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# Variations in mercury concentrations in the muscles of fish in biotopes within the water body and in different water bodies of Russia

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**ABSTRACT.** In recent decades, researchers from Papanin Institute for Biology of Inland Waters Russian Academy of Sciences have been studying mercury concentrations in the muscles of fish from water bodies situated in different natural and climatic zones. Overall, more than 5000 fish samples from 102 lakes and 35 rivers in Russia were analysed. In the absence of local sources of mercury entering the water body, its concentrations in the fish muscles varied in wide ranges, exceeding two orders of magnitude. Minimum concentration (<0.03 mg/kg wet weight) was recorded in the muscles of omul, rotan (Chinese sleeper), minnow, and bleak (Lake Baikal, Transbaikalia and European Russia). Maximum mercury concentration (2-3 mg/kg wet weight) was recorded in the muscles of perches from lakes in the northwest of Russia (Vologda and Novgorod regions, Karelia). Most of the measurement results ranged from 0.05 to 0.30 mg/kg wet weight. Differences in mercury concentrations in the muscles of fish of the same species, similar in size and from one water body, as a rule, did not exceed ranges of one order of magnitude. In the absence of local mercury sources, mercury concentrations in fish muscles from closely spaced water bodies could have more than tenfold differences.

***Keywords*:** mercury, fish, muscles, rivers, lakes

## 1. Introduction

In the Russian Federation, there are a great number of various water bodies that differ in morphometric, hydrological, hydrochemical, and hydrobiological parameters. Fish inhabit many water bodies, which are traditionally an object of fishing and an essential part of the diet of the population. However, the concept of the nature of mercury distribution in muscles of different fish species from different water bodies of the Russian Federation has not yet been formulated. In this regard, the aim of this analysis was to compare mercury concentrations in the muscles of fish caught at closely spaced stations of one or several water bodies situated in different geographical regions.

## 2. Materials and methods

Fish were caught by all possible legal methods depending on the conditions and tasks: fixed nets, seine nets and fishing rod. The caught fish were weighed; the length was measured, and a muscle sample was taken below the dorsal fin. If the conditions did not allow us to do this, the fish was frozen and stored until analysis at -14 to -4 $C^0$. During long expeditions, muscle samples were dried in air (in the absence of refrigerators), then stored in a freezer under laboratory conditions and dried in a thermostat before analysis. Mercury was determined on the Russian analysers: Yuliya 2 until 2007 and RA-915 with the PYRO attachment since 2007. For data control, a certified reference material for trace metals, Dorm II (dogfish muscles, Canadian Institute of Environmental Chemistry), with a standard mercury concentration, was used.

## 3. Results and discussion

Rybinsk Reservoir. The difference between minimum and maximum mercury concentrations in the muscles of the perch from the Rybinsk Reservoir was almost tenfold. Over the past thirty years, there has been a four- or fivefold decrease in mercury concentrations in the muscles of perch from the Sheksna reach (up to 0.10-0.20 mg/kg wet weight) and an increase (up to 0.20-0.30 mg/kg wet weight) in fish from Mologa and Volga reaches. A decrease in mercury concentration in the muscles of perch can be explained by technological reequipment of production in Cherepovets, which was conducted in the 1990s. For all parts of the reservoir, we determined a statistically significant dependence

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of mercury concentration in muscles on the size and weight characteristics. There was a correlation between mercury concentration in the muscles of perch and its concentration in the bottom sediments ($r = 0.95$; $p < 0.047$). The complex multi-component ecosystem of the Rybinsk Reservoir, as well as the interaction of many abiotic and biotic factors that have been poorly controlled and even ignored until recently, did not allow us to propose a simple explanation of the change in mercury concentration in muscles of perch in recent decades. Furthermore, mercury was accumulated in different directions in separate parts of the water body (Gremyachikh et al., 2019).

Lakes of Darwin Nature Reserve, Vologda Region. For the first time in Russia, high mercury concentrations (>0.5 mg/kg wet weight) in the muscles of perch from lakes that do not have local mercury sources in the watershed were recorded in 1989 during the expedition to Darwin Nature Reserve (Haines et al., 1992). The difference between the minimum mercury concentrations in the muscles of perch from the lake with neutral water pH values (~0.10 mg/kg wet weight) and the maximum ones (3.01 mg/kg wet weight) in perch from the acidotrophic (pH<5.0) dark-water lake was more than 30-fold (Haines et al., 1992). At the same time, the size and weight characteristics of the perch from acidotrophic lakes were lower than in the perch from the lake with neutral water pH values. In the perches from acidotrophic lakes, mercury concentrations in muscles did not depend on size and weight characteristics. Long-term changes in mercury concentrations in the muscles of fish from different lakes were multidirectional. For 25 years, mercury concentration in the muscles of perch increased (acidotrophic clear-water lakes Dorozhiv, Temnoye and Motykino), decreased (acidotrophic dark-water Lake Dubrovskoye) or did not change (neutral Lake Khotavets, acidotrophic dark-water lakes Uteshkovo and Zmeinoye) (Komov et al., 2015). Based on data from 1989, there was a statistically significant negative relationship between mercury concentration in perch muscles and the maximum chlorophyll concentration in lake waters during the vegetation period.

Lakes of Rdeysky Nature Reserve, Novgorod Region. The Polistovo-Lovatsky raised bog landscapes are one of the largest areas in Europe. Any economic activity and the presence of humans here are minimal or absent. The lakes in this bog area are shallow and inhabited primarily by perches. Only in some lakes, pikes are also found. At the same time, the variability of mercury concentrations in the muscles of the perches from these lakes was very high. The lowest recorded mercury concentrations in the muscles of perches from lakes Dolgoye, Domshinskoye and Ostrovistoye (0.04 to 0.07 m/kg wet weight) were 30 to 60 times lower than the maximum concentrations in the muscles of the perch from Lake Bolshoye Goretskoye (2.40 mg/kg wet weight). As a rule, the differences in mercury concentrations in the muscles of perches from each lake were 1.5- to 4-fold. Mercury concentrations in muscles did not depend on size and weight characteristics. Maximum accumulation of mercury was detected in fish from lakes with minimum specific watershed (Bolshoye Goretskoye Lake and Maloye Goretskoye Lake), and the minimum mercury concentrations in muscles were typical of lakes with a specific watershed exceeding 8 (Komov et al., 2009). The role of the watershed basin as a factor influencing the intensity of mercury accumulation in fish may include: i) evaporation of mercury from the area uncovered by water; ii) mercury absorption by peatlands; iii) change in the amount of nutrients in the surface runoff of water entering the lakes.

Rivers and lakes of Oka Nature Reserve, Ryazan Region. Mercury concentrations in the muscles of the perches from water bodies and watercourses of the Oka basin in Oka Nature Reserve varied in a wide range of values: from the minimum concentrations (0.01 mg/kg wet weight) recorded in rotan and bream to the maximum concentrations (1.94 mg/kg wet weight) in pike (Gremyachikh et al., 2012). As a rule, mercury concentrations in the muscles of the perches inhabiting lakes were lower than in the fish from rivers. Mercury concentrations in the muscle of perch and pike depended on size and weight characteristics as well as on age of perch. Higher mercury concentrations in the muscles of the perch from the Pra River compared to fish from other rivers and lakes of the reserve, as well as the Volga reservoirs, may be due to the influence of the surface runoff from wetlands. In predatory fish species, mercury concentrations were higher than in non-predatory ones. However, high mercury concentrations in the muscles of silver bream (non-predatory species) and moderate concentrations in the muscles of burbot may indicate the dietary habits of these species.

The Kuybyshev Reservoir, the largest in the Volga River basin, has a length of more than 500 km and is located in five regions of the Russian Federation. Mercury concentrations in the muscles of the perch from the Kuybyshev Reservoir ranged from 0.05 to 0.59 mg/kg, averaging 0.20 mg/kg wet weight throughout the reservoir, which corresponded to the results obtained in other Volga reservoirs (Telezhnikova et al., 2020). Mercury concentration had statistically significant positive correlation with weight and age of the perch. There was no correlation between mercury concentration and the abundance /biomass of aquatic organisms at the sampling sites. The perches inhabiting river areas of the reservoir accumulated more mercury than the perches inhabiting lake part of the reservoir.

The Selenga River basin and Lake Baikal. The identified differences between the mercury accumulation levels in the muscles of the fish from lakes Gusinoye and Karasinoye (Selenga basin) and the fish from the Selenga River may indicate insignificant amount of mercury entering the aquatic ecosystems with precipitation and larger-scale migration of mercury with river runoff. Minimum mercury concentrations (<0.15 mg per 1 kg dry weight) were recorded in the muscles of the rotan from Lake Karasinoye and Baikal omul; the maximum concentrations (1.0 to 2.3 mg/kg dry weight) were recorded in predators (pike, catfish and perch) and euryphages (roach and ide) from the Selenga River delta (Komov et al., 2014). The mercury

accumulation in the muscles of the dace decreased downstream the river.

## 4. Conclusions

Mercury concentrations in the muscles of fish from rivers and lakes in the central and northwestern parts of European Russia were, as a rule, higher than in the muscles of fish from water bodies in the Selenga River basin. High mercury concentrations (>0.5 mg/kg wet weight) were recorded in the muscles of the fish inhabiting i) rivers and lakes in areas with high waterlogging degree, ii) large reservoirs and iii) the Selenga River delta.

## Conflict of interest

Authors declare no conflict of interest.

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