Short communication

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Hg in waste from mining and processing enterprises in the Republic of Khakassia

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ABSTRACT. The article presents the original data on the total Hg concentration in the waste of enterprises for the extraction of iron ore, coal and marble located in the Republic of Khakassia. Hg concentrations in the rocks of the dumps and the material of the tailings depend on the electrical conductivity and magnetic susceptibility. The concentration of this element increases in more acidic environmental conditions, and its higher concentrations are associated with particles having a size of 0.04 mm. Geoecological indicators demonstrate the enrichment of Hg waste from all enterprises studied, as confirmed by the calculation data of the enrichment factor.

Keywords: Hg, mining waste, Khakassia, soils, geoecology, iron ore, coal, marble

1. Introduction

The main cause of the negative impact of mining waste on the environment is associated with the migration of chemical elements formed through the placement and long-term storage of material during mining (overburden and enclosing rock dumps) and processing (tailing dumps and sludge ponds) of ores. The danger of waste can be exacerbated by the fact that they contain a large amount of toxic elements, including mercury (Hg). It is one of the priorities for the study of toxic elements (Alekseenko, 2000). Hg concentration exceeding the established standards is most often associated with tailings. The maximum Hg concentration is observed in the halo of the emission source, and the distribution is associated with the landscape and climatic conditions as well as the direction of the prevailing wind. A significant amount of Hg can enter the atmosphere, surface and groundwater from quarry dumps during blasting as well as during dusting and transportation of ores (Belan, 2005; Krupskaya et al., 2009; Zhuravleva, 2016; Gustaitis et al., 2016; Azarova et al., 2018).

2. Materials and methods

The object of the study were samples of dumps, tailings, sludge pits, ash and slag wastes, as well as soils located near dumps taken in the Teisky iron ore deposit, the Kibik-Kordon marble deposit and the Vostochno-Beisky coal mine. Waste and soil were sampled out using the envelope method (51 points) according to (GOST, 1984).

Hg concentration in the samples was 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 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 granulometric analysis of the soils was carried out using laboratory sieves with diameters of 1. 0.5, 0.25, 0.125, 0.1, and 0.04 mm.

The method of the results processing included the calculation of ecological and geochemical indicators: the concentration coefficient relative to the average for the sample (K_M), maximum allowable concentration (MAC – 2100 ng/g) (Yanin, 1992), soils of the Earth (K_{SE}) (10 ng/g) (Alekseenko, 2000), clarke concentration (K_K) (Yanin, 1992) and enrichment factor (normalization by Sc, own data) (K_E).

3. Results and discussion

The mean Hg concentrations in the wastes of mining and processing enterprises of the Republic of Khakassia ranged from 69 to 126 ng/g (Table), with a range of absolute values of 10 to 1044 ng/g. The

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Table. Geoecological indicators of Hg pressure near the tailings of mining and processing enterprises in the Republic of Khakassia

Sampling site	C_{Hg}, ng/g	K_M^*	MAC	K_E	K_K	K_{SE}
Tey	51-89	1	0.03	2.4	1.5	6.9
East Beyskoye	35-350	1	0.04	1.9	2	9.1
Kibik-Kordonskoye	10-1044	1.4	0.1	13.7	3.9	17.7

Note: * - see Materials and methods

distribution of Hg in tailings was uneven, as confirmed by the calculation of the variation coefficient (79-489%). The maximum mean concentrations were detected in the waste from the Kibik-Kordon marble deposit (171 ng/g), and the minimum - from the Tei iron ore deposit (69 ng/g). In the waste from the Vostochno-Beisky coal mine, the mean concentration was 91 ng/g.

The study of the dependence of element concentrations on the size of soil particles revealed that, in most cases, particles $^{>}0.04$ and <0.004 showed the maximum Hg concentration, i.e. the smallest particles (medium dust, according to (Kachinsky, 1958)). Their proportion was minimum in the soils of all studied tailings. The results obtained were consistent with the statement that the particles with the smallest size had the maximum Hg concentration.

In addition to the Hg concentration in waste samples, we determined such soil characteristics as electrical conductivity, magnetic susceptibility and pH (Fig. 1).

Taking into account the relationship of Hg with these characteristics, it is worth noting a rather high correlation between all factors for waste from the Vostochno-Beysky coal mine (Fig. 2). Therefore, to identify the strongest bonds, the critical value r = 0.8 (at P 0.05) was used, which revealed the strongest bond between the metal and the magnetic susceptibility. In the studied tailings, the connecting center for all indicators was precisely the magnetic susceptibility, through which Hg and other indicators were connected with each other. The magnetic susceptibility value indirectly indicated the presence of other metals in the samples. Thus, we assume that Hg is related to other metals, which requires additional studies. Hg concentration depends on the electric conductivity (both positively and negatively) and increases with the shift in the soil reaction towards oxidation (which is rather natural). The relationships obtained indirectly indicated the connection between Hg with other metals.

Calculations of environmental and geochemical indicators of Hg accumulation by waste from mining and processing enterprises of the Republic of Khakassia by different types of soils revealed an excess relative to the mean value for the sample (Table), the concentrations below MPC (2100 ng/g) and enrichment relative to the Clark of the Earth's crust (45 ng/g) and soils of the Earth (10 ng/g). The enrichment factor also indicates the enrichment of tailings materials and dump rocks in an element.

4. Conclusions

The studies of the concentration and geoecological features of the Hg distribution in the waste of mining and processing enterprises of the Republic of Khakassia revealed that the highest concentrations of this element were observed in the tailings of a marble mining enterprise. In the waste of all enterprises studied, Hg was had the maximum concentrations in the finest fraction, which is consistent with the literature data.

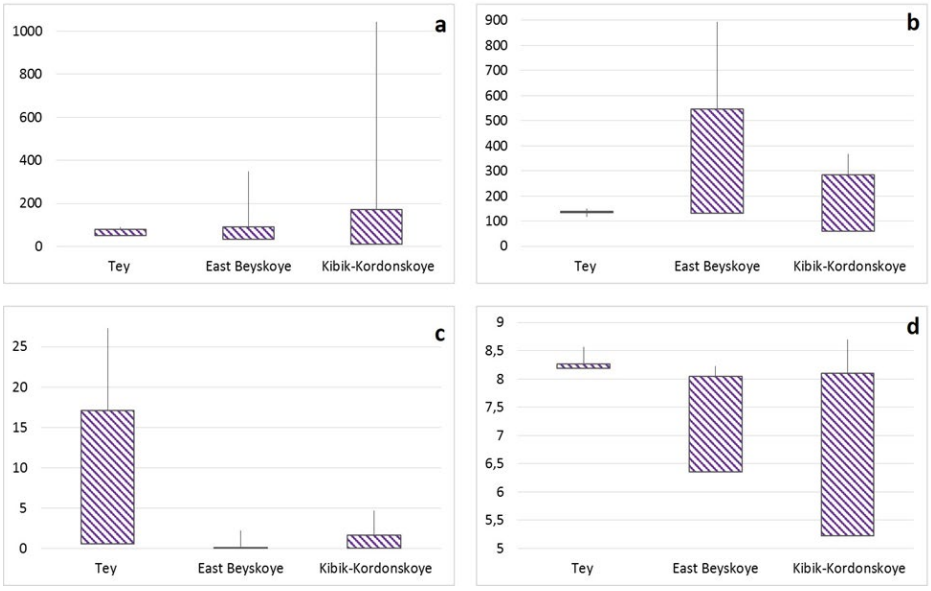

Fig.1. Hg concentrations and physical and technical characteristics of the material from tailings of mining and processing enterprises of the Republic of Khakassia: a - Hg concentration, ng/g; b - electrical conductivity, μS/cm; c - magnetic susceptibility 10-3 units, and d - the pH value of soil extract, pH units.

Furthermore, in the soils of tailings, Hg depended on the value of electric conductivity, magnetic susceptibility and increased with a change in the reaction of the environment towards acidification. The data from geoecological calculations testified to the Hg enrichment of the waste of enterprises extracting marble, iron and coal, as confirmed by the calculation of some indicators, including the enrichment factor relative to Sc.

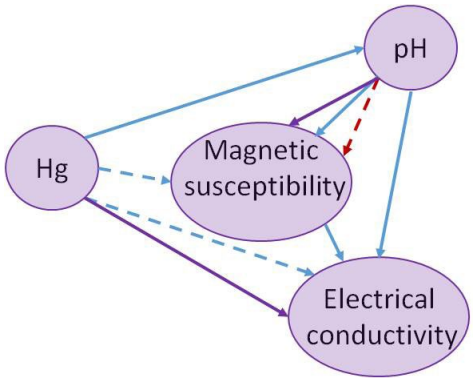

Fig.2. Graphs of the relationship of Hg with material properties of tailings of mining and processing enterprises of the Republic of Khakassia: solid line - positive relationship; dashed line - negative; red – Tey; blue - East Beyskoye and lilac - Kibik-Kordonskoye

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Conflict of interest

The authors declare no conflict of interest.

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