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# Duckweed as an indicator for ecological and geochemical state of the environment

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**Abstract**

The article examines the level of several trace and macroelements in duckweed family (lemnaceae) on the territories of Russian Federation. We characterized the average elemental composition of duckweed in Russia. The relationship of the macrophyte chemical composition with the environment were traced. The role of aquatic plant of the duckweed family as an geo-indicator of technogenesis is considered. The distribution of mercury in macrophyte on the studied area was discovered. The high sensitivity of the biological object to the ecological and geochemical state of the environment was revealed. Also local geochemical specifics of the Tomsk region (Russia) were studied, the influence of the Northern industrial zone particularly studied there.

*Keywords: Duckweed, chemical composition, mercury, urbanized territory, geochemical indicator*

## 1. Introduction

The recent problem of geoecology and ecogeochemistry today is to find out theindicators of the environment state, which are characterized by universality, objectivity and a high frequency of occurrence in various natural and climatic regions. Biological objects at the beginning of food chain could be informative and objective indicators of environmental situation and can have comprehensive information for further predictions. Special attention is given to the search for bioindicators, which can be most sensitive than nonliving nature objects, and reflect the degree of influence of ecological and geochemical factor of theenvironment on a living organism too. The search for such bioindicators is

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especially necessary for urbanized areas, which may be characterized by high technogenic pressure.

Duckweed is an aquatic plant that has been of great interest from both fundamental and applied sciences for 50 years. The duckweed family is ubiquitous and has a simple morphological structure (Landolt, 1987). Researchers discovered a high concentration ability of the macrophyte to a wide range of chemical elements. At the moment duckweed is used for wastewater treatment (Favas et al., 2016; Sasmaz et al., 2016; Ekperusi et al., 2019). Macrophyte can respond to changes in the ecological and geochemical state of the environment and repel this changes in own elemental composition. The most important features of that particular biondicator is widespread occurrence, a rapid increase in biomass, as well as growth at the contact of two media (water and air) (Favas et al., 2016; Ceschin S., et al., 2016).

## 2. Materials and research methods

The object of the study was an aquatic plant of the Lemnaceae family. The most common species of the family Lemnaceae in the Russian Federation are Lemna turionifera Landolt, Spirodela polyrhiza (L.) Schleid, Lemna minor L., and Lemna trisulca L. (Bocuk, 2013; Kapitonova, 2019). Usually these species grow together and form common phytocenoses.

Field studies were carried out during the macrophyte growing season, from June to August (from 2013 to 2017). Samples of plants were taken from 65 settlements of the Russian Federation (Fig. 1).

Sampling was carried out independently and with the help of local residents. Samples of duckweed family were taken from drainless water body (surface areas of up to 500 $m^2$) and related to eutrophic lake in terms of their trophic state.

Analytical sample preparation consisted of generic identification of plants, removing of mineral inclusions and living organisms visible bythe naked eye. Then plant samples were dried to air-dry conditions and homogenized in agate mortar.O.A. Kapitonova carried out the species identification of the studied plants on the basis of the Tobolsk Complex Scientific Station of the Ural Branch of the Russian Academy of Sciences.

29 chemical elements in duckweed were studied by instrumental neutron activation analysis at the Tomsk Research Nuclear Reactor IRT-T (analyst, senior scientist A.F.Sudyko).

The content of mercury in duckweed was determined by the method of atomic absorption spectrometry (AAS) using the mercury analyzer "RA-915 +" (Russia) with the attachment "PIRO-915 +" at the International Scientific and Educational Center "Uranium Geology" of the National Research Tomsk Polytechnic University, in the laboratory of trace element analysis. The accuracy of the AAS method was confirmed by the use of the state standard sample LB-1 (GSO 8923-2007).


Fig. 1. Duckweed sampling points in the Russian Federation: 1 - Kaliningrad, 2 - St. Petersburg, 3 - Vekhruechey (Karelia Republic), 4 - Vologda, 5 - Yaroslavl, 6 - Petushki (Vladimir region), 7 - Moscow region (Moscow, Kolomna), 8 – Mosalsk, 9 -Bryansk, 10 - Orel, 11 - Yakshino (Tula region), 12 - Lipetsk, 13 - Podgorensky (Voronezh region), 14 - Tambov, 15 – Simferopol, 16 - Krasnodar, 17 - Novosvobodnaya station (Adygea Republic), 18 - Novaya Teberda (Karachaevo –Cherkessia Republic), 19 - Nizhnyaya Saniba (North Ossetia-Alania Republic), 20 - Stavropol, 21 – Botalovo (Nizhny Novgorod region), 22 - Lesnoy (Penza region), 23 - Saratov, 24 - Znamensky (Mari El Republic), 25 - Yugan (Tatarstan Republic), 26 - Ulyanovsk, 27 - Samara, 28 - Orenburg, 29 - Syktyvkar, 30 - Prosnitsa (Kirov region), 31 - Ufa, 32 - Berezovka (Perm region), 33 - Magnitogorsk, 34 - Kurgan, 35 - Tyumen, 36 - Nizhnevartovsk, 37 - Tomsk district (Tomsk region), 38 - Novosibirsk (Akademgorodok), 39 - Kemerovo, 40 - Barnaul, 41 - Tuim (Khakassia Republic), 42 - Irkutsk, 43 - Ulan-Ude, 44 -Yakutsk, 45 - Khabarovsk, 46 - Petropavlovsk-Kamchatsky

## 3. Research results and discussion

Based on the research findings, the content of 30 chemical elements in the duckweed, which grow on the territory of 65 settlements of Russia was determined.

Statistical processing of the obtained analysis results has been performed. It was observed thatthe content of all chemical elements in duckweed, which we studied, have broad distribution on search territory. We think that it show the high sensitiveness of plant to elemental composition of the environment with close interchange to geochemical situation.

The geometric mean value of 29 chemical elements in plant of Russian Federation was determined based on the results of instrumental-neutron activation analysis. The average content of the studied elements in duckweed does not exceed the n clarkeof noosphere (N. Glazovsky, 1982). It is interesting to note that average elemental composition of macrophyte from north polar region of Russia much lower than in other duckweed (Fig. 2).

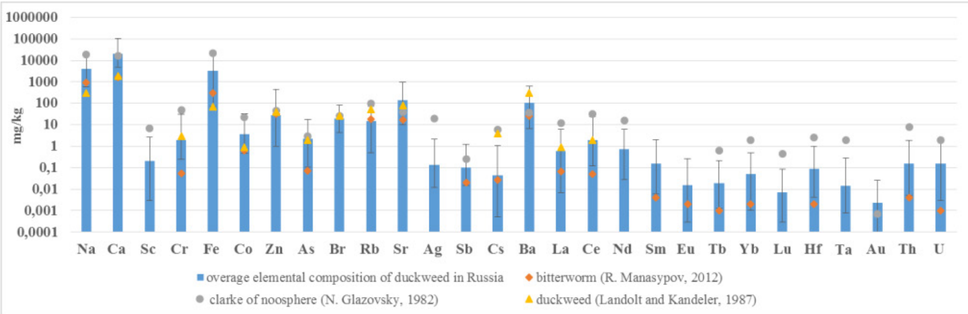


Fig. 2. Average elemental composition of duckweed in Russian Federation

A high correlation ofduckweed elemental composition with habitat was determined. It was revealed that the widest range of elements, which concentrations exceed the average values in Russia, are characteristic of highly urbanized territories with a high anthropogenic load, while the influence of the natural factordeclare itself by the increased values of one or couple of elements in the duckweed.It was revealed that the presence of wide range of elements with high concentrations is the characteristic of the highly urbanized territories.

The indicator ratios of some chemical elements in the plant were also studied. Fig. 3 shows the results of the Th/U ratio values in duckweed on the territory of Russia.

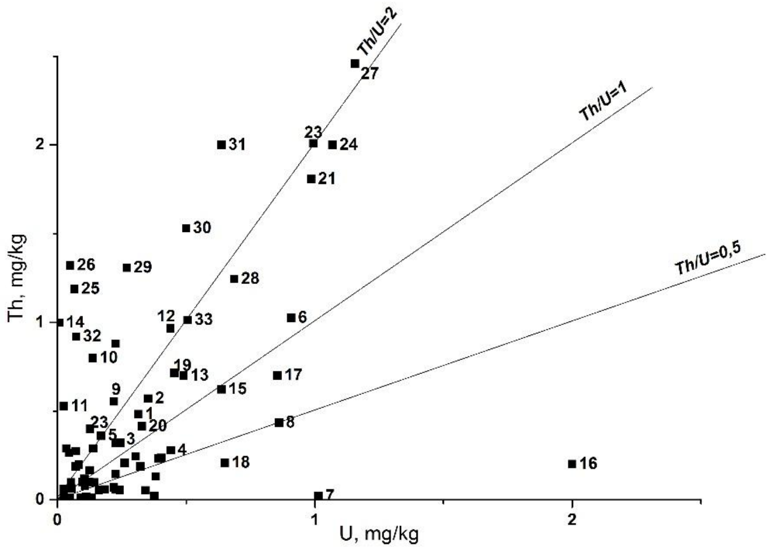


Fig. 3. Th/U ratio in duckweed from urbanized territory of Russia. Duckweed sampling points in the Russian Federation: 1 - Kaliningrad, 2 – Moskow, 3 - Solnechnogorsk, (lake Senezh), 4 - Yakshino (Tula region), 5 - Gus-Khrustalny, 6 - St. Petersburg, 7 - Vyazovka (Orenburg region), 8 – Volgograd, 9 – Stavropol, 10 - Krasnodar, 11 – Kurgan, 12 - Tuim (Khakassia Republic), 13 – Barnaul, 14 - Yurga village (Kemerovo region), 14 - Kolyvan (Novosibirsk region), 15 – Neftyugansk, 16 – Ulan-Ude, 17 - Gazimurskiy Zavod, 18 – Yakutsk, 19 – Khabarovsk, 20 – Partizansk, 21 -Krapivinskoe ilfield (Tomsk region), 22 – Visokiy Yar (Tomsk region), 23 – Tyzyrbak (Tomsk region), 24 - M. Chertany (Tomsk region), 25 – Melnikovo (Tomsk region), 26 - Pobeda (Tomsk region), 27 - Itatka (Tomsk region), 28 – Naumovka (Tomsk region), 29 - Nadejda (Tomsk region), 30 – Temeryazevo (Tomsk region), 31 – Osinovka (Tomsk region)

The average value of Th/U in duckweed is 1,3. Highest values of radioactive elements are founded in duckweed samples from Tomsk region, Ulan-Ude, Vyazovka (Orenburg region) and Gazimurfactory. Chemical composition of duckweedtherecharacterized bythorium nature predominantly.

The content of mercury in the duckweed from Russian Federation was alsodetermined. The average median value of mercury in duckweed is 14.7 ng/g, which is lower than the median value of this ecotoxicant for airborne plants(poplar leaves) from urbanized territories of Siberia and the Far East (23 ng/g) (Yusupov, 2019). The arithmetic mean value of mercury for the studied samples is 18 ng/g, which also does not exceed the background values of mercury for macrophytes (20 ng/g) (Nikanorov, 1985).

We revealed that the content of mercury in duckweed have heterogeneous distribution on the studied area and varies widely: from 4,3 ng/g (Syktyvkar) to 64,8 ng/g (Stavropol). It can indicate about the high sensitivity of the macrophyte to the ecogeochemical state of the environment.

It is worth paying attention to samples of macrophyte with high mercury concentration.Such high concentrations of ecotoxicant are revealed for the following territories: Stavropol (64.8 ± 2.1 ng/g), Prosnitsa village (54.3 ± 2.9 ng/g), Nizhnyaya Saniba village (48.8 ± 1.8 ng/g), Ufa (54.7 ± 3.1 ng/g) and Kemerovo (53.3 ± 1.7 ng/g).These settlements are situated mainly in the western part of the country, while the eastern territory have mercury content, which below the average for duckweed in Russia (Fig. 4).

An abnormally high concentration of mercury in duckweed (54,3 ± 2,9 ng/g) from backwater of the river Prosnitsa (Kirov region) can be a shining example of the technogenesis influence. The ecological and geochemical situation in this area was formed as a result of the impact of the Kirovo-Chepetsk Chemical industrial complex, which uses a mercury electrodes for the production of chlorine and caustic soda (Skugoreva, 2012).
Our data is confirmed by other authors earlier studies, who studied the mercury content in various components of the natural environment on this territory (Skugoreva, 2012; Musikhina et ai, 2015; Eberil, 2005).

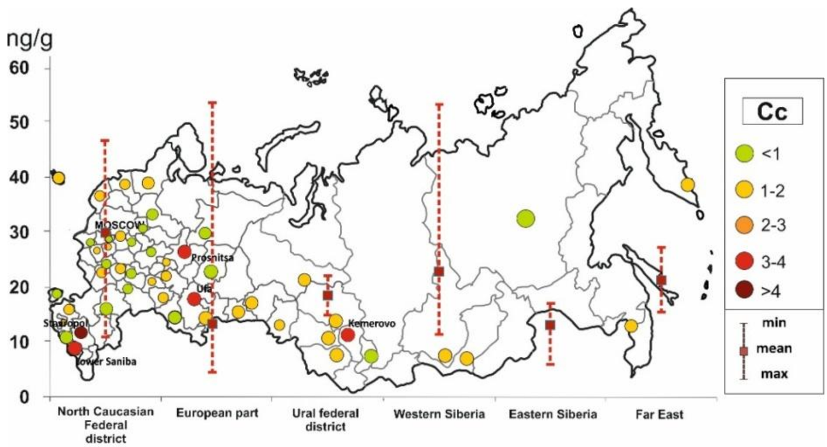


Fig. 4. Schematic map of themercury concentration coefficient ($C_c$) in duckweed from the Russian Federation related to the average median value of the element in the samples

Abnormal concentrations of mercury in duckweed from Kemerovo (53,3 ± 3,2 ng/g) can be indicate the ecological and geochemical situation of the area, which has developed as a result of the natural and technogenic factors influence.

Distribution of mercury was detaillystudiedin the Tomsk district of the Tomsk region, which is characterized by an extremely uneven distribution of industrial facilities (Adam, 1994; Rikhvanov et al., 2006).

The average mercury content in duckweed of the Tomsk region corresponds to the average Russian value(18 ng/g) and does not exceed the background values for macrophytes. At the same time, local areas with high concentration of mercury are observed (20% of the entire sample). These include such settlements as: Georgievka village (34,1 ± 2,8 ng/g), Nadezhda village (30,5 ± 2,8 ng/g), Naumovka village (27,9 ± 1,8 ng/g), Kuzovlevo village (29,9 ± 1,1 ng/g).

These water bodies are located in the main wind rose in the summer season (from the south-south-west to the north-north-east) insidethe 30-km zone, which have influence the Northern industrial hub of Tomsk (SPU). SPU includes a complex of more than 33 diversified facilities (largest complexes of the Siberian Chemical Combine and oil refinery). This territory is characterized by a specific ecological and geochemical situation of mercury pollution, which formed as a result of prolonged exposure to SPU (Adam, 1994; Rikhvanov et al., 2006).

## 5. Conclusion

According to the results of this study, the elemental composition of duckweed in urbanized regions of the Russian Federation were studied.

The analytical results of the average content of 30 chemical elements in duckweed of Russian Federation were presented.

The duckweed ability to concentrate the high amounts of different chemical elements were determined. The relationship of the macrophyte chemical composition with the environment were discovered and high sensitivity of biological object to the ecological and geochemical state of the environment was revealed.

A high sensitivity to mercury was found, what can indicate the influence of anthropogenic sources.The impact of industrial facilities on the concentration of mercury in duckweed is demonstrated in the Tomsk region. Areas with a high pollutant content in duckweed are concentrated in the specificzones with highest technogenic pressure.

Considering the widespread occurrence of duckweed family plants, it can be used as a huge universal indicator of the ecological and geochemical state of the environment.

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