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Mobilization of metals and metalloids during and after burning of an uraniferous coal heap (the Bečkov coal mine, Czech Republic)

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Uranium mining took place in the former coal and uranium mine of Novátor at Bečkov between 1952-1957. Roughly 300,000 tons of coal and 40,000 tons of radioactive material were extracted. The contents of uranium ranged from 8 to 2,020 mg.kg^{-1}. The mineralization was bound to dull and bright banded coals. Uraninite and coffinite were the major uranium minerals accompanied by common galena, sphalerite, chalcopyrite, and pyrite. A spontaneous combustion of the top of the coal heap occurred in the 1960s, while the basal part was not affected by burning. The heap, from the 1970s until the present time, was gradually overgrown with vegetation, mostly birch trees.

The aim of the study was to assess the changes that occurred in the geochemical and mineralogical composition of the waste heap during burning and also during the following long period of its weathering. The contents of some metals and metalloids (Pb, Sb, Bi, and Zn) were found to be much higher in the burnt out part of the heap than in the unburnt part. These metals in the burnt parts of the heap occur in the form of authigenic galena, anglesite, alloys of metals and metalloids, and their oxides. The experimental work performed confirmed that Pb, Sb, Bi, and Sn at 900°C easily migrate in the form of chloride complexes.

A number of elements were found to have been extracted during the weathering and spontaneous revegetation of the heap, mainly by birch. The contents of Zn in the sap of birch trees reach up to 23,067 µg.l^{-1}, Pb up to 532 µg.l^{-1}, Cu up to 84 µg.l^{-1}, and Cd max. 40.2 µg.l^{-1}. Conversely, the uranium contents are very low (<0.05 µg.l^{-1}). Concentrations of metals in leaves of birch trees attain max. 703 mg.kg^{-1} Zn,

16 mg.kg^{-1} Cu, 20 mg.kg^{-1} Pb, 16 mg.kg^{-1} Cu, 3 mg.kg^{-1} Cd, 2 mg.kg^{-1} As, and 0.02 mg.kg^{-1} U, and correlate with contents of the same elements in the heap material. Birch leaves are a major component of the humus layer, which has successively been formed on the surface of the heap. This layer greatly reduces the infiltration of rain water into the body of the heap.

In contrast to the low pH of aqueous leachates from the burnt heap (2.5 to 6.5), the pH of the water effluent from the heap varies between 7.8 and 8.1. These waters are likely to have migrated through and drained the basal, fresh parts of the heap (pH = 6.5 to 8.2), or waters which originated below the heap. Due to their neutral character they contain only high concentrations of uranium (max. 261 µg.l^{-1}), zinc (max. 278 µg.l^{-1}), and sulfates (up to 259 mg.l^{-1}). The modeling results of uranium speciation in water showed that this element is present in the form of uranyl carbonate complex ($UO_2(CO_3)_2^{2-}$), or as a phosphate complex ($UO_2(HPO_4)_2^{2-}$). Regardless of relatively high contents of uranium in the water effluent, the burnt coal heap of the mine does not pose any significant danger to the local environment due to fast adsorption of uranium and other metals on organic matter and clay minerals in nearby swamp. Concentration of uranium in swamp sediments reach up to 256 mg.kg^{-1}.

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