KnE Life Sciences

AgroSMART 2019
International scientific and practical conference
``AgroSMART - Smart solutions for agriculture''
Volume 2019

Conference Paper

Ecological and Physiological Patterns of Selenium Migration within the Volga River Ecosystem

Nikolay A Pudovkin, Denis A Pyrikov, and Petr V Smutnev

Department of Animal Morphology, Pathology and Biology, Faculty of Veterinary Medicine, Saratov State Agrarian University named after N.I. Vavilov, Saratov, Russia

Abstract

The article presents the results of selenium migration analysis within river ecosystem. Maximal concentration of selenium was observed near Tomakovsky and Nazarovsky ravines within Saratov territory. The concentration of this microelement at the right river bank was slightly higher than at the left bank. The concentration of selenium in bottom soil ranged from 0.062--0.099 μg/g. Maximal concentration of microelement was found in clasping-leaved pondweed. Selenium concentration in fish bodies depends on their species and nutrition. Maximal concentration of microelement was found in crucian carps, and minimal -- in rudds.

Keywords: carps, selenium migration, ecosystem, macrovegetation

Corresponding Author:
Nikolay A Pudovkin
niko-pudovkin@yandex.ru

Received: 25 October 2019
Accepted: 15 November 2019
Published: 25 November 2019

Publishing services provided by Knowledge E

Selection and Peer-review under the responsibility of the AgroSMART 2019 Conference Committee.

1. Introduction

Geochemical and biogeochemical processes of biosphere as well as anthropogenic activities result in migration, diffusion and concentration of chemical elements (including microelements) in rocks, soils, water, air, plants and animals, thus, influencing the geochemical balance in a particular geochemical territory.

Recently, the problem of specifying biological role of microelements for population of aqueous ecosystems started to gain attention among hydrobiologists, ichthyologists, fish breeders etc. as it is well known that freshwater ecosystems are some of the most vulnerable to anthropogenic impact. The impact of pollutant on water ecosystem is rather complex, therefore estimation of total anthropogenic impact of aqueous habitat and aquatic organisms, in particular, is a very relevant problem. Fish occupy the top of aquatic food chain, thus they may serve as optimal biological indicators of microelement concentration [2].

The purpose of this study is the investigation of selenium migration patterns within aqueous ecosystem of the Volga River within Saratov territory of Saratov Region.

2. Materials and Methods of Study

Experimental work was conducted in 2018 at the laboratory of ecological monitoring of the Chair of Morphology, Animal Pathology and Biology of the *Saratov State Agrarian University named after Vavilov,* Federal State Budgetary Educational Institution of Higher Education.

The test subjects were chosen from various species of fish prevalent in the Volga River basin (12 specimens for each species were studied): crucian carp *Carassius* (Nilsson, 1832), blue bream *Ballerus ballerus* (L., 1758), silver carp *Carassius gibelio* (Bloch, 1782), common carp *Cyprinus carpio* (L., 1758) and rudd *Scardinius erythrophthalmus* (L., 1758).

The concentration of selenium in aqueous macrovegetation was studied in the following species: mace reed *Typha latifolia* (L., 1753), Canadian pondweed *Elodea Canadensis* (Michx 1803), clasping-leaved pondweed *Potamogeton perfoliatum* (L., 1753) and hornweed *Ceratophyllum* (L., 1753).

The concentration of selenium was also studied in the following shell-fish species: fish mussel *Anodonta piscinalis* (Nillson, 1822); pearl oyster *Unio tumidus* (Philipsson, 1788); pond snail *Lymnaeastagnalis* (Linne, 1758); zebra mussel *Dreissena polymorpha* (Pallas, 1771) -- as well as the following species of planktons and bottom dwellers: scuds *Amphipoda* (Latreille, 1817); oligochaete *Oligochaeta* and midges *Chironomidae* (Jacobs, 1900).

The concentration of selenium was established via fluorometric analysis.

The statistical processing of digital data (including calculation of Student's t-test) was performed using the standard variation statistics software -- Microsoft Excel.

3. Results

First step of this study was the establishment of selenium concentration in the water of the Volga River.

The results of these studies are provided in Table 1.

According to the data provided in Table 1, we can state that maximal concentration of microelement was observed at the areas close to river banks while selenium concentration was lower in the middle of the river.

Maximal selenium concentration was observed at Tokmakovsky and Nazarovsky ravines (0.028 and 0.025 μg/ml, respectively). The concentration of microelement was slightly higher at the right bank than at the left bank.

DOI 10.18502/kls.v4i14.5633

Table 1: selenium concentration in the water of the volga river, μg/ml.

Observation points	Right bank	Middle of the river	Left bank
Guselka river estuary	0.023 ± 0.003	0.021 ±0.004	0.024 ±0.002
Pristannoe village	0.027 ± 0.002	0.023 ± 0.002	0.022 ± 0.003
The city of Engels	0.023 ± 0.004	0.022 ± 0.003	0.020 ± 0.004
The city of Saratov			
Beloglinsky ravine	0.025 ± 0.002	0.021 ± 0.003	0.014 ± 0.005
Krutenky ravine	0.022 ± 0.001	0.021 ± 0.002	0.019 ± 0.003
Tokmakovsky ravine	0.025 ± 0.004	0.019 ± 0.004	0.020 ± 0.003
Nazarovsky ravine	0.028 ± 0.002	0.017 ± 0.002	0.022 ± 0.001

Soils of freshwater continental basins are still relatively underexplored. The bottom soils are formed by mechanical sedimentation and biochemical processes specific for each water entity. The number of mobile forms of microelements, particularly selenium, in the bottom soils increases as their mechanical composition becomes heavier as it changes from sandy to loam soil. Selenium concentration is also affected by composition of parent rocks and soils, climate, ground profile, water characteristics, aquatic organisms' activities and other factors. Therefore, we have studied the bottom soil of the Volga River taken from various points at the territory of the city of Saratov. Results are provided in Table 2.

Table 2: Selenium concentration in bottom soils of the volga river, μg/g.

Observation points	Right bank	Middle of the river	Left bank
Guselka river estuary	0.087 ± 0.004	0.091 ±0.004	0.083 ±0.003
Pristannoe village	0.072 ± 0.002	0.075 ± 0.002	0.068 ± 0.004
The city of Engels	0.068 ± 0.002	0.079 ± 0.002	0.062 ± 0.001
The city of Saratov:			
Beloglinsky ravine	0.083 ± 0.004	0.095 ± 0.004	0.088 ± 0.005
Krutenky ravine	0.091 ± 0.002	0.099 ± 0.005	0.090 ± 0.003
Tokmakovsky ravine	0.085 ± 0.003	0.090 ± 0.004	0.082 ± 0.001
Nazarovsky ravine	0.088 ± 0.001	0.093 ± 0.004	0.081 ± 0.003

According to the experimental data, concentration of selenium in studied ground soils ranged from 0.062 to 0.099 μg/g.

Selenium concentration in the left bank ground soils ranged from 0.062 to 0.090 μg/g. The minimal selenium concentration was observed near the town of Engels -- 0.062 μg/g -- and near Pristannoe village -- 0.068 μg/g, while maximal selenium concentration was observed near Krutenky ravine -- 0.090 µg/g -- and Beloglinsky ravine -- 0.088 µg/g.

Selenium concentration in the right bank ground soils ranged from 0.068 to 0.091 µg/g. The minimal selenium concentration was observed near the town of Engels -- 0.068 µg/g -- and near Pristannoe village -- 0.072 µg/g, while maximal selenium concentration was observed near Krutenky ravine -- 0.091 µg/g -- and Nazarovsky ravine -- 0.088 µg/g.

Aquatic plants -- macrovegetation -- play an important role in microelement (including selenium) migration, therefore, we studied selenium concentrations in most common macrovegetation species of the Volga River. The results of these studies are provided in Table 3.

TABLE 3: Selenium concentration in macrovegetation species of the volga river, µg/g.

Observation points	clasping-leaved pondweed	Canadian pondweed	mace reed	hornweed
Guselka river estuary	0.063 ± 0.005	0.045 ±0.004	0.031 ±0.003	0.023 ±0.004
Pristannoe village	0.051 ± 0.003	0.043 ± 0.001	0.028 ± 0.002	0.019 ± 0.003
The city of Engels	0.051 ± 0.006	0.049 ± 0.005	0.033 ± 0.004	0.025 ± 0.003
The city of Saratov				
Beloglinsky ravine	0.059 ± 0.004	0.042 ± 0.005	0.025 ± 0.001	0.020 ± 0.002
Krutenky ravine	0.058 ± 0.003	0.043 ± 0.001	0.023 ± 0.005	0.024 ± 0.001
Tokmakovsky ravine	0.071 ± 0.007	0.051 ± 0.003	0.032± 0.002	0.018 ± 0.002
Nazarovsky ravine	0.072 ± 0.006	0.047 ± 0.004	0.029 ± 0.004	0.021 ± 0.003

According to the data provided in Table 3, the concentration of selenium in studied aquatic plants decreased in the following order: clasping-leaved pondweed (0.061 µg/g), Canadian pondweed (0.046 µg/g), mace reed (0.029 µg/g) and hornweed (0.021 µg/g).

Clasping-leaved pondweed was the most selenium-saturated plant while hornweed was the least selenium-saturated plant. Mace reed -- a riparian species -- contains less selenium than submerged plant species -- clasping-leaved pondweed and Canadian pondweed.

We have also studied selenium concentration in planktons and bottom dwelling species. These organisms extract inorganic selenium compounds from water.

Planktons and bottom dwelling species can be considered as the most important parts of aquatic food chains which play an important role in concentration and biological migration of selenium. Their grand biological value is contributed to their ability to extract inorganic microelement compounds and transform them to organic compounds, thus transferring them to higher food chain levels.

The results of selenium concentration studies for planktons and bottom dwelling species are provided in Table 4.

Table 4: Selenium concentration in macrovegetation species of the volga river, μg/g.

Observation points	Organism species		
	Scuds	Oligochaete	Midges
Guselka river estuary	0.038 ± 0.005	0.043 ±0.004	0.039 ±0.005
Pristannoe village	0.039 ± 0.004	0.041 ± 0.003	0.042 ± 0.003
The city of Engels	0.040 ± 0.004	0.042 ± 0.006	0.035 ± 0.003
The city of Saratov			
Beloglinsky ravine	0.036 ± 0.003	0.040 ± 0.005	0.042 ± 0.004
Krutenky ravine	0.038 ± 0.004	0.042 ± 0.005	0.050 ± 0.004
Tokmakovsky ravine	0.042 ± 0.005	0.043 ± 0.003	0.039± 0.005
Nazarovsky ravine	0.039 ± 0.002	0.041 ± 0.003	0.038 ± 0.004

According to the results provided in Table 4, we can state that all studied planktons and bottom dwelling species accumulate selenium more or less evenly.

The highest microelement concentration was observed for oligochaete. Average selenium concentration in studied species decreased from oligochaete (0.042 μg/g) to midges (0.041 μg/g) to scuds (0.039 μg/g).

Shell-fishes play an important role in aquatic ecosystems; however the concentration of selenium in shell-fishes inhabiting the Volga river has not been fully determined yet. Therefore, we studied the dominant shell-fish species inhabiting the Volga River.

The results of these studies are provided in Table 5.

According to the analysis results, we can state that selenium concentration for all studied species was very close; however, fish mussel has a greater selenium concentration compared to other species. Average selenium concentration in studied species decreases as follows: fish mussel (0.044 μg/g) -- pearl oyster (0.042 μg/g) -- pond snail (0.040μg/g) -- zebra mussel (0.040μg/g).

We also studied selenium concentration for several prevalent fish species. The results of these studies are provided in Table 6.

According to analysis results provided in Table 6, we can state that the ability of studied species to accumulate selenium decreased in the following order: crucian carp

Table 5: Selenium concentration in shell-fish species of the volga river within the saratov territory area, µg/g.

Observation points	Shell-fish species			
	fish mussel	pearl oyster	pond snail	zebra mussel
Guselka river estuary	0.045 ± 0.001	0.042 ±0.005	0.041 ±0.004	0.035 ±0.004
Pristannoe village	0.049 ± 0.005	0.042 ± 0.004	0.042 ± 0.003	0.041 ± 0.005
The city of Engels	0.042 ± 0.003	0.038 ± 0.001	0.039 ± 0.002	0.037 ± 0.003
The city of Saratov:				
Beloglinsky ravine	0.042 ± 0.005	0.039 ± 0.003	0.040 ± 0.004	0.039 ± 0.002
Krutenky ravine	0.045 ± 0.002	0.049 ± 0.002	0.039 ± 0.003	0.044 ± 0.003
Tokmakovsky ravine	0.047 ± 0.003	0.037 ± 0.001	0.042 ± 0.004	0.042 ± 0.005
Nazarovsky ravine	0.044 ± 0.002	0.043 ± 0.002	0.043 ± 0.005	0.039 ± 0.004

Table 6: Selenium concentration in the tissues of various carp species, µg/g.

Body part	Name of the species				
	crucian carp	blue bream	silver carp	common carp	rudd
Gills	0.078 ± 0.007	0.085 ± 0.008	0.088±0.007	0.071±0.003	0.073±0.006
Intestines	0.067 ± 0.005	0.069 ± 0.006	0.080±0.004	0.056±0.004	0.071±0.002
Reproductive glands	0.074 ± 0.004	0.079 ± 0.005	0.084±0.005	0.068±0.006	0.069±0.003
Muscles	0.047 ± 0.003	0.052 ± 0.006	0.065±0.003	0.058±0.003	0.053±0.003
Liver	0.089 ± 0.008	0.091 ± 0.009	0.095±0.007	0.086±0.007	0.079±0.005
Swim bladder	0.051 ± 0.006	0.057 ± 0.003	0.053±0.004	0.043±0.002	0.046±0.004
Scales	0.082 ± 0.003	0.072 ± 0.006	0.069±0.001	0.077±0.003	0.088±0.008

(0.079 µg/g); silver carp (0.073 µg/g); blue bream (0.072 µg/g); common carp (0.069 µg/g) and rudd (0.068 µg/g). The differences between species were up to 14 %.

The concentration of selenium in gill tissue ranged from 0.071 to 0.088 µg/g. The average concentration of microelement in gill filaments of studied species decreased as follows: silver carp; blue bream; crucian carp; rudd; common carp.

The primary source of selenium for fishes is their nutrition. The concentration of microelement in their intestines ranged from 0.056 to 0.080 µg/g. The highest microelement concentration was observed in silver carp intestines.

For reproductive glands, the lowest selenium concentration was observed for common carp and rudd (0.068 and 0.069 µg/g, respectively) while the highest concentration was observed for silver carp (0.084 µg/g). The difference between species was 23.5 %.

We also found that scales of studied fish species contain a high amount of selenium (selenium concentration ranges from 0.069 to 0.088 μg/g).

The concentration of selenium in skeletal muscles of studied fish species increases in the following order: crucian carp < blue bream < rudd < common carp < silver carp.

4. Discussion

The results of our studies showed that selenium concentration in the Volga river water was spread unevenly and that microelement concentration is influenced by various natural and anthropogenic factors. The concentration of selenium at the middle of the river was lower than near the river banks. This can be explained by a faster flow and more intensive water mixing. Microelement concentration also depends on intensity of industrial discharge which is most intensive in lower urbanized zone (the area of Tokmakovsky and Nazarovsky ravines). This corresponds to the highest selenium concentrations of 0.028 and 0.025 μg/ml, respectively.

A slightly higher concentration of microelement was observed near the right bank (compared to the left bank) which can be attributed to higher anthropogenic impact on that area.

The studies of selenium concentration in bottom soil revealed that concentration of selenium in bottom soil was greater in the samples taken from the middle of the river than in samples taken from the river banks. This can be explained by lower microbiological activity of organic remains decomposition and lower amount of growing plants in the area. The maximal concentration of microelement was observed for the bottom layer as it is accumulated by sedimentary rocks [1].

The studies of selenium concentration in macrovegetation species revealed that submerged species had a higher selenium amount compared to riparian species. This may be attributed to the fact that submerged plants have a greater area of selenium absorption.

The provided plants example shows a full evidence of geochemical heterogeneity of aqueous ecosystem. In such ecosystems, selenium is one of regulators of aquatic organism metabolisms, therefore, selenium deficiency in primary components of aquatic ecosystems restricts matter transformation processes, decreases photosynthesis intensity and negatively affects the fish capacity of the water basin [3].

Selenium concentration in planktons, bottom dwelling species and mollusks is greatly affected by its concentration in water as most mollusks have a sedentary life cycle and are involved in water filtration. The depth of species habitat also affects selenium accumulation.

The studies of selenium concentration in freshwater fish species organism revealed that fish liver contained the highest amount of selenium which is understandable considered the detoxication and protein synthesis functions of this organ. A relatively high concentration of this microelement was also observed in fish scales which can be attributed to uptake functions of this tissue [4].

High microelement concentration in gill filaments can be caused by functional characteristics of this organ as a small amount of selenium may enter fish organism during the breathing process.

We have also found that herbivorous fish species contained a greater amount of selenium that omnivorous species. The species whose primary ration includes invertebrates rarely accumulated more selenium than contained in their food.

High concentration of proteins and easily oxidized substrates in reproductive products lead to accumulation of selenium in these tissues as selenium is contained in several proteins. Moreover, reproductive cells contain mineral substances required for proper development of embryo [5, 6].

The lowest selenium concentration for studied species was observed in their skeletal muscles; however, as these muscles are top contributors to total body weight of fishes, they might be capable of performing uptake and redistribution of this microelement in the fish body.

5. Conclusions

We have established that selenium concentration in water is distributed unevenly. Maximal selenium concentration was observed at Tokmakovsky and Nazarovsky ravines (0.028 and 0.025 μg/ml, respectively). The concentration of microelement was slightly higher at the right bank than at the left bank.

Selenium concentration in the left bank ground soils ranged from 0.062 to 0.090 μg/g. The minimal selenium concentration was observed near the town of Engels -- 0.062 μg/g -- and near Pristannoe village -- 0.068 μg/g, while maximal selenium concentration was observed near Krutenky ravine -- 0.090 μg/g -- and Beloglinsky ravine -- 0.088 μg/g.

Average selenium concentration in studied plankton and bottom dwelling species decreased from oligochaete (0.042 μg/g) to midges (0.041 μg/g) to scuds (0.039 μg/g).

The ability of studied species to accumulate selenium decreased in the following order: crucian carp (0.079 μg/g); silver carp (0.073 μg/g); blue bream (0.072 μg/g); common carp (0.069 μg/g) and rudd (0.068 μg/g). The differences between species were up to 14 %.

References

[1] Lu, Y., Zhang, A., Li, C., Zhang, P., Li, T. (2013). The link between selenium binding protein from Sinonovacula constricta and environmental pollutions exposure. *Journal Fish & Shellfish Immunology*, vol. 35, iss. 2, pp. 271--277.

[2] Pudovkin, N.A., Salautin, V.V., Garipov, T.V., Karimova, R.G., Salautina, S.E. (2018). Seasonal changes of free-radical initiated processes in cyprinids from the middle Volga river basin. *Journal Bulgarian Journal of Veterinary Medicine*, vol. 21, no. 4, pp. 478--483.

[3] Rene Buesa, J. (1990). Light assimilation curves of some tropical macroscopic marine plants. *Journal Aquatic Botany*, vol. 37, iss. 4, pp. 315--324.

[4] Thresher, R.E. (1999). Elemental composition of otoliths as a stock delineator in fishes. *Journal Fish & Shellfish Immunology*, vol. 43, iss. 1--3, pp. 165--204.

[5] Zheng, L., Feng, L., Jiang, W.D., Wu, P., Liu, Y. (2018). Selenium deficiency impaired immune function of the immune organs in young grass carp (Ctenopharyngodon idella). *Journal Fish & Shellfish Immunology*, vol. 77, pp. 53--70.

[6] Zheng, L., Jiang, W.-D., Feng, L., Wu, P., Liu, Y. (2018). Selenium deficiency impaired structural integrity of the head kidney, spleen and skin in young grass carp (Ctenopharyngodon idella). *Journal Fish & Shellfish Immunology*, vol. 82, pp. 408--420.