

Mercury in the landscape components of the Don River Delta

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Abstract. The Don River Delta acts as a protective environmental barrier to the washout of pollutants from adjacent drainage areas. The priority pollutant is mercury, which comes as an industrial, agricultural and domestic wastewater's part. The mercury concentrations levels in soils were determined by expeditionary and laboratory studies: the indicators ranged from 0,025 to 0,082 $\mu\text{g/g}$ d.m. in the sandy-psammophyte meadow (section №1), in the sandy steppe (section №2) – from 0,012 to 0,022 $\mu\text{g/g}$ d.m., in the true meadow (section №3) – from 0,027 to 0,4 $\mu\text{g/g}$ d.m. and on the landscape with near-water vegetation (section №4) – from 0,035 to 0,565 $\mu\text{g/g}$ d.m. The mercury accumulation in soils according to concentration coefficients is noted in the series «the Near-water landscape_(13,5) > the True meadow landscape_(5,9) > the Sandy-psammophyte meadow landscape_(2,5) > the Sandy steppe landscape₍₁₎». It was found that the soil moisture increased from the section №1 to the section №4 (on average from 18,06 to 35,4%), and the highest total biomass was recorded on the sandy-psammophyte landscape (46,55 t/ha) and the landscape with near-water vegetation (41,85 t/ha).

1 Introduction

The Don River Delta is a triangular formation, which is located in the lower section of the river basin geochemical system and is subject to the pollutants accumulation [1-2]. This unique territory is an indicator of the ecological state of the landscape components in the Don basin. After the construction of the Tsimlyansk Reservoir, the delta growth stopped, and the current area reaches 340 km². In 2005, due to the special favorable natural conditions of the site, the Donskoy Natural Park with the Don Delta section was organized on the territory [3].

Within the Lower Don Delta and floodplain there are also large industrial centers (Rostov-on-Don and Azov), which are the main sources of water and soil pollution. Heavy metals are among the priority pollutants in the delta region soils. Soils act as a participant in biochemical processes that control both the accumulation and mass transfer of these elements, and mercury is one of the most significant pollutants [4-5].

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This study is carried out to analyze the main types of the Don River Delta landscapes and assess the priority microelement pollutant concentrations in the soil cover and its spatial variability.

2 Materials and Methods

The work is based on the results obtained as part of expeditionary research in the summer 2023 in the Don River Delta. Soil sampling at monitoring stations (Fig. 1) was carried out according to the GOST 17.4.4.02-84 methodology. Four landscape types with different natural features were identified: the sandy-psammophyte meadow (№1), the sandy steppe (№2), the true meadow (№3) and the near-water meadow (№4).

The dominant vegetation on the study sites is described, the above-ground, underground, total biomass, the grass height and soil moisture levels are calculated. The authors analyzed soil samples for mercury content using the pyrolysis method, which involves thermal destruction of the mercury sample and atomization (PND F 16.1:2:2.2.80-2013 (M 03-09-2013)). The determinations were carried out by the authors using a mercury analyzer “RA-915M” with the “URP” attachment in the Southern Federal University’s interdepartmental laboratory.

To assess and compare the chemical elements content in the soils of the presented landscapes, the concentration coefficient (K_c) was calculated using the formula:

$$K_c = C_i / C_{b.v.} \quad (1),$$

where $C_{b.v.}$ – is the background element content, and C_i – is the chemical element content in the studied objects soil. Calculation of concentration coefficients allows one to identify geochemical associations of accumulating elements. In associations, they are usually arranged in decreasing order of their K_c values [6].



Fig. 1. Location map of sampling stations

3 Results and discussion

Table 1 shows the main results of the landscape analysis in the selected areas. It was determined that the grass height stand in all areas varied from 5 to 183 cm, and the total biomass – from 0,6 to 14,8 t/ha.

Table 1. Main characteristics of landscape complexes

Landscape	Dominant vegetation (<i>lat.</i>)	Biomass. t/ha			Grass height. cm
		above-ground	underground	total	
The Sandy-psammophyte meadow	<i>Lepidium latifolium</i>	2.45	3.5	5.95	65
	<i>Spergularia media</i>	0.7	0.5	1.2	5
	<i>Calamagrostis epigejos</i>	4.3	1.05	5.35	121
	<i>Puccinellia distans</i>	3	2.4	5.4	80
	<i>Xanthium orientale</i>	9.3	7	16.3	52
	<i>Typha latifolia</i>	7.3	4	11.3	86
The Sandy steppe	<i>Rumex acetosa</i>	3.4	0.57	3.97	57
	<i>Festuca beckeri</i>	2	0.77	2.77	50
	<i>Trifolium arvense</i>	0.3	0.3	0.6	13
	<i>Koeleria sabuletorum</i>	7.5	0.5	8	51
	<i>Helichrysum arenarium</i>	8.1	0.85	8.95	45
	<i>Tanacetum vulgare</i>	4	0.5	4.5	58
The True meadow	<i>Elytrigia repens</i>	3.8	5.47	9.27	70
	<i>Poa pratensis</i>	1.95	1.87	3.82	64
	<i>Artemisia absinthium</i>	5.65	3.25	8.9	50
	<i>Trifolium repens</i>	2.3	0.6	2.9	25
	<i>Medicago falcata</i>	6.7	1	7.7	62
The Near-water	<i>Ballota nigra</i>	0.57	0.73	1.3	34
	<i>Artemisia lavandulifolia</i>	8.05	4.2	12.25	46
	<i>Glycyrrhiza glabra</i>	5	2.3	7.3	72
	<i>Melilotus officinalis</i>	4.15	2.05	6.2	58
	<i>Typha latifolia</i>	8.55	6.25	14.8	183

The obtained data on mercury content and moisture levels in selected samples in all study areas are presented in Table 2. In general, in the territory under consideration, concentrations in soils did not exceed the maximum permissible values (2.1 µg/g d.m.) and varied from 0.012 to 0.565 µg/g d.m., averaged 0.086 µg/g d.m. The results obtained are comparable with previously obtained data. Thus, according to the data [7-9], the average mercury content in agricultural soils of the Rostov region in the period 2013-2022 was 0.021 µg/g d.m. (min – 0.007 µg/g d.m., max – 0.22 µg/g d.m.). The authors [10] note that the Hg content in soils was in the range of 0.035-0.065 µg/g d.m. (on average 0.053 µg/g d.m.). It is worth noting that the concentrations determined for the near-water type of landscape are comparable with the results obtained in areas with high anthropogenic load [11]. Obviously, this is due to the high biomass of plants and, as a consequence, the accumulation organic matter in soils.

Table 2. Mercury concentrations and moisture levels in soils.

Station name	Hg concentration. µg/g d.m.			Soil moisture. %		
	max	min	average	max	min	average
№1	0.082	0.025	0.038	23.9	7.5	18.06
№2	0.022	0.012	0.015	31.2	20	23.7
№3	0.4	0.027	0.089	41.5	4.85	21.4
№4	0.565	0.035	0.203	48.3	25	35.4

The section №1 presents a sandy-psammophyte meadow landscape (Fig. 2), located 6.5 km from Azov on the left bank of the Don River. The grass height stand varied from 5 to 121 cm. The value of above-ground and underground biomass, with soil moisture of 7.5-23.9% (on average 19,06%), was 27.05 t/ha and 19.5 t/ha. Dominance in the species composition belongs to *Xanthium orientale* and *Spergularia media*. The mercury

concentrations in soils varied from 0.025 to 0.082 $\mu\text{g/g}$ d.m., with an average of 0.038 $\mu\text{g/g}$ d.m.

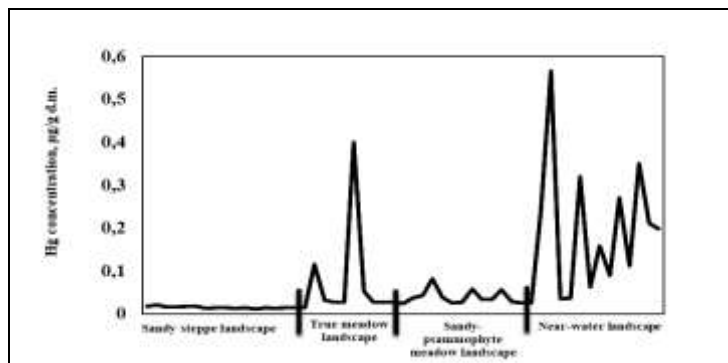


Fig.2. Mercury concentrations in the soils of the studied landscapes

The sandy steppe landscape (section №2) is located 2 km from «the Rostov-on-Don – Rogozhkin» road. There were 6 species of plants on it with a predominance of *Helichrysum arenarium* and *Koeleria sabuletorum*. The total phytomass was 28.79 t/ha. The Hg content in soil samples varied from 0.012 to 0.022 $\mu\text{g/g}$ d.m. (average 0.015 $\mu\text{g/g}$ d.m.). The percentage of total soil moisture to dry soil is on average 23.7% (max – 31.2%, min – 20%) with grass height from 13 to 58 cm for all types.

In section №3, which is represented by the true meadow landscape, near the Rogozhkin farm, the mercury concentrations range is slightly higher compared to previous sites and amounts to 0.027 – 0.4 $\mu\text{g/g}$ d.m. (average 0.089 $\mu\text{g/g}$ d.m.). Soil moisture varies from 4.85 to 41.5% (average 21.4%), while the total aboveground mass is 20.4 t/ha, and the total underground mass is 12.19 t/ha. There were also about 5 plant species in this area. The grass height stand varied from 25 cm (*Trifolium repens*) to 70 cm (*Elytrigia repens*).

In the near-water landscape (section №4), the maximum values for the Hg content in the soil and its moisture were recorded. The maximum values were 0.565 $\mu\text{g/g}$ d.m. and 48.3%, minimum – 0.035 $\mu\text{g/g}$ d.m. and 25% (on average – 0.203 $\mu\text{g/g}$ d.m. and 35.4%). The section is located on the left bank of the Dead Donets River. The dominant types of vegetation and the amount of total biomass are *Artemisia lavandulifolia* (12,25 t/ha) and *Typha latifolia* (14,8 t/ha). The grass height stand varied from 34 to 183 cm.

It is noted that the results obtained are comparable with those of previous years. According to [4], the minimum values for mercury concentration in soils ranged from 0.033 to 0.05 $\mu\text{g/g}$ d.m. and averaged 0.41 $\mu\text{g/g}$ d.m. The total biomass values reach high values in sections 1 and 4, and the highest grass level height is characteristic of a landscape with near-aquatic vegetation.

In addition to the levels of mercury concentrations in the soils of the studied landscapes, it is necessary to understand the degree of enrichment or depletion of the element relative to the area background. Calculations of concentration coefficients K_c were carried out. The average minimum mercury concentration recorded in the Don River Delta was taken as background values [4]. This is due to the fact that the territory under consideration is located at a distance from the main pollution sources. A series has been formed based on the degree to which the mercury content in the soil exceeds its background values:

– the Near-water landscape_(13,5) > the True meadow landscape_(5,9) > the Sandy psammophyte meadow landscape_(2,5) > the Sandy steppe landscape₍₁₎.

Metal intensive accumulation in soils is noted, in which the mercury content in section №4 is 13.5 times higher, and the relative concentration of the microelement in the sandy steppe landscape ranges from 0.9 to 1.1 and is considered close to background parameters.

4 Conclusion

The conducted studies indicate that the highest values of total biomass are observed in the sandy-psammophyte meadow and the near-aquatic landscapes – 46.55 t/ha and 41.85 t/ha, while the grass height stand with maximum values is found on the latter object. Mercury levels in selected areas of the Don River Delta are below the maximum permissible concentrations. Increased values are observed in the area with the near-aquatic vegetation (on average 0.203 µg/g d.m.). This may be due to some swampiness of the area and, as a consequence, mercury intensive accumulation in the soil and in the vegetation. Soil moisture increases from the sandy-psammophyte meadow to the near-water landscape (on average from 18.06 to 35.4%). The intensity of accumulation and migration of microelements in the soil is inversely related to the level of soil moisture. The calculated concentration coefficients indicate mercury intensive accumulation in the soils of the Don River Delta.

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