Analysis of the soil cover from the mercury province Aydarken (Kyrgyzstan)

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Abstract. Kyrgyzstan holds a prominent position globally as a significant source of antimony and mercury, with considerable scope to enhance the output of these metals. Nevertheless, safety concerns related to mercury possess both ecological and societal consequence, which demand attention. Transport and transformation dynamics of mercury within ecosystems necessitates specific focus. This article elucidates findings from physical-chemical analyses carried out in Mercury Province of Aydarken - situated within Kyrgyzstan's Batken area - over a span of four years (2013 - 2017). The research delved into exploring different soil types and their individual mechanical components at various sea-level altitudes ranging from 1684 m to 2078 m. The investigation used atomic absorption techniques to gauge levels of mercury concentration in the soil cover; noteworthy observations emerged during this process. It was discerned that across every zone studied, there was an elevated level of concentration compared not only to control plots but also against Maximum Permissible Concentration (MPC) thresholds pertinent for safety standards: this held notably true around areas such as tailing dumps and metallurgical plants with variations observable per proximity from contamination sources.

1 Introduction

Aydarken, Chauvay, Uluu-Too are considered the largest mercury deposits in Central Asia. The Aydarken deposit belongs to the quartz-fluorite-antimonite – cinnabar mineral type [1]. The average mass ratio of Hg:Sb:As for fahlores of Aydarken approaches elemental mercury, and cinnabar contains from 0.1 to 2% selenium [1]. The background content of mercury in soils is difficult to estimate due to widespread anthropogenic contamination with this metal [1]. Mercury can bind strongly with soil constituents [2], however, are also determined by soil morphology and genesis, content, texture, and pH of soil [3]. Thus making it a topic requiring urgent attention within the field of geochemical ecology, which studies chemical composition relation with environmental objects in both natural and technological biogeochemical territories. The soil plays a crucial role within the mercury bio-geochemical

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cycle due to its dual function - depositing medium for mercury compounds alongside facilitating their integration into ecosystem components [4]. Specifically focusing on Aydarken region has revealed localized industries like mining plants in addition to tailings dump acting as primary sources contributing to chronic mercury pollution. Anthropogenic influence significantly disrupts the normal biogeochemical cycle of heavy metals [5,6]. The main sources of pollution in the investigated mercury province of Aydarken are the mining plant and the tailings dump.

The study is mainly aimed at finding out the mercury content and status of the Aydarken soil cover, as continuous monitoring is required. The dimensions geographically extendable up to 24 kilometers long by 12 kilometers wide situated approximately between altitudes varying from 1360 meters rising till 2360 meters above sea level [7].

2 Materials and Methods

The objects of the study are the soil cover of Aydarken biogeochemical province. Using GPS, we established the altitudes and coordinates. Soil samples were taken following the standards from horizon A with a depth of 0-20 cm. An extensive scientific examination was performed at eight designated locations within the mercury province of Aydarken, taking into account their geographic proximity to pollution sources (Table 1). Determinations of the amount of mercury in the objects under study (soil) were carried out by the atomic absorption method (with a hydride attachment) on an MGA-915 spectrometer, and in some samples - on an RA-915M mercury analyzer [7].

3 Results and discussion

In the studied province, we identified dark Turan light soils at points AMP 1, AMP 2, AMP 3, AMP 4, AMP 5, and brown dry steppe mountain soils at points AMP 6, AMP 7, AMP 8 (Table 1). Altitude above sea level ranged from 1684 m to 2078 m. With an increase in altitude above sea level, mountainous brown dry steppe soils are formed.

Table 1. Places of sampling of soils, and soil type

Sample code	Collected place	Height above the sea level, m	Soil type
AMP 1	Tailing dump	1756	sand, Turan light soils
AMP 2	Upper part of the tailing dump	1700	Turan light soils dark sandy
AMP 3	Lower part of the tailing dump	1684	Turan light soils dark sandy
AMP 4	Lower part of the tailing dump	1685	Turan light soils dark sandy
AMP 5	Metallurgical factory, 20 m from the road	1913	Turan light soils dark light clay sandy
AMP 6	1 km from the metallurgical factory, 100 m from the road	1931	Mountainous brown dry sandy light soils
AMP 7	Eastern border of the Aydarken, 100 m from the road	1996	Mountainous brown dry light soils
AMP 8	On the Aydarken pass, 100 m from the road	2078	Mountainous brown dry sandy light soils

The higher the concentration of pollutant ion solution, the more cations near the surface of solid particles, indicating that the mixed soil absorbs more metal ions [8].

The main element in this province, mercury, was determined by atomic absorption (with a hydride attachment). The results of the concentration of mercury in the soil by years are presented (Table 2). The dynamics of these indicators in the soil cover depends on many factors, therefore, from 2013 to 2017, the data changed. The highest value for mercury in the area of the tailing dump was observed in 2014, with a subsequent decrease in 2015. In 2015, the amount of precipitation was above normal, therefore, the concentration of mercury in the soils of the tailing dump is slightly lower, but on the contrary, the highest value of mercury was observed approximately the metallurgical plant.

This enriches the soil and hydrosphere. During thermal processes, heightened volatility results in mercury evaporation from soil composition [9].

The improvement of economic development level will aggravate the regional environmental pollution [10]. Recorded minimum values for soil-based mercury were identified on metallurgical plant premises during our observation period in 2014. As reported in the report on the socio-economic development of the Kyrgyz Republic, in 2014 the drop in mercury production was 34.5%.

Table 2. Dynamics of the mercury content in the soil cover by years (mg/kg)

Sample code	**Hg**				
	2013	**2014**	**2015**	**2016**	**2017**
AMP 1	206.24	456.12	169.2	218.9	208.7
AMP 2	43.14	57.41	118.34	87.5	92.1
AMP 3	29.05	28.46	29.8	32.17	29.56
AMP 4	24.13	43.23	25.5	20.62	22.35
AMP 5	438.6	365.17	508.4	431	423
AMP 6	28.98	41.3	31.2	34.82	38.05
AMP 7	25.68	18.2	29.7	17.51	18.4
AMP 8	13.48	9.5	11.4	10.22	11.75

The average content of mercury in the soil cover of the mercury province of Aydarken is 191 times higher than the MPC (MPC = 2.1 mg/kg) on the territory of the metallurgical plant, and 101 times higher on the territory of the tailing dump at the Aydarken pass (conditionally control area) by 6 times (Fig 1).

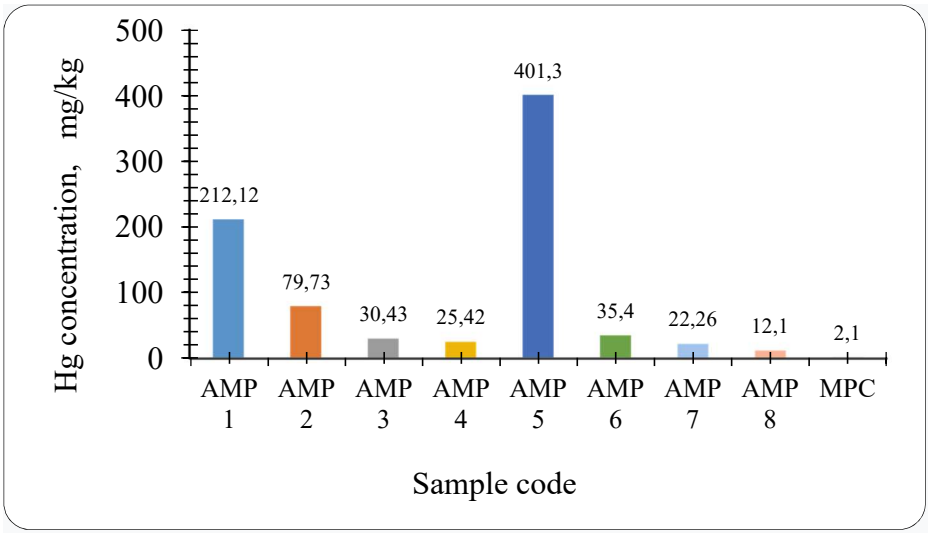

Fig. 1. The average content of mercury in the soil covers during 2013-2017

4 Conclusion

Thus, it can be argued that the main source of pollution in this province is the mining plant and tailings, which occur during ore processing and the technological process, as well as from tailings due to climate change. The data obtained on mercury in the soil cover of the province are significantly higher than in the background plots and MPC, and their amounts depend on the distance to the source of pollution. The dynamics of mercury content in the soil depend on many factors; therefore, the results obtained from 2013 to 2017, are not the consistent. Our findings from 2014 reveal that the metallurgical plant grounds persisted with minimal presence of mercury concentration within its soil stratum, which is explained by a drop in production and other factors. In summer, when the temperature rises, mercury evaporates and rises to the topsoil.

Remarkably elevated concentrations - possibly reaching up to 456 mg/kg by the tailing dump and peaking at an astounding 508.4 mg/kg near the metallurgical plant - were discovered as well; a stark contrast considering the Maximum Permissible Concentration (MPC) for mercury in soil is set merely at 2.1 mg/kg. This is explained by the diversity of both the forms of its existence in nature and the routes of entry into soils, so periodic monitoring must be carried out in this province.

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