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# Characteristics of Hg accumulation in mushrooms and fish in areas disturbed by mining activity (Western Siberia)

Gustaytis M.A.[1,2]*, Myagkaya I.N.[1]

[1] V.S. Sobolev Institute of Geology and Mineralogy SB RAS, Novosibirsk, Academician Koptyug Ave, 3, 630090, Russia.
[2] Novosibirsk State University, Novosibirsk, Pirogov Str, 1 630090, Russia.

**ABSTRACT.** We studied the distribution of Hg in mushrooms and fish on the example of three objects (Kurai mercury zone, Ursk ore field and Saralinsk ore field) located in the area with the elevated geochemical background of this element (Altai-Sayan province) and affected by the mining waste. Maximum mercury concentrations in mushrooms and fish were observed in the Ursk ore field. Both in mushrooms and in fish, Hg concentrations exceeded MPC, posing significant human health risks if consumed.

***Keywords:*** mercury, fish, mushrooms, bioconcentration factor

## 1. Introduction

The impact of food polluted by potentially toxic elements on human health is recognised as a global problem (Franco-Uría et al., 2009; Machado et al., 2017). Anthropogenic activity and industry led to a significant release of heavy metals and other pollutants into the environment (Hajeb et al., 2009).

Mushrooms and fish, being a source of various minerals and vitamins, can actively accumulate heavy metals, which allows considering them a source of chronic poisoning of people (Racz et al., 1996). Mercury occupies a special position among toxicants because it has a wide variety of chemical forms in nature, and its compounds are extremely toxic, especially in the form of methylmercury (Kuzubova et al., 2000). World Health Organization established the values of the maximum weekly human intakes of total mercury and methylmercury at a level of 300 and 200 µg, respectively. However, some species of higher fungi accumulate mercury in their sporocarps in higher concentrations, up to 32 µg/g (Gustaitis et al., 2016). Also, these food products can be indicators of mercury pollution in the environment. This study aimed to identify the characteristics of Hg accumulation in food products in areas with elevated geochemical background of this element and additional technogenic activities.

## 2. Materials and methods

Three objects within the Altai-Sayan mercury province were selected for the study. The first object belongs to the Kurai mercury zone of Gorny Altai (Ulagan District, Aktash settlement) where the deposits and ore occurrences of Hg are located with a high density. Near the Aktash settlement, there are remains of the Aktash Mining and Metallurgical Enterprise (AMME) that develops the mercury deposit of the same name. This area is recognised as a territory with a high level of accumulated environmental damage. The AMME dumps of are stored on the banks of the Yarly-Amry River and are carried into it by rains, melt water and wind. Soils of intermountain basins are used in agriculture, but their formation occurs with active participation of matter brought from other geomorphological positions (Robertus et al., 2015).

The second object is located within the Salair mercury zone in the Ursk volcanoplutonic structure of the Salair Ridge (Kemerovo Region, Ursk settlement), in the area of Novo-Ursk gold-bearing sulfide ore deposit and its tailings dumps. Cyanidation and amalgamation waste are carried to a waterlogged ravine (Myagkaya et al., 2022). Initially, Hg was present in ores in the form of cinnabar, thin inclusions of mercury telluride and mercury selenide in pyrite and barite. We also assume that Hg is present in pyrite in the form of an isomorphic admixture and as a physically sorbed form ($HgCl_2$ and $Hg^0$) that, according to some data, can be localised in crystal defects (Gustaitis et al., 2010).

The third object is located within the Saralinsk ore field in the area of the Kuznetsk Alatau (Ordzhonikidzevsky District, Priiskovy settlement and Ordzhonikidzevsky settlement, the Republic of Khakassia) and has belonged to the mining industry

*Corresponding author.
E-mail address: gustaitis@igm.nsc.ru

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(Au mining) since 1834. Initially, Au was mined from placers and ores by amalgamation (Shirokikh et al., 1998). The Saralinsk tailings dump of gold-bearing sulfide ores is situated in close proximity to the Priiskovy settlement; nearby areas (Ordzhonikidzevsky settlement) experience the anthropogenic impact of the mining industry.

Samples of fish and mushrooms were taken for the study within the selected study objects. Fish samples were divided according to the food type (predators and nonpredators); mushroom samples – according to the species (agaricales and spongy). To calculate the bioconcentration factor (BCF) (BCF; Formula 1), soil and water were sampled together with mushrooms and fish, respectively.

$$BCF = \frac{C_{foodproduct}}{C_{habitat}} \qquad \text{Formula 1,}$$

where $C_{food\ product}$ is Hg concentration in mushrooms or fish (µg/g), and $C_{habitat}$ –Hg concentration in soil or water (µg/g or µg/L).

In the Kurai mercury zone, four sites were tested (Lake Cheybekkel, Lake Geizernoe and water bodies in the Aktash settlement and Kurai steppe). The Kurai steppe was considered a background site because it is a zone of removal of matter from the surrounding areas. In the Ursk ore field, three sites were tested (water bodies above the influence of the tailings dump considered as background, water bodies in the area of the tailings dump and water bodies in the influence zone of the tailings dump). In the Saralinsk ore field, three sites were tested (water bodies in the surroundings of the Priiskovy settlement, including the Bezymyanny stream, and water bodies near the tailings dump in the Priiskovy settlement).

Muscle tissue weighing 20 to 25 gram was sampled immediately after catching fish with a plastic tool (Popov et al., 2018). Soil was sampled using a ring with a diameter of 10 cm in depth by the indentation technique. The samples (soil, mushrooms and fish) were dried under laboratory conditions to an air-dry state at 20–22 ˚C, avoiding exposure to sunlight.

The Hg concentration in water was determined by the cold vapor method, followed by atomic absorption detection (AAS; RA-915M analyzer with the RP-92 attachment manufactured by Lumex (Russia) (ISO 12846-2012). Detection limit was 0.02 µg/L; the method error was up to 20%. The total Hg concentration in solid samples was determined by AAS (RA-915M analyzer with the RP-91C pyrolytic attachment according to the PND F 16.1:2:2.2.80-2013 (M 03-09-2013) method). The detection limit was 0.01 µg/g; the method error was less than 20%. The correctness of Hg measurements was controlled using standard samples of the SDPS-3 composition (sod-podzolic soil) and ERM-CE464 (Tuna fish).

## 3. Results and discussion

Edible mushrooms tend to accumulate toxic elements in areas of industrial emissions. Moreover, this ability is manifested in them much greater than in higher plants and other organisms (Gorbunova, 1999). Hg concentration in mushrooms from the studied sites varied from 0.052 to 32 µg/g (Fig. 1). Mushrooms from the studied areas were divided into agaricales and spongy, but we did not detect any difference in Hg accumulation. Notably, Hg concentrations did not exceed MPCs at all studied sites. MPCs were 1.2 to 34 times exceeded in the Saralinsk ore field, 4 to 80 times – in the Kuray mercury zone, and from 3.4 to 642 times (the maximum value among all objects) – in the Ursk ore field.

The BCF values for mushrooms indicated (Fig. 1) that the highest Hg concentration was observed in the Ursk ore field. Within the Kurai ore zone, active mercury accumulation occurred near Lake Geizernoe; within the Usk ore field – near ore dumps. In the Saralinsk ore field, the maximum BCF was recorded in the vicinity of the Priiskovy settlement located near the tailings dump. The concentration degrees in the studied objects varied from low to moderate.

Hg concentrations in fish of all objects ranged from 0.02 to 1.35 µg/g (Fig. 2). In the Kurai mercury zone, there was no excess of MPC in fish, while mercury concentrations in fish from the studied sites in the Ursk ore field and the Saralinsk ore field exceeded MPC (2-4 times and 2.4 times, respectively, according to SanPiN 2.3.2). BCF values for fish (Fig. 2) indicated the active mercury accumuation in the area of the Ursk ore field both at background sites and in water bodies subjected to technogenic impact. In the Saralinsk ore field, mercury absorption in fish was active only in water bodies subjected to technogenic impact. The concentration degree in the studied objects was classified as low. Notably, individuals of predatory fish species sampled in the water bodies of the Saralinsk

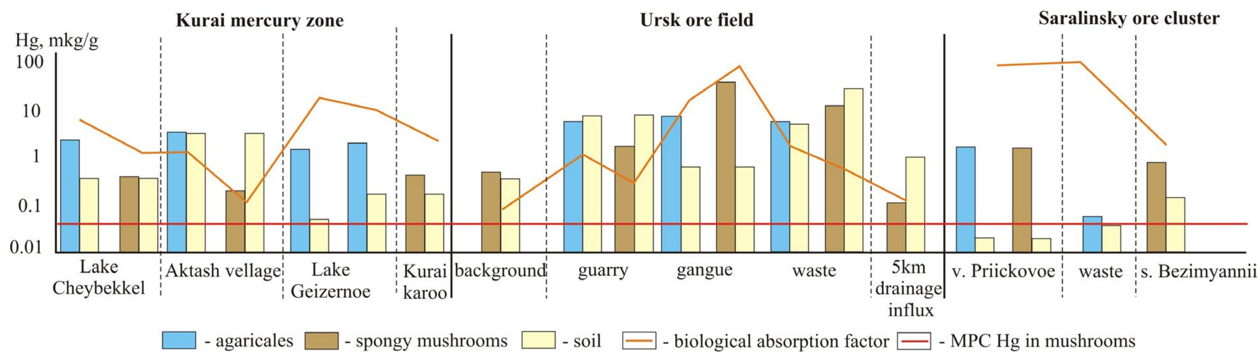


**Fig.1.** Mercury distribution in soil-mushrooms of the studied areas.

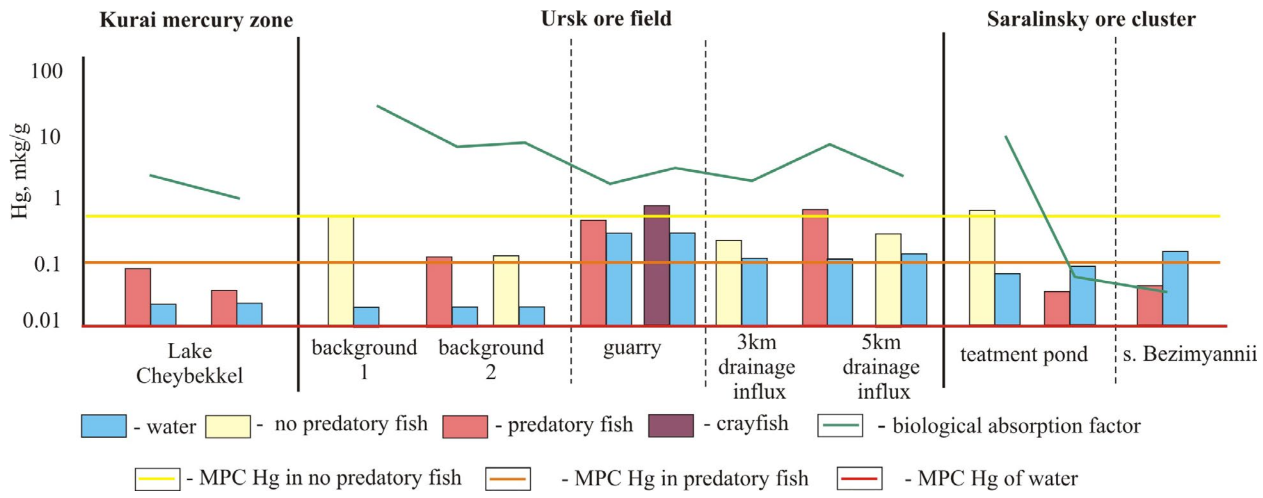


**Fig.2.** Mercury distribution in the water-fish system of the study areas.

ore field had much lower mercury concentrations than other studied species. This was likely due to the small length of the studied fish (8-10 cm) than the peculiarity of this species. However, according to the literature, 95% of the organic mercury in fish was present in the methylated form (Watras and et al., 1995). Therefore, the consumption of fish in the studied areas is extremely dangerous.

## 4. Conclusions

This study revealed that in areas subject to technogenic pressure in the form of mining waste, Hg was actively accumulated in mushrooms and fish. In areas with elevated geochemical background of Hg (mercury province) without technogenic pressure, there was less active mercury accumulation in mushrooms and fish.

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## Conflict of interest

The authors declare no conflict of interest.

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