

Mercury content in tree plants in the industrial area of Cherepovets, Russia

Marina Ulianova^{1,*}, *Olga Rumiantseva*¹, *Elena Ivanova*¹, *Darya Bazhenova*¹, *Polina Baboshina*¹, *Anna Pluzhnikova*¹

¹Cherepovets State University, Cherepovets, Russia

Abstract. The aboveground organs of plants are natural bioindicators of atmospheric precipitation, and their study makes it possible to assess the state of the geochemical background of a number of elements, including mercury. Mercury is a highly toxic element for all living organisms. The mercury content was determined on the RA-915M mercury analyzer with PIRO attachment of the Regional shared services center of Cherepovets State University. The data on the content of mercury in the leaves of different types of woody and shrubby plants of the industrial area of Cherepovets are presented. The mercury content in the leaves of the studied plant species varied from 0.40 ng/g to 34.90 ng/g. It was noted that non-deciduous trees have the lowest levels of mercury in leaves – 9.80 ± 1.01 ng/g, shrub forms have intermediate values – 12.47 ± 0.92 ng/g and deciduous trees the highest concentrations – 16.95 ± 0.56 ng/g. The results obtained can be used for scientifically-based regulation of the phytotechnology system of urbanized area and for more efficient landscaping.

1 Introduction

Mercury and its compounds belong to substances of the first hazard class and are capable of having a wide and diverse range of negative effects on living organisms. When mercury enters the air space, it falls on the earth or water surface both near the emission sources and at a great distance from them as a result of atmospheric transport [1]. Approximately half of all mercury emissions into the atmosphere are provided by natural sources. The main anthropogenic sources of atmospheric mercury emissions are coal and oil products combustion plants, as well as non-ferrous and ferrous metallurgy [1].

Cherepovets is an industrial city with enterprises of ferrous metallurgy, a chemical complex, wood and metal processing, food and light industry, and a construction complex [2].

According to the data of the Department of Natural Resources and Environmental Protection of the Vologda Region, the level of atmospheric air pollution in 2021 in Cherepovets was characterized as increased, gross emissions of pollutants from stationary sources into the atmosphere amounted to 283.456 tons/year [3].

* Corresponding author: maulianova@chsu.ru

Mercury is part of the fuel and various raw materials, is present in devices and products used at ferrous metallurgy enterprises, which does not exclude the possibility of it getting into dust and gas emissions. Dust generation is typical for a wide variety of industrial processes, while the amount of mercury in dust emissions is usually not taken into account. [1].

Plants are a natural biological filter, while leaves occupy one of the leading positions in the absorption of emissions from industry and vehicles, and accumulate heavy metals, including mercury [4, 5]. It is possible to estimate the aerotechnogenic load on the ecosystem (the level of environmental pollution with a toxicant) by studying the mercury content in the organs of green spaces [6, 7].

There are few studies on the determination of mercury in the leaves of tree plantations on the territory of the Russian Federation, and no studies have been conducted on the territory of the city of Cherepovets [8]. The results obtained can be used for scientifically-based regulation of the phytotechnology system of urbanized area and for more efficient landscaping [9].

2 Methodology

The collection of material was carried out in the summer of 2022 in the industrial area of Cherepovets (59°08' N, 37°55' E) (fig. 1). The city is located in the temperate continental climate zone with relatively warm short summers and long cold winters [2].

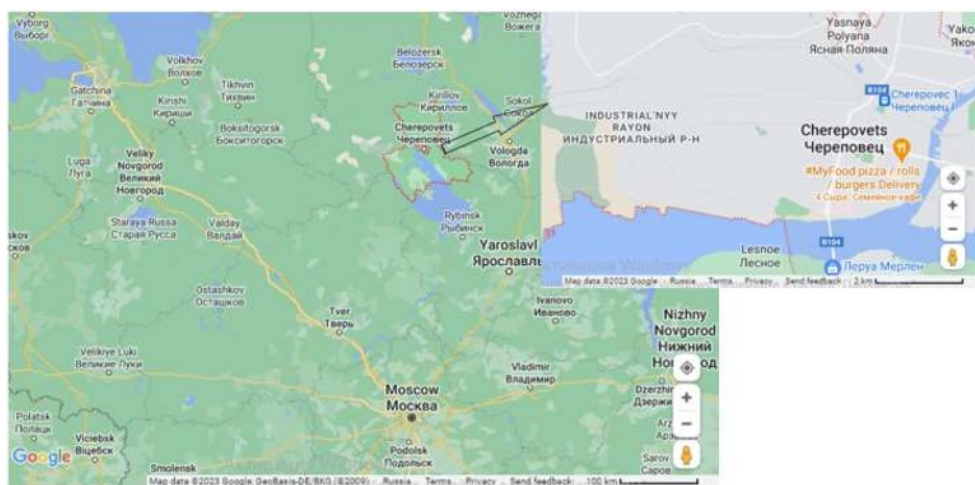


Fig.1. Map-scheme of collecting material for research (2022).

Plant organs were sampled from a height of one and two meters, from different sides of the crown. Before analysis, the samples were dried to constant weight and ground.

The mercury content was determined on the RA-915M mercury analyzer with PIRO attachment (Lumex) of the Regional shared services center of Cherepovets State University in the leaves of the following plant species: *Acer negundo*, *Acer platanoides*, *Betula pendula*, *Cornus alba*, *Crataegus* sp., *Larix* sp., *Lonicera tatarica*, *Malus* sp., *Picea abies*, *Picea pungens*, *Pinus sylvestris*, *Populus nigra*, *Populus tremula*, *Quercus robur*, *Sorbus aucuparia*, *Symphoricarpos albus*, *Taraxacum officinale*, *Thuja occidentalis*, *Tilia cordata*, *Tilia platyphyllos*.

To analyze the obtained data, the nonparametric Mann-Whitney U Test and Kruskal-Wallis test were used, with a significance level of $p \leq 0.05$.

3 Results

When comparing the mercury content in leaves collected at different levels and from different sides of tree crowns no statistically significant differences were found (table 1). Thus, the height and orientation of the crown do not affect the results. Therefore, when comparing mercury concentrations between species, the average value of leaves from all crowns and heights was used.

Table 1. Mercury content (ng/g) in leaves taken from different crown heights of different green spaces.

Type of plant	Height	Arithmetic mean	Crown Orientation	Arithmetic mean
<i>Picea pungens</i>	1 meter	8.19	Northwest	11.05
	2 meters	9.17	South	6.04
<i>Pinus sylvestris</i>	1 meter	6.5	Northwest	5.92
	2 meters	6.15	South	6.73
<i>Acer negundo</i>	1 meter	13.31	Northwest	13.84
	2 meters	11.8	South	11.26
Malus sp.	1 meter	17.64	Northwest	20.19
	2 meters	17.88	South	15.33
<i>Betula pendula</i>	1 meter	11.46	Northwest	11.94
	2 meters	11.49	South	11.01
<i>Populus nigra</i>	1 meter	14.13	Northwest	14.67
	2 meters	16.93	South	16.39
<i>Sorbus aucuparia</i>	1 meter	14.95	Northwest	16.3
	2 meters	14.42	South	13.1
Crataegus sp.	1 meter	11.34	Northwest	13.04
	2 meters	11.84	South	10.78
<i>Tilia platyphyllos</i>	1 meter	22.96	Northwest	24.19
	2 meters	21.4	North	20.18
<i>Thuja occidentalis</i>	1 meter	9.55	Northwest	9.24
	2 meters	10.45	South	10.76
<i>Quercus robur</i>	1 meter	19.6	Northwest	17.88
	2 meters	15.18	South	13.07
<i>Tilia cordata</i>	1 meter	15.9	Northwest	21.3
	2 meters	18.93	South	13.53

The mercury content in the leaves of the studied plant species varied from 0.40 ng/g to 34.90 ng/g (table 2). The minimum concentrations of mercury (ng/g) are noted in the shrub – *Cornus alba* – 6,66±0,97, and also at the *Picea pungens* – 7.05±1.52 and *Pinus sylvestris* – 10.35±2.17. The maximum concentrations of mercury (ng/g) are noted in the *Tilia cordata* – 22.03±2.64, *Tilia platyphyllos* – 25.41±1.30 and *Larix sp.* – 26.34±3.28. *Populus*

balsamifera is the dominant species of the industrial district of Cherepovets. The amount of mercury in the leaves of *Populus balsamifera* is 14.96 ng/g, almost two times lower than in the studies of Siberia and the Far East (25 ng/g) [8].

Table 2. Mercury content (ng/g) in the leaves of different plant species in the industrial area of Cherepovets

Type of plant	AM	Med	Min	Max	SD	SE	Differences
<i>Cornus alba</i>	6.66	6.50	1.20	13.60	3.49	0.97	a
<i>Picea pungens</i>	7.05	5.90	0.40	21.50	5.88	1.52	a
<i>Pinus sylvestris</i>	10.35	7.15	4.40	31.40	7.51	2.17	ab
<i>Thuja occidentalis</i>	12.46	11.70	5.50	23.50	4.76	1.32	bc
<i>Betula pendula</i>	12.72	13.95	5.00	22.05	4.71	1.18	bc
<i>Lonicera tatarica</i>	13.10	13.10	13.10	13.10			abcde
<i>Symphoricarpos albus</i>	14.25	14.25	12.80	15.70	2.05	1.45	abcde
<i>Populus balsamifera</i>	14.96	14.50	4.90	26.10	4.80	1.05	cd
<i>Sorbus aucuparia</i>	15.17	15.90	6.80	26.50	4.89	1.19	cd
<i>Crataegus</i> sp.	15.33	16.30	4.50	22.30	4.98	1.00	cd
<i>Quercus robur</i>	15.83	16.10	7.05	21.00	5.18	2.11	cde
<i>Acer platanoides</i>	16.46	16.88	12.70	18.70	2.20	0.90	cde
<i>Acer negundo</i>	17.18	15.90	7.90	31.00	6.66	1.28	de
<i>Malus</i> sp.	17.70	19.00	6.00	29.65	6.85	1.43	de
<i>Tilia cordata</i>	22.03	21.58	17.10	27.85	5.27	2.64	ef
<i>Tilia platyphyllos</i>	25.41	23.90	22.15	31.25	3.44	1.30	f
<i>Larix</i> sp.	26.34	24.90	19.10	34.90	7.33	3.28	f

Note: AM is the arithmetic mean; Med is the median value; Min – minimum value; Max - maximum value; SD - standard deviation; SE is the standard error of the mean; different letters denote statistically significant differences in the content of mercury in the leaves of different plant species, at $p \leq 0.05$.

It was noted that non-deciduous trees have the lowest levels of mercury in leaves - 9.80 ± 1.01 ng/g, shrub forms - an intermediate value - 12.47 ± 0.92 ng/g. Statistically, the highest concentrations of mercury were noted in the leaves of deciduous trees - 16.95 ± 0.56 ng/g (fig. 2).

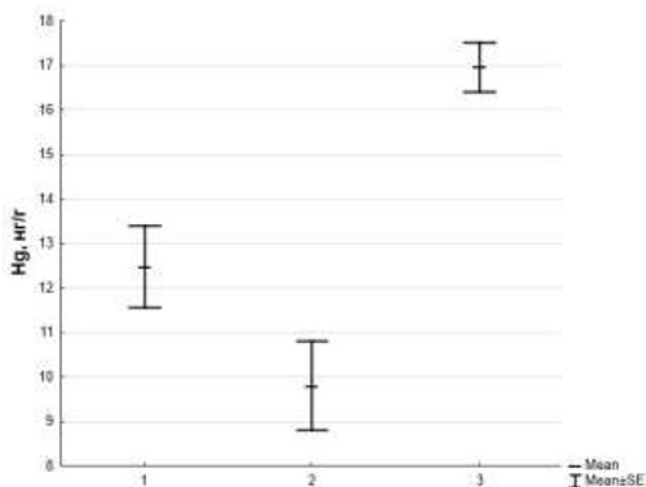


Fig. 2. The content of mercury in shrubs is 1, non-deciduous - 2 and deciduous trees - 3.

According to the results of the study, it was found that the absorption capacity of mercury by the leaves of tree plantations decreases in the series (table 2): *Larix sp.* > *Tilia platyphyllos* > *Tilia cordata* > *Malus sp.* > *Acer negundo* > *Acer platanoides* > *Quercus robur* > *Crataegus sp.* > *Sorbus aucuparia* > *Populus balsamifera* > *Symphoricarpos albus* > *Lonicera tatarica* > *Betula pendula* > *Thuja occidentalis* > *Pinus sylvestris* > *Picea pungens* > *Cornus alba*.

4 Conclusion

The green spaces of Cherepovets experience a significant technogenic load and accumulate various pollutants, including mercury.

Studies have shown that the bioaccumulation of mercury by the leaves of different plant species occurs unequally. The mercury content was determined in the leaves of the following plant species: *Acer negundo*, *Acer platanoides*, *Betula pendula*, *Cornus alba*, *Crataegus sp.*, *Larix sp.*, *Lonicera tatarica*, *Malus sp.*, *Picea abies*, *Picea pungens*, *Pinus sylvestris*, *Populus nigra*, *Populus tremula*, *Quercus robur*, *Sorbus aucuparia*, *Symphoricarpos albus*, *Taraxacum officinale*, *Thuja occidentalis*, *Tilia cordata*, *Tilia platyphyllos*.

The mercury content in the leaves of the studied plant species varied from 0.40 ng/g to 34.90 ng/g. The highest values of metal accumulation were noted in *Tilia sp.* and *Larix sp.* The amount of mercury in the leaves of *Tilia sp.* and *Larix sp.* is twice as high as in non-deciduous tree species: *Picea pungens*, *Pinus sylvestris* and *Thuja occidentalis*. *Populus balsamifera* is the dominant species of the industrial district of Cherepovets. The amount of mercury in the leaves of *Populus balsamifera* is 14,96 ng/g.

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