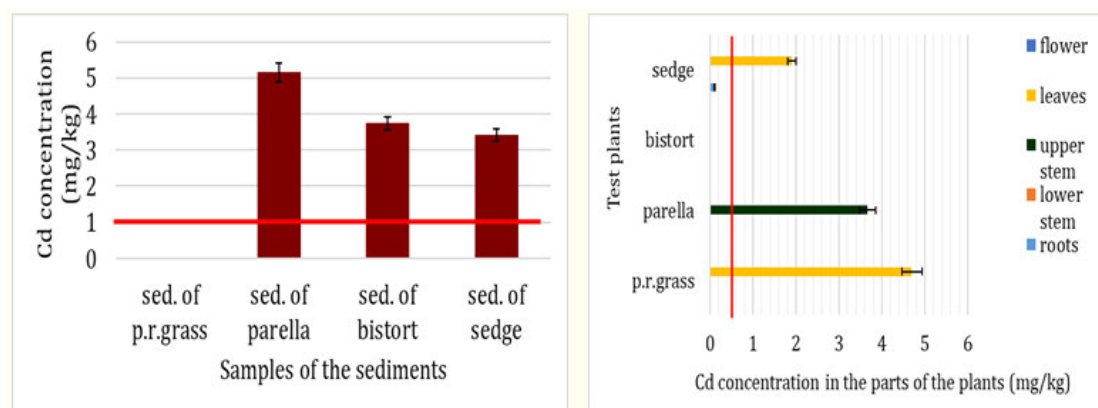


Figure 3 The cadmium content of the sediment and plant samples

3.2. The nickel content of the sediment and plant samples

This element was not detected only from the sediment of the riparian sedge (Figure 4). The Ni contents of the other sediment samples were lower than the standard limit (40 mg/kg).

This pollutant was measured only from the parts of the parella and bistort. The Ni contents of the parts of the plants did not exceed the tolerable limit (10-100 mg/kg).

The nickel concentration was the highest in the upper stem of parella and the leaves of bistort. Bistort contained the 53%, parella contained 70% of the total Ni content of the sediment and plant system [4-9].

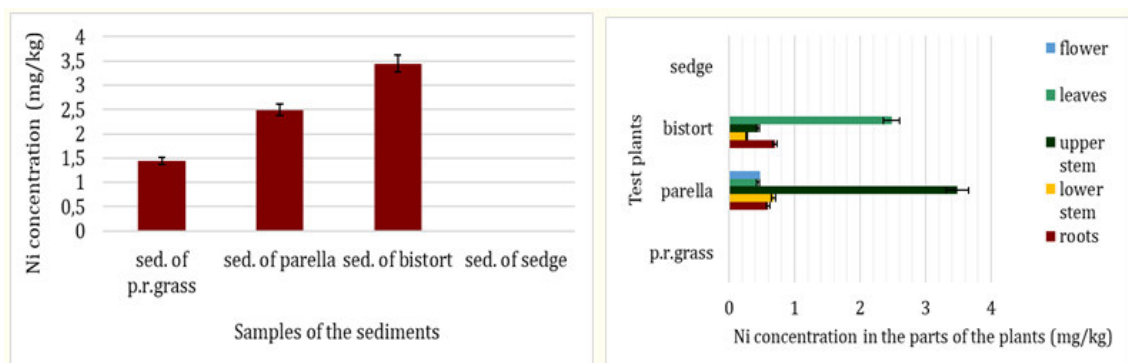


Figure 4 The nickel content of the sediment and plant samples

3.3. The lead content of the sediment and plant samples

The Hungarian standard level for lead content is 100 mg/kg. According to Figure 5 it is determined that the Pb content of the sediment samples of bistort and parella exceeded the standard limit (100 mg/kg).

From between the four test plants only bistort could accumulate this element. The highest Pb concentration was detected from the roots and the leaves of this plant. In these parts the Pb concentration was higher than the tolerable limit (30-300 mg/kg). In bistort the 88 % of the total lead content of the plant-sediment system was observed [4-9].

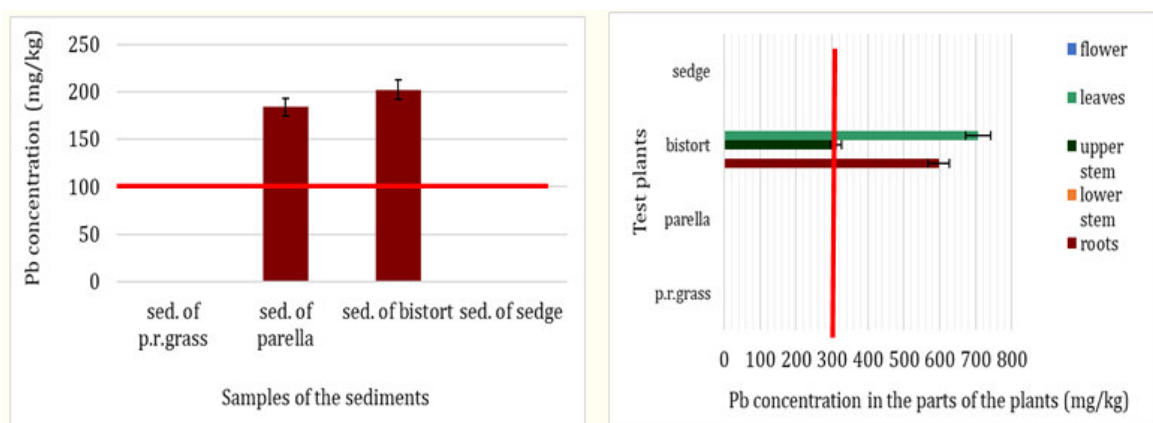


Figure 5 The lead content of the sediment and plant samples

3.4. The chromium content of the sediment and plant samples

According to Figure 6 chromium concentration was measured only from the sediment sample of the parella and bistort. The concentration of this element was higher in the sediment samples than the Hungarian standard level (75 mg/kg).

The distribution of chromium between the parts of parella was uniform. The roots and the leaves of bistort could accumulate chromium in the highest concentration. The concentration of this pollutant was higher in the test plants than the tolerable limit 1-10 mg/kg. Parella and bistort could accumulate 80% of the total chromium content of the sediment and plant system [4-9].

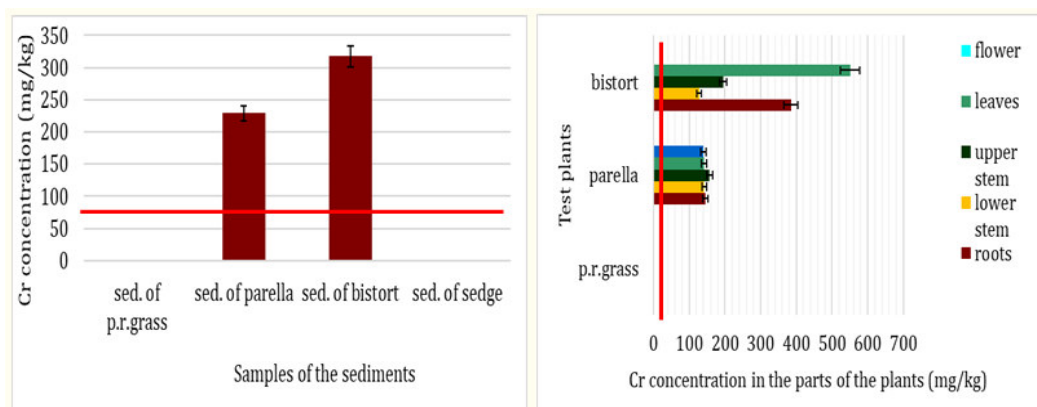


Figure 6 The chromium content of the sediment and plant samples

3.5. The copper content of the sediment and plant samples

Cu concentration was higher than the standard limit (75 mg/kg) in the sediment of the sedge sample. The sediments of the other plant species had lower copper concentrations (Figure 7).

In plants the copper concentration was higher than in the sediment samples. Every plant could accumulate this element. In the case of sedge and perennial rye-grass, the roots contained in higher rate this pollutant. On the other hand, we could detect copper in higher concentration from the upper stem of parella and the lower stem of bistort. The copper concentration of the plants was higher than the sufferable value (35 mg/kg). Plants could accumulate 70-90% of the total Cu concentration of the sediment and plant system [4-9].

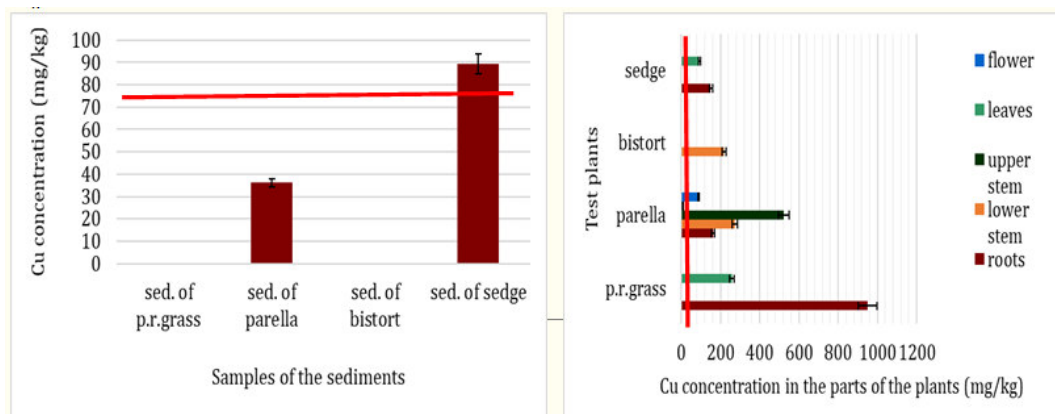


Figure 7 The copper content of the sediment and plant samples

3.6. The zinc content of the sediment and plant samples

The zinc content of the river sediments exceeded the standard limit (200 mg/kg) (Figure 8). Every test plant could accumulate this element. In the case of the perennial rye-grass and sedge samples the higher zinc concentrations were measured from their leaves. Higher zinc content was detected from the upper stem of parella and bistort. The content of this element exceeded the tolerable value (250 mg/kg) only in the upper stem of parella and in the leaves of perennial rye-grass. Plants could uptake the 30-40% of the total Zn content of the plant and sediment system [4-9].

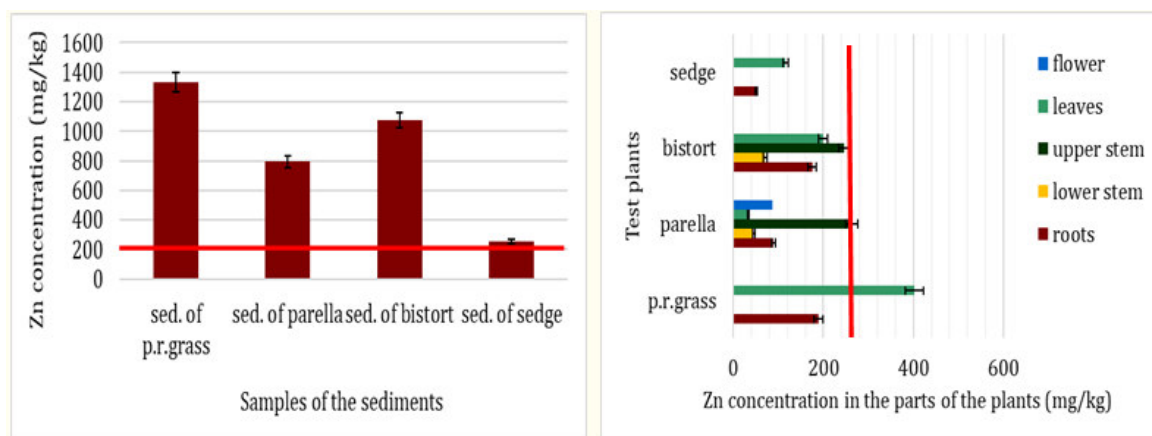


Figure 8 The zinc content of the sediment and plant samples

Conclusions

The mobilization of cadmium between the sediment and plants was insignificant, it remained mainly in the sediment. Only the 30-40% of the total cadmium content could accumulate in the stems and leaves of test plants. Nickel (50-70 %) and chromium (80%) could accumulate in the upper parts of parella and bistort. 50-70% of the total nickel content and 80% of the total chromium content were detected from these plants. Test plants could uptake in higher rate copper (70-90%) and zinc (30-40%), because these elements are essential. Copper was detected mainly the lower parts (roots) of the test plants. On the other hand the highest zinc concentration was observed in the upper parts (stems and leaves) of the test plants.

According to the results of the heavy metal content of the test plants, parella and bistort are recommendable for the phytoremediation of the sediment of the river Danube.

We are planning to make more laboratory experiments on other kinds of plant species to measure the continuous phytoextraction of the heavy metals from river sediments or industrial sludges.

ACKNOWLEDGMENT

Thank you for the support of EFOP-3.6.2-16-2017-00018 „Produce together with the nature – agroforestry as a new outbreaking possibility” project.

6. REFERENCES

- [1] Kádár I.: *A talaj-növény-állat-ember tápláléklánc szennyeződése kémiai elemekkel Magyarországon* (Környezetvédelmi és Területfejlesztési Minisztérium MTA Talajtani és Agrokémiail Kutató Intézete Budapest, 1995., ISBN 963 04 5362
- [2] MSZ 12739/4-78 szabvány
- [3] SIMON L.: *Toxikus elemek akkumulációja, fitoindikációja és fitoremediációja a talaj-növény rendszerben* (Doktori értekezés, 2006.)
- [4] 6/2009. (IV.14.) KvVM-EüM-FVM együttes rendelet a földtani közeg és a felszín alatti víz szennyezéssel szembeni védelméhez szükséges határértékekről és a szennyezések méréséről
- [5] 44/2003 (IV. 26.) FVM rendelet a Magyar Takarmánykódex kötelező előírásairól
- [6] Simon L.: *Fitoremediáció* (Környezetvédelmi Füzetek. 2004. Budapest. Azonosító: 2318. BMKE OMIKK, p.1-59., ISBN:963 593 429 0, ISSN 0866-6091)

- [7] Szegedi L.: *Toxikus nehézfémzennyezés utóhatásának vizsgálata barna erdőtalajon* (Doktori PhD értekezés, SZIE, Gödöllő, 2011)
- [8] Kovács-Bokor É., Kiss E.: *Dunai iszap nehézfém tartalmának akkumuláció vizsgálata lóromban (*Rumex obtusifolius*)* (Dunaújváros, 2017, Dunakavics 5 (7) pp. 5-22.
- [9] Kovács-Bokor É., Kiss E., Szydłowska M., Sledz J.: *Felszíni vizek iszapos üledékeinek nehézfém tartalom monitorozása Dunaújvárosban* (Tájékoztató Dunaújváros MJV környezeti állapotáról, 2017, pp. 159-168, ISSN 1786-7592)

Corresponding author:

Éva KOVÁCS-BOKOR

Institute of Engineering, Department of Natural Sciences and Environmental Protection

University of Dunaújváros

1/A. M. Táncsics St.

H-2400, Dunaújváros, Hungary

phone: +36 25 551 613

E-mail: kovacsbe@uniduna.hu