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Geoecological features of mercury pressure on the south coast of the Republic of Crimea based on the study of needles

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ABSTRACT. The article presents the original data on the total Hg concentration in the needles of different tree species in the recreational zones of settlements on the south coast of the Republic of Crimea. Mean Hg concentrations were lower than in the Tomsk Region and the Republic of Sakha-Yakutia but higher than in Southern Siberia. Hg concentrations increased from west to east along the south coast of Crimea. Pine needles showed increased sorption properties relative to mercury, juniper needles had the least sorption. There was no dependence of the element input on height relative to sea level. 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, Republic of Crimea, geoecology, bioindication

1. Introduction

Needles, as a bioindicator of the ecological condition of the atmospheric air, together with epiphytic lichen species and poplar leaves, reflect even weak effects of anthropogenesis due to the cumulative effect. They show the total effect of all the impacts of human activity, which are important for the natural environment and the geochemical features of the territories. They indicate the trends and degree of negative impact on humans through the biota. They allow for predicting the state of the individual components and the environment as a whole in the future. Needles reflect the state of atmospheric air for one growing season and up to five years. During the destruction of the coniferous litter, its accumulated substances are involved in the formation of the chemical composition of the soil cover, surface and groundwater (Anoshin, 1995). Plants can not only accumulate mercury (Hg) to very high concentrations but also release it back into the atmosphere during respiration (Chernenkova, 2002).

Hg is recognized as one of the most dangerous environmental pollutants strictly regulated in its components (Vinogradov, 1988; Alekseenko, 2000). This element belongs to the group of thiol poisons; it constantly transforms under changing environmental conditions with the formation of highly toxic compounds; it is hazardous even at very low concentrations (Ermakov, 2010). Atmospheric transport contributes the most to Hg migration (Saukov, 1966).

The aim of the study was to determine Hg concentrations in needles from the recreational zones of settlements on the south coast of the Republic of Crimea (hereinafter referred to as the South Coast) as well as to identify the characteristics of the mercury pressure depending on the type of coniferous and landscape conditions (height above sea level and location relative to sea).

2. Materials and methods

Needles were sampled in the recreational areas (parks, embankments and avenues) of the settlements on the South Coast of the Crimea: Sevastopol (including the Balaklava area), Yalta (embankment, Massandra winery), Bakhchisaray, and the Miskhor village (embankment, Ai-Petri) (8 sites) according to (Alekseenko, 2000). Overall, 15 samples of needles of Crimean pine (Pinus pallasiana), common spruce (Picea abies), European larch (Larix decidua Repens), Algerian fir (Abies numidica), and stink juniper (Juniperus foetidissima) were selected.

Hg concentrations in the samples were determined on a RA-915+ Hg analyzer using the atomic absorption method with the PYRO-915 attachment (pyrolysis method; Hg detection limit 5 ng/g; determination

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accuracy 5 ng/g; element concentrations are 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 (C_F - 4 ng/g) (Yanin, 1992), temporary allowable concentration (TAC - 8 ng/g), Clark of living matter (K_{LM} - 50 ng/g g) (Vinogradov, 1988), noosphere (K_N – 180 ng/g) (Glazovskaya, 1988), mean dry matter concentration in terrestrial plants (K_{LP} – 15 ng/g) (Kovalsky, 1974), and sample mean value (K_M – 18.5 ng/g).

3. Results and discussion

The mean Hg concentrations in the needles from all studied recreational areas, regardless of the tree species, differed significantly from each other and ranged from 8 to 47 ng/g. Hg distribution in the needles from the South Coast was uneven, as confirmed by the calculation of the variation coefficient (59%). The Hg maximum concentrations were observed at the easternmost sampling site, the Massandra winery (Yalta), and the minimum - at the western: Balaklava area (Sevastopol) as well as in the park areas of Sevastopol, Balaklava, Bakhchisaray, and at the Ai-Petri peak (Table). On average, Hg accumulates better in the needles of pine, fir and larch (24-27 ng/g); juniper needles contained the lowest concentration of the pollutant (10 ng/g).

A more detailed analysis indicated the maximum Hg concentrations in pine needles from the city of Yalta (Massandra - 47 ng/g), and the minimum ones - in the city of Sevastopol (Grafskaya Wharf - 14 ng/g). In larch needles, the highest concentrations of the pollutant were in the city of Sevastopol (Grafskaya Wharf - 31 ng/g), in the lowest concentrations - in the city of Yalta (embankment - 14 ng/g). Maximum and minimum Hg concentrations were detected in the needles of spruce in Sevastopol (15-24 ng/g). Juniper needles were distinguished by the lowest Hg accumulation at all sampling sites compared to other studied coniferous species. Elevated concentrations of the pollutant in juniper needles were identified in the park of the Miskhor village, the lowest ones – on the embankments of Sevastopol and Yalta as well as at the Ai-Petri peak.

In addition to species diversity, landscape conditions of tree growth also influence the degree of mercury accumulation. The mean Hg concentration in the needles, regardless of the tree on the coast, was 17 (8-31 ng/g). In the mountains, the range of values was much wider, 8-47 ng/g, averaging 22 ng/g. At the same time, it should be noted that the mercury accumulation by conifers did not depend on their height, as confirmed by calculations of the correlation coefficient (0.1), except for the city of Yalta where such a relationship was found (0.88).

The obtained Hg concentrations in the coniferous trees on South Coast were significantly lower than the literature data on other bioindicators of the condition of the atmospheric air: epiphytic lichen species and poplar leaves (Evstafieva et al., 2021). The mean mercury concentration in lichens was from 3 to 15 times higher, and in poplar leaves - from 1.5 to 2 times higher (Fig.). It is preferable to compare the Hg concentrations in needles with data on poplar leaves, as they reflect the level of mercury impact on the atmosphere of the region in one season, while lichens show the long-term input of the element. At the same time, the mean mercury concentration in the air of the Republic of Crimea was 2 ng/m^3; background concentrations in soils - 8-3000 ng/g; bedrock - 12-10000 ng/g and sea water - 3-680 ng/g.

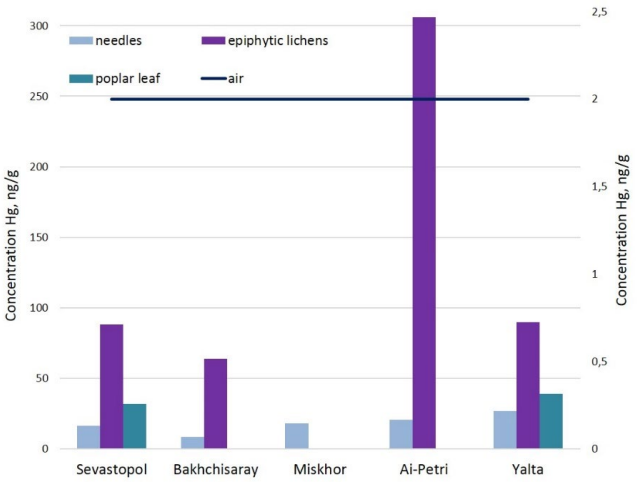

Fig. Hg in adjacent environments on the South Coast of Crimea.

Table. Geoecological indicators of mercury pressure on the South Coast of Crimea

Sampling site	C_{Hg}, ng/g	K_C*	TAC	K_M	K_N	K_{LM}	K_{LP}
Sevastopol	18 ± 0.8	4.6	2.3	0.4	0.1	0.4	1.2
Balaklava	17 ± 0.9	4.2	2.1	0.3	0.1	0.3	1.1
Bakhchisaray	8 ± 1.5	2.1	1.1	0.2	0.05	0.2	0.6
Miskhor	18 ± 0.9	4.5	2.1	0.4	0.1	0.4	1.2
Yalta	27 ± 0.5	6.7	3.3	0.5	0.1	0.5	1.8
Ai-Petri	21 ± 1.7	5.1	2.6	0.4	0.1	0.4	1.4

Note: * - see materials and methods

The average Hg concentration in needles from the recreational zones on the South Coast was lower compared to the data on the Tomsk Region and the Republic of Yakutia but higher than in the Altai Territory, the Irkutsk Region and the Republic of Buryatia (Lyapina et al., 2018).

The data on the Hg concentration in the needles on the South Coast were comparable with those in other regions of Russia and the world (Lyapina et al., 2018). Since 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 results of the calculations revealed that the concentrations in the needles were up to 6.7 times higher than the background (4 ng/g); VDC - up to 3.3 times, and the mean value for terrestrial plants - up to 1.8 times, which indicates the accumulation of this metal. However, compared to Clarke, the noosphere and living matter were lower (Table).

4. Conclusions

The of studies of the concentration and geoecological features of Hg accumulation in needles from recreational zones on the south coast of the Republic of Crimea revealed that Hg concentrations corresponded to the data obtained by other researchers in Russia. The highest mercury concentrations were observed in the needles of pine, fir and larch, and the lowest - in the needles of juniper. Eastwards along the coast, Hg concentrations increased. Moreover, there was no increase in pollutant influx to the needles with height relative to sea level, except for the city of Yalta. The data of geoecological calculations testified to the cumulative nature of the Hg levels in the needles in comparison with the Clark of the noosphere and living matter. However, it was significantly lower compared to the concentration of element No. 80 in epiphytic lichen species and poplar leaves in the study area.

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Conflict of interest

The authors declare no conflict of interest.

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