Biogeochemistry of macrophytes in reservoirs of St.-Petersburg

MARGARITA UFIMTSEVA[1], NATALIA TEREKHINA[2]
[1]Earth Crust Research Institute
St.-Petersburg State University
Universitetskaya nab., 7/9, St.-Petersburg,
RUSSIA

[2]Dpt. of Biogeography and Nature Protection
St.-Petersburg State University
10 line V.O., 33, 199178, St.-Petersburg
RUSSIA

Abstract

Accumulative properties of macrophytes of different ecological groups in urban reservoirs were investigated. Hydatophyte (*Elodea canadensis*) concentrates maximal amount of microelements. High positive correlation between contamination indexes of macrophytes and surface water was determined. Main elements-contaminants for all components of aquatic landscapes are Pb, Ni and Cr. Contents of mobile forms of heavy metals in sediments are insignificant. Indicator parameter Fe/Mn characterizes transformation of biogeochemical cycle of substances in urban aquatic geosystems.

Key-Words: urban reservoirs, macrophytes, heavy metals, surface water, sediments

1 Introduction

Contemporary megapolyses are remarkable for increased anthropogenic pressure on environment. Surplus amounts of chemical elements come into migration flows of urban landscapes. The last spot of these flows are exclusive reservoirs.

Phytogeochemical peculiarities of high water plants are extensively determined by their belonging to one of the major ecological group – hygrophytes (aero-aquatic), hydrophytes (emergent), and hydatophytes (submerged), with systematical differences inside them [1, 2]. High indication significance of macrophytes depends on their pronounced capacity to accumulate many chemical elements. Using of macrophytes as indicators is especially perspective for control of heavy metals level in water by ecological state assessment, by monitoring and with purposes of reservoirs remediation.

2 Problem formulation

The task of the work is assessment of degree of contamination of biotic and abiotic components of main reservoirs of St.-Petersburg. Determination of regularities of chemical elements accumulation by different objects will make it possible to give recommendations for remediation of urban reservoirs. The objective method for estimation of ecological state as land as water ecosystems is phytoindication.

3 Problem solution

Assessment of ecological state of ten reservoirs in St. Petersburg was carried out in 1997-1998. It was the beginning stage of monitoring investigations, which late were continued by other researchers [3, 4]. Ten reservoirs were investigated in order to reveal contamination process. Chemical composition of macrophytes, benthic deposits and surface water were investigated.

3.1. Materials and methods

In this work characteristic of three indicator species, which demonstrated intensity of heavy metals (HM) accumulation by plants of different ecological groups: hygrophyte *Phragmites australis* (Cav.) Trin. Ex Steud., hydrophyte – *Potamogeton natans* L., hydatophyte – *Elodea canadensis* Michx., is given.

Plant samples were ashed at 400–450 °C over 6 hours. Concentrations of HM in plant and water samples were determined by AAS.

Intensity of technogenic influence on biota and water was estimated by coefficient of concentration (Kk): Kk=Cc/Cg, where Cc – concentration of element in urban plants/water; Cg – concentration of the same element in plants/water of background habitats.

Index of summary contamination was calculated: $Zc = \sum Kk - (n - 1)$, where Kk – coefficient of concentration above 1; n – number of elements with Kk>1.

Total content and mobile forms of HM in benthic deposits were determined by complex of methods.

3.2. Results and discussion

Total content of HM in benthic deposits of investigated aquatic geosystems characterized by high (more than 2 times) range between different reservoirs [5]. Average total concentrations are: Mn – 501.2, Fe – 8262.9, Zn – 210.7, Cu – 74.7, Pb – 118.9, Ni – 65.35, Cr – 179.3 mg/kg of dry matter. Exceeding of Maximum Level for benthic deposits by Cu and Ni are 2.1 and 1.9 accordingly. The most part of HM is connected with organic structures, minority part is connected with hydroxides and insoluble compounds of benthic deposits, and only small part is in soluble form (table 1).

Table 1. Variation of different forms of microelements content in benthic deposits of reservoirs (% of total content) [5].

Forms of microelements	Ni	Zn	Cr	Cu	Pb
water-soluble and sorptioned	0,6-23,3	4,6-59,1	0,5-15,5	15,2-29,5	4,0-15,5
connected with organic structures	34,1-97,8	2,2-6,2	27,4-97,5	43,0-55,7	69,7-87,6
connected with carbonates	0,5-5,1	3,1-56,1	0,3-9,9	2,1-3,3	0,9-5,6
connected with hydroxides and insoluble compounds	1,1-48,4	23,9-44,9	1,7-58,2	18,6-35,2	6,6-15,1

Surface waters content Fe and Mn, which concentrations exceed Maximum Permissible Concentrations in 2.3 and 1.3 accordingly. Comparison with background data demonstrated considerable increasing of Ni, Cr, Cu, Mn and Zn in urban reservoirs.

Concentrations of HM in macrophytes are decreased in row: Fe > Mn > Ba > Zn > Sr > Pb > Cu > Ti > Ni > Cr. High constant of variation (V) for them (for example, reed has V = 64 % Fe, 98 % Mn, 55–59 % Ni, Cr, Ba, 70–75 % Ti, Sr) shows different contamination level of urban reservoirs. Hydatophyte *Elodea canadensis* contains more HM than plants of other ecological groups that is peculiarity of HM accumulation by macrophytes (fig. 1). These results are in agreement with results of other researcher [6].

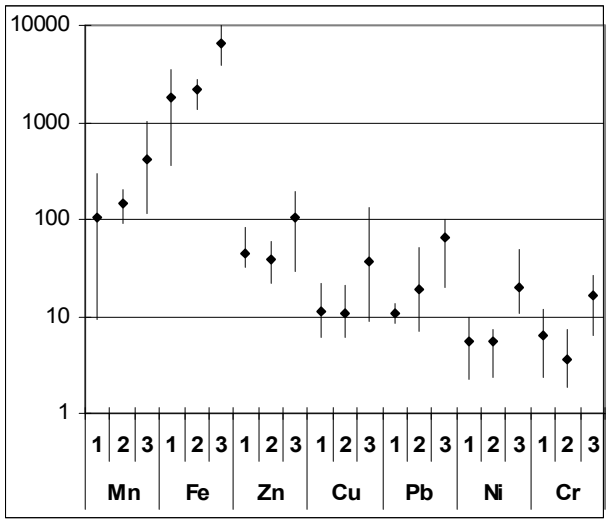

Fig. 1. Contents of heavy metals (mg/kg of dry weight) in macrophytes: 1 – *Phragmites australis*, 2 – *Potamogeton natans*, 3 – *Elodea canadensis*.

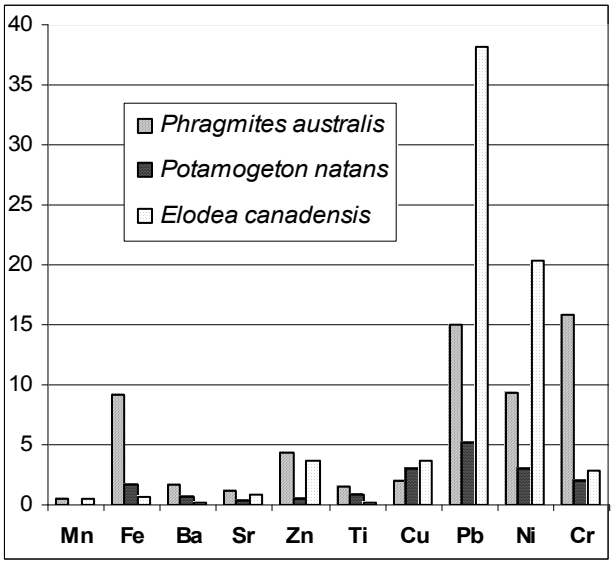

Fig. 2. Coefficients of concentrations of heavy metals in macrophytes of urban reservoirs.

Coefficients of concentrations for technophylic elements Pb, Ni, Cr are the most high (fig. 2). Average concentrations of Fe and Mn in reed leaves are 1796.3 и 104.4 mg/kg of dry matter accordingly, which 9.3 times more for Fe and 2.4 times less for Mn in compare with background data.

Other peculiarity of microelement content of ecologo-morphological groups of macrophytes are inversion of ratio Fe/Mn. For reed leaves Fe concentration exceed Mn concentration more than 13 times. For background habitats this ratio is 0.87 (table 2).

Table 2. Values ratio Fe/Mn and their limits for macrophytes of small reservoirs in St. Petersburg and relatively clean reservoirs

Species	Average	Limits
Urban reservoirs		
Phragmites australis	13.3	3.76 – 71.5
Potamogeton natans	15.8	9.57 – 25.35
Elodea canadensis	20.3	6.34 – 33.75
Background reservoirs		
Phragmites australis	0.87	0.40 – 1.93

Indicator parameter Fe/Mn of different species varies in wide range and characterizes transformation of biogeochemical cycle of substances in urban aquatic geosystems.

Indexes of summary contamination are 59.9 for *Phragmites australis*, 14.8 for *Potamogeton natans*, 68.6 for *Elodea canadensis*. It is demonstrated not only species differences of HM accumulation, but peculiarities of ecological conditions of reservoirs different facieses. Estimation of contamination intensity for different urban reservoirs is given in the book (Ufimtseva, Terekhina, 2005).

Phytocenotic investigation showed that these reservoirs experience as HM contamination as eutrophication. It finds expression in abundant propagation of *Elodea canadensis* Michx., species of genus *Lemna* L., and littoral species *Ranunculus sceleratus* L.

Comparison of Kk macrophytes, Kk surface water and indexes of exceeding of Maximum Level for benthic deposits revealed essential similarity between Kk for plants and water (coefficient of correlation 0.59–0.84). Such dependence between plants and benthic deposits was not found that is related with insignificant part of mobile forms of HM in sediments, and with physical-chemical and mineralogical peculiarities of benthic deposits.

4 Conclusion

The investigation revealed significant technogenic influence on urban reservoirs, which are manifested in next facts:

- enrichment of water, benthic sediments and macrophytes by heavy metals is occurred;
- the main contaminants are: Pb, Ni, Cr for macrophytes; Ni, Cr, Cu, Mn and Zn for surface water; Cu, Ni for benthic deposits;
- macrophytes manifest the disturbance of HM biogeochemical cycle, that expresses in sharp increase of evolutionary formatted ratio Fe/Mn;
- phytocenotic indicators of reservoirs eutrophycation are *Elodea canadensis* Michx., species of genus *Lemna* L., and *Ranunculus sceleratus* L.
- accumulative indicator of urban reservoirs is hydatophyte *Elodea canadensis*, which can be recommended for using in remediation of water ecosystems.

Acknowledgements

D. Safiullina and A. Shuvalova are gratefully acknowledged for the help in this investigation.

References

[1] X1. Mikryakova T. F. Accumulation of Heavy Metals by Macrophytes at Different Levels of Pollution of Aquatic Medium. *Water Resources*, Vol. 29, No. 2, 2002, pp. 230–232.

[2] X2. Demirezen Dilek, Aksoy Ahmet Common hydrophytes as bioindicators of iron and manganese pollutions. *Ecological Indicators*, Vol. 6, Issue 2, April 2006, pp.388-393

[3] X3. Novikov A.M., Kurilenko V.V., Osmolovskaya N.G. Assessment of ecological state of interior reservoirs of St. Petersburg by method of biogeochemical indication. Materials of 2-nd conf. "*School of ecological geology and rational using of depth*". St. Petersburg, 2001, pp.232-233 (Rus.)

[4] X4. Osmolovskaya N.G., Kurilenko V.V. Ecologo-biogeochemical role of macrophytes in water systems of urban territories (on example of small reservoirs of St. Petersburg). *Ecology*, 3, 2006, pp. 163-169 (Rus.)

[5] X5. Kurilenko V.V., Ufimtseva M.D., Shuvalova A.R., Il'ina M.V., Alekseeva D.A. Behavior of mobile forms of HM in subaquatic and aquatic landscapes. Materials of symposia "*Geochemical barriers in zone of hypergenesis*." Moscow, 1999, pp.243-248 (Rus.)

[6] X6. Åsa Fritioff *Metal accumulation by plants Evaluation of the use of plants in stormwater treatment*. Academic dissertation. Stockholm, 2005

[7] X7. Ufimtseva M.D., Terekhina N.V. *Phytoindication of ecological state of urban geosystems in St. Petersburg.* Nauka, 2005 (Rus.)