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Distribution of mercury concentrations in lichens, mosses and larch needles in Western Siberia (according to the 2019 data)

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ABSTRACT. This paper presents data on mercury concentrations in samples of lichen and moss, as well as needles of trees (larch, cedar and pine), taken in September 2019 along a rare sampling network on the meridional transect from the Novy Urengoy area in the north to Tobolsk in the south. The mean Hg concentration (ng/g) in samples of moss, lichen and larch needles was 26, 15 and 17, respectively. The Hg concentrations in samples of annual needles of pine and cedar were below the detection limit of the method (<10 ng/g). We discuss possible factors that affect the heterogeneity of the Hg distribution in biomonitors and the discrepancy between the Hg concentrations for samples taken at the same sites. There was a systematic increase in background mercury concentration near the Novy Urengoy city and the Gubkinsky town. We assume a possible decrease in the Hg concentration in the mosses of the middle part of Western Siberia compared to its northern part.

Keywords: Hg, Arctic, Western Siberia, lichen, moss, needles, larch

1. Introduction

Mercury is a heavy metal that is hazardous for the ecosystem, which makes it relevant to identify cases of its elevated concentrations in ecosystem components. The high volatility of elemental mercury determines the dependence of its migration and distribution in ecosystem components on atmospheric transport (Carpi, 1997; De Simone et al., 2014). Covers of lichens, mosses and tree needles are natural atmospheric fallout biomonitors, and their study provides an assessment of the state of the geochemical background of some elements, including mercury (Bargagli, 2016; Vosel et al., 2021). This paper presents data on mercury concentrations in samples of lichen and moss, as well as (larch, cedar and pine), taken in September 2019 along a rare sampling network, the meridional transect from the Novy Urengoy area (north) to Tobolsk (south).

2. Material and methods

The study area includes several landscape zones: tundra, forest-tundra, taiga, and forest-steppe. Epigean lichen (*Cladonia rangiferina* (L.) Weber ex F.H.Wigg.), moss (*Hylocomium splendens* (Hedw.) Schimp., and *Cladonia stellaris* (Opiz) Pouzar & Vezda), as well as annual needles of larch (*Larix sibirica* Ledeb.), pine (*Pinus sylvestris* L.) and cedar (*Pinus sibirica* Du Tour), were selected as end-to-end objects of study. From Novy Urengoy, sampling was carried out along the highways in the direction of Omsk (south), Nadym (west), Yamburg (north), and Tazovsky (north-east). Samples were taken at a distance of 100–200 m from the road. The distance between the sampling sites in the Yamal-Nenets Autonomous Area (YNAA) ranged from 20 to 60 km, and within the Khanty-Mansi Autonomous Area – Yugra (KMAA) and the Tyumen Region, it was 80 to 150 km. In the region of the Arctic tundra, lichen covers were ubiquitous. In more southern regions lichen was less common and found in the form of small islands. Moss was less common at the sampling sites; in the northern sampling sites, areas covered with moss were represented by rare patches, and in the southern sampling points, longer moss covers could be found. Larch was most often found in the arctic and subarctic regions; in the more southern regions, there were not larch trees suitable for needle sampling at sampling sites. Pine and cedar were widespread south of Novy

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Urengoy and almost never met further north, in the tundra zone.

Lichen and moss samples were collected in plots of 0.04-0.09 sq.m. Needle samples were taken at a height of 1-2 m. Larch needles were sampled along the entire length of the branches, and during the sampling of cedar and pine needles that formed in one season, only the meristem ends of the branches were involved. Before the determination of mercury, the samples were kept at room temperature until they acquired an air-dry state.

The bulk contents of Hg in the plant samples were measured by flameless AAS on a Lumex RA-915M Hg analyzer with a RP-91C pyrolysis attachment (analyst M.A. Gustaitis). Prior to analyses, the plant samples were reduced to a fine powder in a mortar. The technical specifications of the instrument allowed avoiding special preconditioning of solid samples. The national standard of birch leaf (LB-1) certified for heavy metals and mercury was used to calibrate the spectrometer and check the quality of analyses. Relative analytical errors did not exceed 20%. The detection limit for Hg concentrations in samples was 10 ng/g.

3. Results

The results of the mercury determination in biomonitors are presented in the sampling scheme (Fig.). Hg concentrations in the samples of annual needles of pine and cedar was below the detection limit of the method (<10 ng/g) and would not be considered further.

There was a difference in the distribution of mercury concentrations in biomonitors. The mean Hg concentrations (ng/g) in samples of moss, lichen and larch needles were 26 (min-max 17-54, SD 9, n 23), 15 (min-max (<10)-29, SD 5, n 47) and 17 (min-max 10-27, SD 4, n 28), respectively. Estimates of the mean, minimum and maximum Hg contents in moss samples were 1.5-2 times higher than the corresponding estimates in the case of lichen or larch needles. The distribution of mercury concentration in larch needles was more homogeneous (variation coefficient 24%) compared to lichens or mosses (33 and 35%, respectively). Based on the mercury concentration in lichen, there was no difference between samples taken in the north (YNAA) and in the central (KMAA, Tyumen Region) parts of Western Siberia. Based on the mercury concentrations in moss samples, there was a trend to decrease in the central part of Western Siberia. However, it should be noted that the number of samples in the central part was small.

The spatial distribution of Hg concentrations in all biomonitors indicated an increase in Hg concentration in the Novy Urengoy area. In some cases, north of Novy Urengoy towards Yamburg, elevated mercury levels in biomonitors were observed: for mosses, these sites were closer to Yamburg, and for lichens and larch needles, the corresponding sited were closer to Novy Urengoy. The area of Gubkinsky stands out: an increased Hg concentration in moss was observed to the north, and an increased Hg concentration in lichen – to the south of the town.

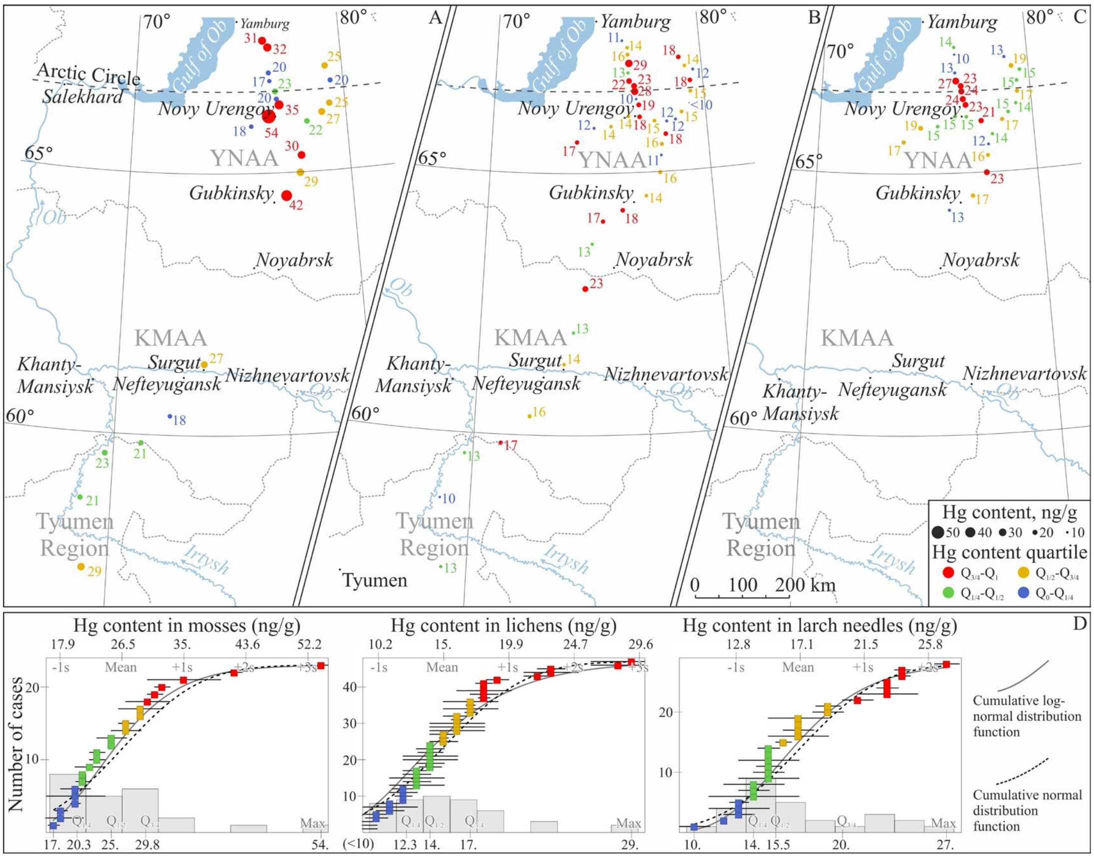

Fig. The sampling scheme (A, B and C) and distribution of mercury concentrations (D) in mosses (A), lichens (B) and larch needles (C) collected in September 2019 along the Novy Urengoy - Tobolsk transect.

4. Discussion and conclusions

We assume that the data obtained characterize the background values of Hg concentrations in the studied samples, without traces of significant pollution. It should be noted that previously (in 1998 to 2002), for lichens collected in the YNAA (without dividing into background and polluted areas), higher Hg concentrations were detected: mean value 56 (min-max 10-310, n 210) ng/g (Strakhovenko et al., 2005). Below, there is a comparison with three neighboring regions. In the eastern direction, at the Taimyr Peninsula (Krasnoyarsk Territory), according to the generalized data for 1986-2004 (Zhulidov et al., 2011), Hg concentrations in mosses and lichens were lower or comparable with the data of this study. The mean background concentrations of Hg for the mosses in this area were 14 to 21 ng/g, and for the lichens - 11 to 26 ng/g (Zhulidov et al., 2011). Shevchenko et al. (2013) and Elsakov et al. (2018) described higher background mercury levels in lichens from more western region. For lichens sampled in 2004–2006 in the White Sea catchment area in Murmansk and Arkhangelsk Region, as well as the Republic of Karelia, the mean Hg concentration was 33 (min-max 13-68, SD 14, n 25) ng/g (Shevchenko et al., 2013). For lichens sampled in 2014 and 2015 in the Kola Peninsula (Murmansk Region), in the Pasvik Nature Reserve, mean Hg concentration was 27 (min-max 14-46, SD 8, n 15) ng/g (Elsakov et al., 2018). In the southeast direction of the study area, in the Tomsk Region, higher Hg concentrations were determined in mosses and lichens collected in 2003 to 2013 (Lyapina, 2015). The mean Hg concentration was 59 (min-max 35-95) ng/g in lichen and 58 (min-max 27-90) ng/g in mosses.

Two points could explain the difference in the homogeneity of the distributions of Hg concentrations in moss and lichen samples, on the one hand, and in larch needle samples, on the other hand: i) the difference in the history of the interaction of samples with the atmosphere and ii) finding samples in different tiers of biocenosis. Mosses and lichens, unlike larch needles, are indicators of long-term Hg influx from the atmosphere with interruptions for periods of snow cover formation (October-April). Moreover, the surface position of mosses and lichens, unlike larch needles, firstly, entails a more intense effect of dust particles raised by the wind from the soil surface, and secondly, leads to the possibility of the influence of meltwater during the spring flood. In turn, one-year tree needles are an indicator of seasonal (May-September) accumulation of mercury from the atmosphere, which are not directly affected by snowmelt waters. Notably, the more than a twofold excess of Hg concentrations in larch needles compared to cedar and pine needles is fully consistent with our previous assumption about more efficient capture of dust and aerosol microparticles from the atmosphere of larch needles based on the concentration distribution of atmospheric isotopes ^{210}Pb and ^{7}Be (Belyanin et al., 2021).

The difference in the distributions of Hg concentrations in biomonitor samples in the same areas can be considered random and associated with the heterogeneous (mosaic) distribution of mercury from the atmosphere. Since in this study, during the selection of moss and lichen samples, there was no clear documentation of the age of the identified areas, this could lead to an additional complication of the result obtained. The time spent by mosses and lichens in contact with the atmosphere and episodes of spring floods should be considered factors contributing to the leaching and redistribution of Hg accumulated from the atmosphere (Bargagli, 2016). For lichens, there is a known description of mercury removal indicators for different levels of pollution, depending on the time of further staying in a clean atmosphere (Vannini et al., 2021).

The increase in mercury concentrations in biomonitors in the area of Novy Urengoy city and Gubkinsky town is possibly associated with human economic activity. It is impossible to draw a conclusion about significant regional differences in the Hg concentrations in mosses and lichens of Western Siberia based on the presented data from an irregular sparse network. However, there is a trend to a decrease in the Hg concentrations in mosses sampled in the central part of Western Siberia compared to its northern part.

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Conflict of interest

The authors declare no conflict of interest.

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