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Comparative analysis of the sources of mercury concentration formation in the water of the Paatsjoki River basin

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ABSTRACT. We overview the content of mercury compounds in ore formations, the deposit development of which is the source of mercury compounds entering the environment. The vast majority of mercury in pyritic ores passes into concentrates and is taken in this composition for processing; only a small amount of it (up to 2–7% of the total amount in ores) goes into processing waste that is stored in tailings dams. We analyze the mercury concentrations in the water objects in the Paatsjoki River basin, the watershed of which is associated both with the Monchegorsk copper-nickel deposit where the mercury concentration can reach 9 g/t and with the production sites of PJSC MMC Norilsk Nickel. From 2017 to 2020, the concentration of mercury compounds in the water of the cascade of reservoirs on the Paatsjoki River, in the transborder sections of the Russian Federation border with Finland and Norway, increased evenly from the earlier to the later time of reservoir creation. The concentrations of mercury compounds in the waters of reservoirs generally exceeded the concentrations in the water of the Kolosjoki River at the observation site of the Nickel settlement in the area of the JSC Kola MMC activity. We conclude that the activation of microbial processes occurring in the bottom sediments during the formation of reservoirs with the increase in the amount of organic matter received and under certain geochemical conditions in the region affect the levels of mercury concentrations in the water.

Keywords: mercury compounds, the Paatsjoki River, reservoirs,the Kolosjoki River, river transborder sections

1. Introduction

Mercury is an accompanying element in most ore formations. In some deposits, e.g. copper-silver ones, mercury is present in the ore in mineral form. In platinoid deposits, mercury is part of complex minerals; in copper-pyritic, copper-nickel, sulfur-pyritic, and polymetallic deposits, mercury is present in a dispersed form. Sulfide deposits are distinguished by significant amounts of mercury, and zinc sulfideores are the most enriched in mercury (up to 10–100 g/t). The average content of mercury in ores of pyritic deposits is approximately 1 g/t and 1.1 g/t in polymetallic ores. The average content of mercury in sulfide copper-nickel ores is 1 g/t, although, for example, in ores of the Monchegorsk copper-nickel deposit, its concentration can reach 9 g/t. The bulk of mercury in ores is present in sulfide form as a finely dispersed admixture in ore-forming minerals. Sphalerite is the main concentrator and carrier of mercury. Additionally, fahlore, galena, bornite, chalcopyrite, and pyrite are mercury concentrators. During ore processing at concentrating plants, methods for crushing and grinding ores are used, followed by flotation and production of various industrial concentrates. The vast majority of mercury in pyritic ores passes into concentrates and is taken in this composition for processing; only a small amount of it (up to 2–7% of the total amount in ores) goes into the processing waste that is stored in tailings dams. Nevertheless, the presence of concentrating plants in the regions and significant volumes of waste containing mercury in one amount or another predetermines the potential for its inclusion in migration chains. The extraction of ores, especially those containing zinc, copper, nickel, lead, and gold, releases significant amounts of mercury into the environment. The bulk of mercury is mobilized with zinc and copper concentrates processed in Russian metallurgical enterprises. During the processing, mercury is either released into the air or goes into waste or byproducts such as industrial sulfuric acid. A very small amount of mercury is delivered with the produced metals to consumers (Bobrova et al., 1990; Rtutnoye zagryazneniye…, 2014).

At the end of 2020, PJSC MMC Norilsk Nickel, a diversified mining and metallurgical company, the world's largest producer of palladium and high grade nickel, as well as one of the largest producers of platinum and copper, stopped the work of the smelter

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in the Nickel settlement (Murmansk Oblast). Todate, thiswastheoldestcompany'sproduction. Its shutdown was part of the Norilsk Nickel comprehensive environmental programme designed to significantly reduce the impact on the environment at all production sites. With the shutdown of the smelter, harmful emissions into the atmosphere at the Russian-Norwegian border were stopped. The company's management plans to modernize metallurgical production in the city of Monchegorsk. Analysis of the concentrations of mercury compounds in the surface waters of the region would reveal the contribution from each of the potential sources to the formation of their levels.

2. Materials and methods

Data on the concentrations of mercury compounds in the waters of reservoirs on the Paatsjoki and Kolosjoki rivers were obtained within the Programme for monitoring the pollution of surface waters of the land of federal monitoring network by hydrochemical indicators in the territory of operation of Murmansk Service for Hydrometeorology and Environmental Monitoring (Roshydromet) for 2017-2020 (Yezhegodnik…, 2017; 2018; 2019; 2020) (Fig. 1).

Fig.1. Layout of the sites of the Roshydromet federal monitoring network

3. Results and discussion

Based on the Murmansk Roshydromet data, the highest levels of water pollution were observed in the area of the JSC Kola MMC activity (Monchegorsk, Zapolyarny and Nickel) and in the city of Murmansk. The Kolosjoki River in the Nickel settlement is the most polluted watercourse in the watershed basin. A characteristic feature of water objects located in the area of the Kola MMC activity is the presence of nickel and copper compounds in natural water (according to Roshydromet data). An analysis of the data obtained by Roshydromet from 2017 to 2020 (five-year period before the shutdown of the smelter in the Nickel settlement) indicated the presence of dissolved mercury compounds in the water of the Paatsjokibasin in the river transborder sections near the state border with Norway and Finland. Notably, in the Kolosjoki River (Nickel settlement)polluted by wastewater from Kola MMC, the water of which is characterized by the fourth class with interannual fluctuations in grades from "a" and "b" ("dirty") to "c" and "d" ("very dirty"), the concentrations of mercury compounds were much lower than in the Paatsjoki River, the water of which in the sections upstream of the confluence with the Kolosjoki River is characterized as "roughly clean" of the first quality class or "weakly polluted" of the second quality class (Fig. 2).

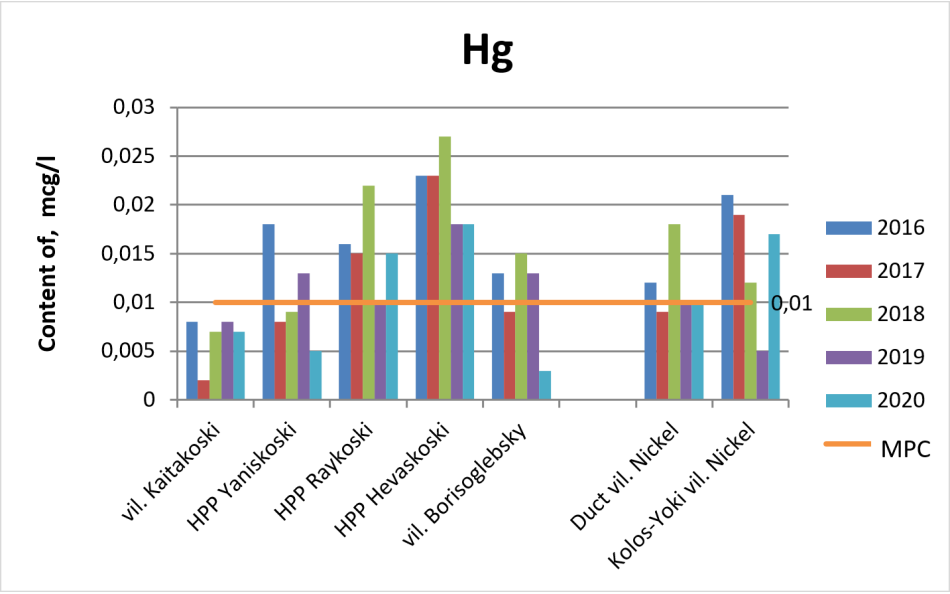

Fig.2. Histogram of the average annual concentrations of mercury in the water of the Paatsjoki River basin

Near the dam of the Hevaskoski Hydroelectric Power Plant (HPP), there were the most significant concentrations of mercury compounds. As this is the border with Norway, and there are no production facilities in this area, we can state that this is the consequence of the natural accumulation of mercury in the bottom sediments as well as of relatively recently created reservoir (the Hevaskoski HPP was the last constructed in the cascade of reservoirs) that was dispersed in the geochemical landscape of the region. In the Borisoglebskaya HPP of the Paatsjoki River, which is the last downstream and located farther off the confluence with the Kolosjoki River, the concentrations of mercury compounds were almost the same as in the Kolosjoki River, and the water quality varied from the third class of grade "a" ("polluted") to the second class ("weakly polluted"). Hence, the elevated concentrations in the surface waters of the region were due to the geochemical conditions.

Previously, it was shown that the creation of new or expansion of existing artificial reservoirs significantly increased the production of methylmercury, although in the new lakes in Finland, this increase was rather short-term. A similar phenomenon of the increase in mercury in new reservoirs, which fish and mammals that feed on them consume, was also observed when the runoff of the Churchill River in the province of Manitoba was diverted. Methylation levels in one of the reservoirs, which was flooded 20 years ago, returned to baseline. Mercury in all these artificial reservoirs, apparently, was also of natural rather than anthropogenic origin. The flooding of a large amount of organic matter and subsequent activation of microbial activity were considered the causes of the increased involvement of mercury in the methylation process (Gigiyenicheskiye kriterii..., 1992).

4. Conclusions

As over 50 years have passed since the commissioning of the youngest reservoir from the cascade on the Paatsjoki River, the Hevaskoski HPP, and the rate of bottom sediment formation has stabilized, we can more likely conclude that the mercury methylation process in the bottom sediments has also returned to its original volumes there. The increased geochemical background of the concentrations of mercury compounds in the surface waters of this region requires a more detailed study of microbial activity in the bottom sediments of the cascade of reservoirs on the Paatsjoki River located along the state border of the Russian Federation with Finland and Norway.

Conflict of interest

The authors declare no conflicts of interest.

References

Bobrova L.V., Kondrashova O.V., Fedorchuk N.V. 1990. Ekonomika geologorazvedochnykh rabot na rtut, surmu i vismut [Economics of geological exploration for mercury, antimony and bismuth]. Moscow: Nedra. (in Russian)

Gigiyenicheskiye kriterii sostoyaniya okruzhayushchey sredy 86. Rtut'. Ekologicheskiye aspekty primeneniyu [Environmental hygiene criteria 86. Mercury. Ecological aspects of application]. 1992. A joint publication of the United Nations Environment Programme, the International Labor Organization and the World Health Organization. Moscow: Medicina. (in Russian)

Rtutnoye zagryazneniye v Rossii: problemy i rekomendatsii [Mercury pollution in Russia: problems and recommendations]. 2014. In: Romanov A.V., Ignatieva Yu.S., Morozova I.A. et al. (Eds.). (in Russian)

Yezhegodnik kachestva poverkhnostnykh vod Rossiyskoy Federatsii [Quality of surface waters in the Russian Federation, annual report]. 2017. In: Lobchenko E.E. (Ed.). Rostov-na-Donu: Federal service for hydrometeorology and environmental monitoring. (in Russian)

Yezhegodnik kachestva poverkhnostnykh vod Rossiyskoy Federatsii [Quality of surface waters in the Russian Federation, annual report]. 2018. In: Trofimchuk M.M. (Ed.). Rostov-na-Donu: Federal service for hydrometeorology and environmental monitoring. (in Russian)

Yezhegodnik kachestva poverkhnostnykh vod Rossiyskoy Federatsii [Quality of surface waters in the Russian Federation, annual report]. 2019. In: Trofimchuk M.M. (Ed.). Rostov-na-Donu: Federal service for hydrometeorology and environmental monitoring. (in Russian)

Yezhegodnik kachestva poverkhnostnykh vod Rossiyskoy Federatsii [Quality of surface waters in the Russian Federation, annual report]. 2020. In: Trofimchuk M.M. (Ed.). Rostov-na-Donu: Federal service for hydrometeorology and environmental monitoring. (in Russian)