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Mercury in the Baikal aquatic ecosystem (Lake Baikal, its tributaries, Angara River source)

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ABSTRACT. This article discusses the features of mercury distribution in the water of the Baikal ecosystem. We present an analysis of Hg concentrations in the surface and deep water of Lake Baikal, its outflow, the Angara River, and the largest tributaries of Lake Baikal. The study revealed that all significantly elevated mercury concentrations in Baikal water were preceded by earthquakes or geodynamic impacts. We propose a death of Baikal endemic species, Baikal seal, due to mercury intoxication.

Keywords: mercury, earthquake, water, Lake Baikal, tributaries, Angara River source

1. Introduction

Lake Baikal is located in the Baikal Rift Zone (BRZ) (Fig. 1.) characterized by frequent earthquakes and geodynamic impacts (Grebenshchikova et al., 2020; 2021). An average thickness of the Earth's crust under the central part of the Baikal basin is about 36 km. The basement within the southern Baikal depression appears to have a very imbricate structure due to many faults and frequent earthquakes occurring here.

Previous studies in the Baikal region revealed that significant changes in climate and water level of Lake Baikal can occur approximately in the space of a single century. It was also shown that surface water in Lake Baikal moves horizontally counterclockwise, and the water movement in its three basins is even more complex. The dynamic uplift of deep water was suggested for Lake Baikal previously (Didenkov et al., 2006; Troitskaya et al., 2022). Scientific research proved the rise of deep waters and the lowering of surface waters along the coasts (upwelling/downwelling) (Shimaraev et al., 2012).

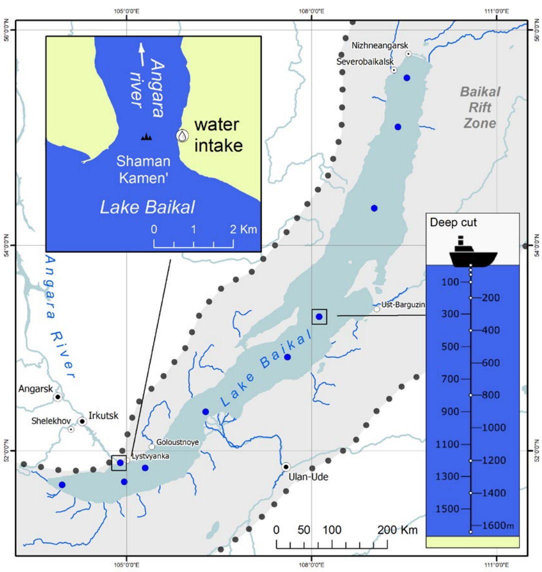

Fig.1. Scheme of water sampling in the Baikal aquatic ecosystem (Angara River source, surface and deep Baikal water, and water from the tributaries) for chemical analyses (Grebenshchikova et al., 2021).

2. Materials and methods

In winter, Lake Baikal freezes, but the water of the source of the Angara River does not freeze because warm water comes from under the ice Baikal thermocline to the Angara River. This feature makes water sampling at the river source possible all year round and, hence, long-term geochemical monitoring studies (1950-2022).

Measurements of mercury concentrations in water samples were carried out using the atomic absorption method with flameless determination of vapors of reduced atomic mercury on an RA-915+ instrument with an RP-91 attachment. The measurement accuracy was controlled by annual testing and adjustment of the instrument by the manufacturer (LUMEX, St. Petersburg). Chemical analysis of water samples was performed using the equipment of the certified Center of Collective Use for Isotope-Geochemical Research at the Institute of Geochemistry, SB RAS (Irkutsk, Russia)

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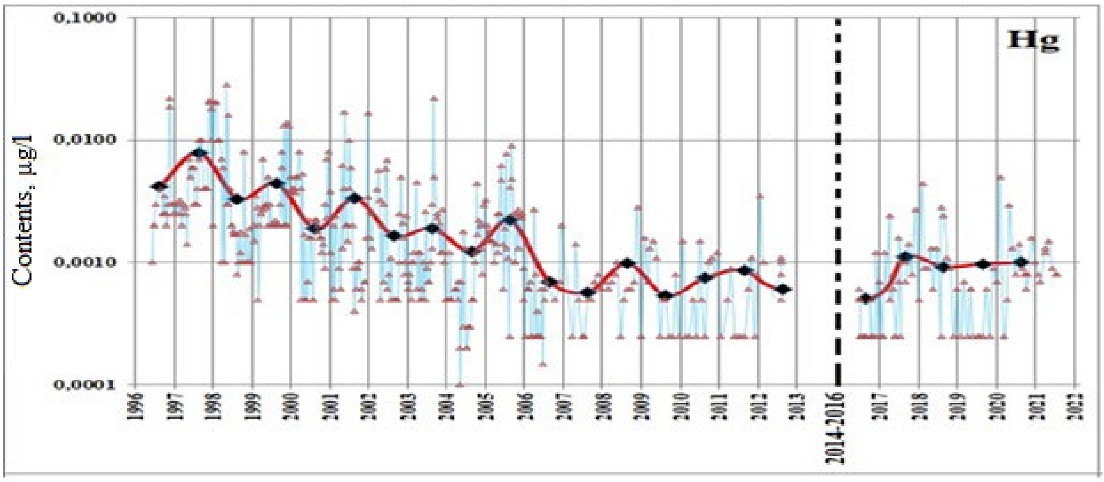

Fig.2. Distribution of Hg concentrations in the Angara River source water in 1996 to 2022.

(Skuzovatov et al., 2022). The accuracy of the results was confirmed by the analysis of reference samples of the Baikal water composition.

Monitoring (monthly) studies to analyze mercury concentrations in the water of the Angara River source have been conducting in Institute of Geochemistry SB RAS since 1997 (Fig. 2). The water samples from Lake Baikal and 30 tributaries were taken within the time span from 2007 to 2022 in the warm seasons, mainly in spring and autumn. Analytical information for about 1000 water samples from the Baikal aquatic ecosystem has been acquired by the present time. Of special interest is the study of mercury concentrations in the water of the Baikal ecosystem related to its specific chemical properties, high bioactivity, and the possible entry of mercury from the faults of the Baikal Rift Zone (Koval et al., 2003).

3. Results and discussion

The plots of time variations in the mercury concentrations in the Angara River source indicate that the most significant maxima and increased data spread were recorded between 1997 and 2000 (Fig. 2). P.V. Koval (Koval et al., 2003) called this time span a “mercury breath of Lake Baikal”. Deaths of seals were recorded on the shores of Lake Baikal during this time span. In 2001 to 2006, data volatility gradually decreased, and there were individual maxima of mercury concentrations in 2002, 2004, and 2006. Since 2007, there was a low mercury level in the water; data spread was minimum, and the small maxima were observed in 2007, 2009, and 2012 against the general quasi-stationary background.

The maximum level and increased volatility of mercury concentrations in the Angara River source between 1997 and 2000 coincided with the strong earthquake in the southern basin of Lake Baikal (February 25, 1999).

During extrapolation of the plot towards the decrease in time, the mercury concentration increased: over intervals of one month and half a month, the predictive values of the mercury concentrations amounted to approximately 0.36 and 0.64 μg/l, which exceeds the maximum permissible concentration of water bodies for fish farming (0.01 μg/l) and drinking water (0.5 μg/l) purposes. Predictive estimates differed from the actual measurements, in which the mercury concentration did not exceed 0.028 μg/l. However, these Hg concentrations indicated that, after a strong geodynamic impact or a strong earthquake, the mercury concentration may increase significantly for a short time in a local area the fault fluid discharge. Over time, the maxima of mercury concentrations dissipate through the water column to elevated and then background values (Fig. 3). The background mercury concentration in the water of Lake Baikal and the Angara River source amounts to ≤ 0.0005 μg/l.

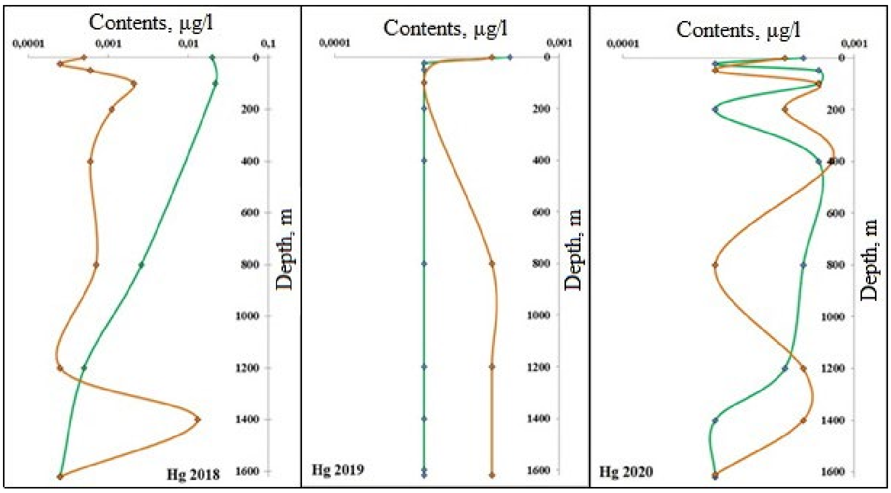

Fig.3. Distribution of Hg concentrations in Baikal water throughout the depth in 2018 to 2020.

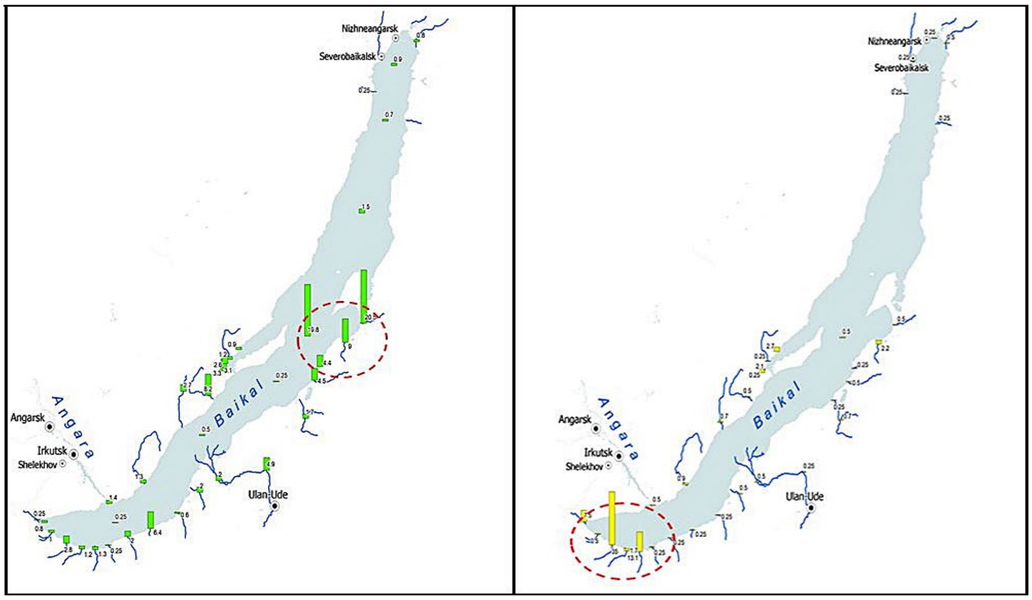

Fig.4. Distribution of mercury concentrations (n·10^{-3}) in the water of Lake Baikal, the Angara River source and the mouths of tributaries in spring (25 May 2018; green) and autumn (27 August 2018; yellow).

Sampling and analysis of water samples taken from Lake Baikal and its tributaries in the spring and autumn of 2018 during significant earthquakes and geodynamic impacts in BRZ revealed that significant maxima of mercury concentrations in the waters of Lake Baikal and some of its tributaries (Barguzin, Kultuk) coincided with earthquakes occurring here as well as with deaths of Baikal seals (red dotted line) (Fig. 4). The intoxication due to the transformation of mercury into methyl mercury in living organisms can possibly explain poisoning and death of seals.

4. Conclusions

We compared the results of estimating the mercury concentrations in the water of the Baikal ecosystem with the timing of the earthquakes of different magnitudes, which occurred at various distances from the water sampling sites. All significant maxima of mercury concentrations in the water appeared to be responses to strong geodynamic impacts. Predictive estimates of the trend for average annual mercury concentrations suggested the possibility of considerable increases in mercury concentrations in the local area of fault fluid discharge under a strong geodynamic impact. We proposed that the opening of deep faults under strong geodynamic impacts leads to decompression with boiling, degassing of mercury, and a rapid rise onto the surface along the zones of open faults.

The results obtained indicate that the state and preservation of the water in the Baikal ecosystem depend on both natural cataclysms (intoxication of seals), and anthropogenic impact. Consequently, it will be necessary to continue constant geochemical and geodynamic studies in the monitoring regime.

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Conflict of interest

The authors declare they have no conflict of interest.

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