**ENVIRONMENT PROTECTION**

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# ACCUMULATION OF HEAVY METALS BY HIGHER AQUATIC VEGETATION OF ARTIFICIAL CANALS

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**Abstract**. *Accumulation of heavy metals by high plants of artificial canals of Desnyanskiy district in Kyiv was considered. Cleansing ability of different types of submerged and air-water vegetation was compared. Types of plants improving sanitary conditions of reservoirs in urban sites were determined.*

**Keywords:** artificial reservoirs; cadmium; copper; heavy metals; higher aquatic vegetation; lead; zinc.

## 1. Introduction

Protection of water from pollution is one of the most important and urgent problems nowadays.

Numerous scientific researchers showed the existence of close relationship between vegetation of higher aquatic plants, self-purification processes in water bodies and formation of water quality [1, 2, 5]. Higher aquatic plants due to their morphological, physiological and ecological characteristics are observed to serve as a biological filter during admission of various pollutants in reservoirs.

Water bodies located in urban areas are experiencing significant anthropogenic impact due to the operation of cities infrastructure.

The main factors that determine the degree of urbanization of the reservoir is anthropogenic changes of their morphometric characteristics, loss of natural vegetation of catchment areas and its pollution, changes in the hydrological regime, anthropogenic transformation of coast (concreting, dam construction), anthropogenic eutrophication, recreational activity, pollution with rainwater.

During construction of residential area Troeshchyna (Desniansky district, Kyiv) a system of interconnected flowing drainage canals was set up along Zakrevskogo street.

The upper canal is located on the edge of the residential area, it has steep sandy banks up to 5 m, filled up during construction.

Banks are surrounded by floodplain forest, the top is waterlogged.

The lower reservoir of the system is in 3 km from the upper canal and is the penultimate in this system of reservoirs.

In its planning among alluvial sandy massif the bed was dug and banks are handled with concrete slabs (see Figure).

Researched reservoirs are contaminated by surface-slope runoff coming from the urban catchment area.

Wastewater from industrial and construction sites, as well as surface - slope runoff from urban area and roads bring significant number of pollutants and suspended particles.

## 2. Analysis of publications

Because of water bodies' pollution condition of higher aquatic vegetation has been researched by several authors [1, 3, 5].

Content of Heavy Metals (HM) and features of their accumulation by macrophytes of the most common species in the coastal zone of reservoirs have been established.


Canals of residential area Troeshchyna (Desniansky district, Kyiv):
*1* – Top Cannel;
*2* – Bottom Canal

Also the cleaning ability of tbeen dhese plants has etermined.

Kyiv reservoirs are not investigated enough, while at the same time the pollution situation on urban areas tends to change rapidly.

The **purpose** of work was to investigate the dynamics of accumulation of HM – Cu, Pb, Cd, Zn in higher aquatic plants and determine their role in purification processes of artificial water bodies from heavy metals in urban areas.

## 3. Materials and Methods

Atomic absorption spectrometry method was used for determination of heavy metals in higher aquatic plants. Sampling took place in two stages: first – in May 2012, second – in August 2012.

The following types of higher aquatic vegetation were selected from the Upper and Lower Canals:

– *Phragmites australis (Cav.) Trin. Ex Steud.;*
– *Glyceria maxima (C.Hartm.) Holmb.;*
– *Týpha latifólia L.;*
– *Potamogeton crispus L.;*
– *Hydrocharis morsus-ranae L.;*
– *Myriophyllum spicatum (L.);*
– *Lemna minor L.;*
– *Ceratophyllum demersum L.;*
– filamentous algae.

Samples of air-aquatic vegetation were taken in different parts (root, stem, leaves, buds), while completely submerged vegetation used totally.

For the heavy metals analysis the plants were dried to constant weight, and then 2 g of each sample were incinerated in an oven (automated sample preparation "Temos – Express" TE – 1) according to the methodology [4].

Extraction of mobile forms of heavy metals was carried by nitric acid.

The mixture was filtered through a filter, "The White Ribbon".

Determination of heavy metals was performed on atomic absorption spectrophotometer C-115-M1.

Statistical analysis of the results was conducted by conventional methods.

## 4. Results and Discussion

The data showed that in all organs of Reed (*Phragmites australis (Cav.) Trin. Ex Steud.*) there is the biggest amount of zinc among other studied metals (Table 1).

In the lower part of this plant, in comparison with other organs, in larger quantities are accumulated copper and lead, in the leaves and inflorescence – zinc.

Cadmium is not found in any part.

**Table 1.** Content of heavy metals in different parts of *Phragmites australis* on Lower Canal, mg / kg $_{dry\ mass}$

| Part of plant | Cu | | Pb | | Cd | | Zn | |
|---|---|---|---|---|---|---|---|---|
| | Sping | Summer | Sping | Summer | Sping | Summer | Sping | Summer |
| Middle part of the stem | 0.00 | 0.32 ±0.01 | 1.08 ±0.02 | 0.75 ±0.01 | 0.00 | 0.00 | 1.93 ±0.02 | 8.82 ±0.02 |
| Lower part of the stem | 0.46 ±0.01 | 2.52 ±0.02 | 1.66 ±0.02 | 3.59 ±0.02 | 0.00 | 0.00 | 2.96 ±0.02 | 11.23 ±0.10 |
| Leaves | 0.14 ±0.01 | 0.04 0.01± | 1.12 ±0.02 | 0.89 ±0.01 | 0.00 | 0.00 | 7.06 ±0.02 | 18.48 ±0.10 |
| Inflorescence | – | 0.72 ±0.01 | – | 1.56 ±0.02 | – | 0.00 | – | 17.96 ±0.10 |

Heavy metals accumulation in Reed is more intense in summer than in spring.

So Reed is able to accumulate HM in significant quantities, excluding them from the substrate, thereby delaying their entry into groundwater.

The data showed that submerged aquatic vegetation mostly accumulates heavy metals in summer (Table 2).

In particular, copper and lead are mainly accumulated by small duckweed, zinc and cadmium – by Potamogeton curly.

The results of heavy metals content in higher water plants on the Upper Canal are presented in Tables 3–6.

The data showed that *Glyceria maxima* on the Upper Canal mainly accumulates zinc in the roots and lower part, the smallest amount of it is in the leaves (Table 3).

The content of copper, lead and cadmium is negligible compared to zinc.

In roots of the reeds and in its bottom part the content of lead is dominating (Table 4).

There is more zinc in upper part of the plant.

Copper content is found in small amounts in the roots and lower part.

There is a very small quantity of cadmium.

It should be noted that in Týpha latifólia zinc, copper, lead and cadmium are accumulated mainly by the roots (Table 5).

According to the research (Table 6) was determined, that *Lemna minor L.* accumulates mostly zinc, *Potamogeton crispus L.* – copper, filamentous algae – lead and cadmium. *Ceratophyllum demersum L.* accumulates small amounts of copper, zinc and lead.

Analysis of references concerning the content of heavy metals in higher water plants of fresh water reservoirs showed that the investigated water bodies are average contaminated medium, in comparison with Zaporizhskyi reservoir that is more polluted and Danube Delta, which is less affected (Table 7) [3,5].

**Table 2.** Comparative characteristics of heavy metals in different types of submerged hydrophytes on the Lower Canal, mg / kg $_{dry\ mass}$

| Type of plant | Cu | | Pb | | Cd | | Zn | |
|---|---|---|---|---|---|---|---|---|
| | Sping | Summer | Sping | Summer | Sping | Summer | Sping | Summer |
| Filamentous algae | 3,13 ±0,02 | 5,12 ±0,02 | 1,00 ±0,02 | 1,20 ±0,02 | 0,00 | 0,00 | 18,85 ±0,20 | 19,50 ±0,20 |
| *Potamogeton crispus* | 2,85 ±0,02 | 10,33 ±0,10 | 5,00 ±0,04 | 8,15 ±0,08 | 0,00 | 1,37 ±0,02 | 31,26 ±0,10 | 64,15 ±0,10 |
| *Hydrocharis morsus-ranae* | 9,08 ±0,09 | 12,17 ±0,10 | 5,35 ±0,05 | 10,02 ±0,01 | 0,00 | 0,71 ±0,01 | 1,72 ±0,02 | 43,07 ±0,10 |
| *Myriophyllum spicatum* | 1,74 ±0,02 | – | 4,36 ±0,03 | – | 0,00 | 0,00 | 19,63 ±0,10 | – |
| *Lemna minor* | 16,92 ±0,10 | – | 11,53 ±0,10 | – | 0,18 ±0,01 | 0,00 | 21,69 ±0,20 | – |

**Table 3.** Content of heavy metals in *Glyceria maxima* in spring on the Upper Canal, mg / $kg_{dry\ mass}$

| Parts of plant | Cu | Pb | Cd | Zn |
|---|---|---|---|---|
| Upper part of the stem | 1,19±0,02 | 0,92±0,01 | 0,20±0,01 | 11,10±0,10 |
| Roots | 2,80±0,02 | 3,50±0,02 | 0,22±0,02 | 14,52±0,10 |
| Lower part of the stem | 0,49±0,01 | 0,95±0,01 | 0,00 | 12,40±0,10 |
| Leaves | 0,32±0,01 | 0,24±0,01 | 0,09±0,01 | 3,89±0,02 |

**Table 4.** Content of heavy metals in different parts of *Phragmites australis* on Lower Canal, mg / $kg_{dry\ mass}$

| Part of plant | Cu | | Pb | | Cd | | Zn | |
|---|---|---|---|---|---|---|---|---|
| | Sping | Summer | Sping | Summer | Sping | Summer | Sping | Summer |
| Leaves | 0,43 ±0,01 | 0,37 ±0,01 | 1,99 ±0,02 | 1,26 ±0,01 | 0,09 ±0,01 | 0,00 | 9,76 ±0,09 | 3,72 ±0,03 |
| Upper part of the stem | 2,74 ±0,02 | 1,02 ±0,01 | 5,88 ±0,05 | 7,04 ±0,07 | 0,19 ±0,01 | 0,01 ±0,001 | 18,95 ±0,10 | 19,12 ±0,10 |
| Lower part of the stem | 1,24 ±0,01 | 3,02 ±0,03 | 32,76 ±0,30 | 21,03 ±0,20 | 0,00 | 0,00 | 12,32 ±0,10 | 12,89 ±0,10 |
| Roots | 2,32 ±0,02 | 5,38 ±0,05 | 34,12 ±0,30 | 23,09 ±0,20 | 0,00 | 0,00 | 14,93 ±0,10 | 17,09 ±0,10 |

**Table 5.** Content of heavy metals in different parts of *Týpha latifólia* on the Upper Canal, mg / $kg_{dry\ mass}$

| Part of plant | Cu | | Pb | | Cd | | Zn | |
|---|---|---|---|---|---|---|---|---|
| | sping | summer | sping | summer | sping | summer | sping | summer |
| Middle part of the stem | 0,69 ±0,01 | 0,21 ±0,01 | 0,50 ±0,01 | 1,31 ±0,01 | 0,16 ±0,01 | 0,00 | 8,61 ±0,08 | 0,29 ±0,01 |
| Lower part of the stem | 0,35 ±0,01 | 2,38 ±0,02 | 0,31 ±0,01 | 0,74 ±0,01 | 0,17 ±0,01 | 0,00 | 6,52 ±0,06 | 7,43 ±0,07 |
| Upper part of the stem | 0,00 | 0,39 ±0,01 | 0,33 ±0,01 | 0,42 ±0,01 | 0,00 | 0,00 | 2,78 ±0,02 | 3,07 ±0,03 |
| Leaves | 0,26 ±0,02 | 0,56 ±0,01 | 0,93 ±0,01 | 0,56 ±0,01 | 0,11 ±0,01 | 0,00 | 2,89 ±0,02 | 3,58 ±0,03 |
| Roots | 23,91 ±0,20 | 31,06 ±0,30 | 1,82 ±0,01 | 2,85 ±0,02 | 0,37 ±0,01 | 0,00 | 25,20 ±0,20 | 32,00 ±0,30 |

**Table 6.** Comparison of HM content in different types of submerged hydrophytes on the Upper Canal, mg / $kg_{dry\ mass}$

| Type of plant | Cu | | Pb | | Cd | | Zn | |
|---|---|---|---|---|---|---|---|---|
| | Sping | Summer | Sping | Summer | Sping | Summer | Sping | Summer |
| *Potamogeton crispus* | 0,94 ±0,01 | 0,28 ±0,01 | 3,34 ±0,03 | 0,62 ±0,01 | 0,00 | 0,49 ±0,01 | 11,06 ±0,10 | 5,62 ±0,05 |
| *Ceratophyllum demersum* | 0,61 ±0,01 | 0,12 ±0,01 | 2,33 ±0,02 | 0,91 0,01± | 0,17 ±0,01 | 0,00 | 18,42 ±0,10 | 5,31 ±0,05 |
| *Lemna trisulca.* | 1,72 ±0,01 | 0,23 ±0,01 | 0,78 ±0,01 | 3,69 ±0,03 | 0,20 ±0,01 | 0,39 ±0,01 | 16,63 ±0,10 | 20,36 ±0,20 |
| Filamentous algae | 0,00 | – | 8,28 ±0,08 | – | 0,66 ±0,01 | – | 19,99 ±0,10 | – |

**Table 7.** Heavy metals content in higher aquatic plants of fresh water bodies according to different authors, mg / $kg_{dry\ mass}$

| Type of plant | Cu | Zn | Pb | Cd | Authors |
|---|---|---|---|---|---|
| Zaporizhskyi reservoir | | | | | |
| *Phragmites australis* | 6,10 | 40,00 | 1,30 | 0.08 | O. Fedonenko [5], E. Filippova[5], T. Sharamok [ 5] |
| *Potamogeton crispus* | 11,00 | 114,00 | 3,00 | 1.00 | |
| *Týpha latifólia* | 7,00 | 51,00 | 1,80 | 0.12 | |
| Danube Delta | | | | | |
| *Phragmites australis* | 0,36 | 0,67 | 0,54 | – | N. Smirnova [3] |
| *Týpha latifólia* | 0,83 | 0,86 | 0,87 | – | |
| *Potamogeton crispus* | 13,60 | 69,8 | 16,00 | – | |
| *Glyceria maxima* | 0,34 | 0,44 | 0,50 | – | |

## 5. Conclusions

Our results indicate that higher aquatic vegetation of investigated water bodies accumulates HM.

Less contaminated vegetation of Upper Canal than the lower. Submerged plants in comparison with air-water accumulate HM better, due to the wide ramified surface contact with water, which contains minerals that are absorbed by plants.

There are the following types of higher aquatic plants that have the greatest accumulating ability: *Lemna trisulca L., Potamogeton crispus L. and Hydrocharis morsus-ranae L.*

They are characterized by high concentration capacity in relation to zinc, copper and lead, resistance to pollutants and prevalence in different parts of the canal.

This allows to recommend application of mentioned species for water purification and improving sanitation and environmental conditions of water bodies.

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**Т.І. Білик[1], О.В. Шило[2], Г.О. Карпова[3], О.В. Чуманова[4].** **Накопичення важких металів вищою водяною рослинністю штучних водойм**

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Досліджено акумуляцію важких металів вищою водяною рослинністю штучних каналів Києва. Показано, що занурена рослинність порівняно з повітряно-водяною більшою мірою накопичує важкі метали, що обумовлено широкою розгалуженою поверхнею її контакту з водою, яка містить мікроелементи, що поглинаються рослинами. Розглянуто види вищої водяної рослинності, які мають найбільшу акумулюючу здатність *(Lemna trisulca L., Potamogeton crispus L., Hydrocharis morsus-ranae L.*) та характеризуються високою концентраційною здатністю відносно до цинку, міді та свинцю, стійкістю до полютантів, а також поширеністю на різних ділянках каналів. Запропоновано використання зазначених видів рослин для очищення води та поліпшення санітарно-екологічного стану водойм.

**Ключові слова:** важкі метали; вищі водяна рослинність; кадмій; мідь; свинець; цинк; штучні водойми.

**Т. И. Билык[1], О.В. Шило[2], Г.А. Карпова[3], Е.В. Чуманова[4]. Накопление тяжелых металлов высшей водной растительностью искусственных водоёмов**
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Исследована аккумуляция тяжелых металлов высшей водной растительностью искусственных каналов Киева. Показано, что погруженная растительность в сравнении с воздушно-водной в большей мере накапливает тяжелые металлы, что обусловлено широкой разветвленной поверхностью ее контакта с водой, содержащей микроэлементы, которые поглощаются растениями. Рассмотрены виды высшей водной растительности, которые имеют наибольшую аккумуляционную способность (*Lemna trisulca L., Potamogeton crispus L.*, *Hydrocharis morsus-ranae L.)* и характеризуются высокой концентрационной способностью по отношению к цинку, меди и свинцу, стойкостью к полютантам, а также распространенностью на разных участках канала. Предложено использование перечисленных видов растений для очищения воды и улучшения санитарно-экологического состояния водоёмов.

**Ключевые слова:** высшая водная растительность; искусственные водоёмы; кадмій; медь; свинец; тяжелые металлы; цинк.

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