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Mercury pressure in the Tomsk Region based on biomonitoring studies

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ABSTRACT. The article presents the original data on the total Hg concentration in needles of different tree species and aspen foliage in the Tomsk Region. Mean Hg concentrations were lower than in the Republic of Sakha-Yakutiya but higher than in Southern Siberia. Hg concentrations increased from the southeast to the northeast of the Tomsk Region. Cedar needles had increased sorption properties relative to this metal, and pine needles had the lowest ones. Aspen foliage accumulated mercury better in one growing season compared to needles. The calculated indicators indicated elevated Hg concentrations in needles relative to the background, the temporary allowable concentration and the mean value for terrestrial plants.

Keywords: mercury, needles, Tomsk Region, geoecology, bioindication

1. Introduction

Needles, epiphytic lichen species, poplar leaves, and aspen leaves are the most popular and frequently used representatives of vegetation for biomonitoring and bioindication both in Russia and abroad. They are convenient and informative as bioindicators of the ecological condition of the atmospheric air. These representatives of the diagnostics of the state of environmental components are distinguished by a wide range of growth, species diversity, collection ease, sample preparation, and analysis. The data obtained with needles allows us to accurately and representatively assess the quality of the surface atmosphere both for one growing season and up to five years. Furthermore, coniferous and leafy litter is involved in the formation of the soil, and the chemical elements accumulated in it contribute to the formation of the chemical composition of the soil, surface and groundwater (Anoshin et al., 1995). Plants can release accumulated mercury (Hg) back into the atmosphere during respiration (Chernenkova, 2002).

Hg is extremely toxic and pathological; it belongs to the group of thiol poisons and is an element of hazard class I, which is recognized as one of the most dangerous environmental pollutants. Therefore, it is rigidly normalized in its components (Saukov, 1966). During migration, it methylates, forming highly toxic compounds (Ermakov, 2010). The main pathway of Hg migration in the environment is atmospheric transport.

The aim of the study was to determine Hg concentrations in needles and aspen leaves from the Tomsk Region as well as to identify the characteristics of the mercury pressure depending on the type of bioindicator, the area of the region and the calculation of geoecological indicators.

2. Materials and methods

Needles were sampled in the Tomsk Region (TR) from 2018 to 2020, according to (Alekseenko, 2000). A total of 113 samples of bioindicators of mercury exposure were taken: 85 samples of needles of Scots pine (Pinus sylvestris L.), Siberian pine (Pinus sibirica L.), Siberian larch (Larix sibirica L.), and Siberian fir (Abies sibirica) as well as 28 samples of aspen trembling (Populus tremula).

Hg concentrations in the samples were determined on a RA-915+ Hg analyzer using the atomic absorption method using the PYRO-915 attachment (pyrolysis method; Hg detection limit 5 ng/g; determination accuracy 5 ng/g; element concentrations were calculated per 1 g of dry substances) in the educational and scientific laboratory on the basis of the School of Natural Resources Engineering at National Research Tomsk Polytechnic University (Shuvaeva et al., 2008).

The method of results processing included the calculation of ecological and geochemical indicators: the concentration coefficient relative to the background

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(CS - 4 ng/g, needles; 8 ng/g, leaves) (Yanin, 1992), temporary allowable concentration (TAC - 8 ng/g, needles; 16 ng/g, leaves) (Yanin, 1992), Clark of living matter (KLM - 50 ng/g) (Vinogradov, 1988), noosphere (KN - 180 ng/g) (Glazovskaya, 1988), mean concentration in dry matter of terrestrial plants (KLP - 15 ng/g) (Kovalsky, 1974), mean value for the sample (KM - 24.5 ng/g, needles; 21.9 ng/g, aspen leaf), and enrichment factor (normalization by Sc, own data) (KE).

3. Results and discussion

The mean Hg concentrations in the needles from all studied areas of TR, regardless of the tree species, differed significantly from each other and ranged from 11 to 51 ng/g, averaging 26 ng/g; in aspen leaves, it ranged from 12 to 24 ng/g, averaging 22 ng/g (Fig.). Aspen foliage accumulated the element better in one growing season compared to needles.

The distribution of Hg in needles and aspen leaves of the studied areas was homogeneous, as confirmed by the calculation of the variation coefficient (C_V = 7% and 28%, respectively).

The Hg maximum concentrations in needles are observed in the Verkhneketsky (32 ng/g) and Pervomaisky (34 ng/g) Districts that are located in the northeast and east of TR and border with each other. The minimum Hg concentrations were recorded in Krivosheinsky District (13 ng/g) located in the central part of TR (Table). In the aspen foliage, the maximum (25 ng/g) and minimum (15 ng/g) Hg concentrations were detected in the central Kolpashevskiy and Molchanovskiy districts of TR, which also border with each other (Table).

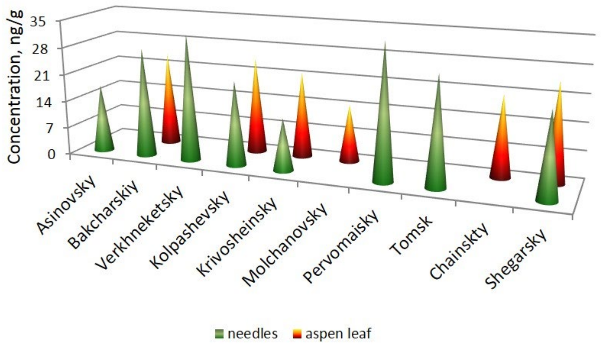

Fig. Hg in aspen needles and leaves from TR.

Mean Hg concentration in the needles from TR was lower than in the Republic of Sakha-Yakutiya (47 ng/g) but higher than in the Altai Territory (15 ng/g), Irkutsk Region (14 ng/g), Republics of Buryatia (15 ng/g). d) and Crimea (18 ng/g) (Lyapina et al., 2018).

A more detailed analysis of the Bakcharsky District indicated that Hg concentration both in needles and in poplar leaves was significantly lower than in adjacent environments: sphagnum peat and swamp waters (Domarenko et al., 2017). The excess ratio of the mean mercury concentration in peat to needles ranged from 1.5 to 46 times, and in swamp waters - from 4 to 39 times. For aspen leaves, the indicators were as follows: in peat - from 1.3 to 3.5 times and in swamp waters - from 3.4 to 29 times. Among the wide species diversity of coniferous tree species in the region, the data on Hg concentrations in pine and cedar needles are the most widely presented.

Table. Geoecological indicators of mercury pressure in the districts of the Tomsk Region

District	C_{Hg}, ng/g	K_C[2]	TAC	K_M	K_N	K_{LM}	K_{LP}	K_E
Asinovsky	17.3[1] n/d[3]	4.3 n/d	2.2 n/d	0.7 n/d	0.1 n/d	0.3 n/d	1.2 n/d	0.1 n/d
Bakcharskiy	27.9 24	7.0 3	3.5 1.5	1.1 1	0.2 0.1	0.6 0.5	1.9 1.6	0.3 0.004
Verkhneketsky	32.4 n/d	8.1 n/d	4.1 n/d	1.3 n/d	0.2 n/d	0.6 n/d	2.2 n/d	0.3 n/d
Kozhevnikovsky	1 n/d	1.8 n/d	0.9 n/d	0.3 n/d	0.04 n/d	0.1 n/d	0.5 n/d	1.4 n/d
Kolpashevsky	21.6 24.7	5.4 3.1	2.7 1.5	0.9 1	0.1 0.1	0.4 0.5	1.4 1.6	0.08 0.02
Krivosheinsky	13.3 22	3.3 2.8	1.7 1.4	0.5 0.9	0.1 0.1	0.3 0.4	0.9 1.5	0.02 0.01
Molchanovsky	n/d 14.7	n/d 1.8	n/d 0.9	n/d 0.6	n/d 0.1	n/d 0.3	n/d 1	n/d 0.01
Peromaisky	34.2 n/d	8.6 n/d	4.3 n/d	1.4 n/d	0.2 n/d	0.7 n/d	2.3 n/d	0.2 n/d
Tomsk	27.5 n/d	6.9 n/d	3.4 n/d	1.1 n/d	0.2 n/d	0.6 n/d	1.8 n/d	0.2 n/d
Chainskty	n/d 20.7	n/d 2.6	n/d 1.3	n/d 0.8	n/d 0.1	n/d 0.4	n/d 1.4	n/d 0.02
Shegarsky	21.5 25	5.4 3.1	2.7 1.6	0.9 1	0.1 0.1	0.4 0.5	1.4 1.7	0.2 0.02

Note: 1 – needles/aspen leaf; 2 - see Materials and methods; 3 n/d - no data

The data on Hg concentration in the needles and leaves of the aspen from TR were comparable with those in other regions of Russia and the world (Lyapina et al., 2018). As the concentration of element No. 80 in all studied samples was not high, background concentrations from the literature were used to calculate geoecological indicators (Lyapina et al., 2018). The calculation results indicated that the concentrations in the needles were up to 8.6 times higher than the background (4 ng/g), and in aspen leaves (8 ng/g) - up to 3.1 times; VDC - up to 4.3 times in needles and up to 1.6 times in aspen leaves; the mean value up to 2.3 times for terrestrial plants and up to 1.7 times in aspen leaves, which indicated the Hg accumulation. However, compared to Clarke, the noosphere and living matter were lower (Table). The calculation of the enrichment factor revealed the absence of Hg enrichment in both aspen leaves and needles, except for the Kozhevnikovsky District.

4. Conclusions

The studies of the concentrations and geoecological features of the Hg accumulation by bioindicators (needles and aspen leaves) in the Tomsk Region revealed that the Hg concentrations were comparable with the data obtained in other regions of Russia. Aspen foliage accumulated this element better in one growing season compared to needles. Elevated Hg concentrations were detected in the northeast of the Tomsk Region. Moreover, there was no pollutant enrichment in aspen leaves and needles, except for the Kozhevnikovsky District. The data from geoecological calculations indicated the cumulative nature of Hg levels in needles and aspen leaves for all calculated indicators, except for the Clarke of the noosphere and living matter.

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Conflict of interest

The authors declare no conflict of interest.

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