Radioactive Contaminant Transport of Aue Mine Dump 371: A Geochemical and Isotopic Case Study

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Abstract. In order to evaluate the current and future environmental impact of the disposal site, investigations of environmental and radioactive isotopes have been performed as part of a hydrogeological and hydrochemical case study at Aue Mine Dump 371. The results were summarised in a hydrogeological model of the dump. The main contaminants reaching the nearby rivers are of uranium and arsenic. The mean residence time of those waters percolating the dump is about 2 to 5 months. The ^{3}H and ^{85}Kr contents in the groundwater of the first aquifer yield a mean residence time of about 10 to 20 years.

Introduction

The Aue Uranium Mine in Saxony, East Germany, was shut in 1990 due to the end of uranium production in the former GDR. As a result of the exploitation of the uranium mine 371 about 40 dumps were left in the Aue area. The main dump is Aue Mine Dump system 371, which consists of two dumps of about 45 ha (Aue Mine Dump 371/I) and 22 ha (Aue Mine Dump 371/II). After in-situ remediation of the dumps, the ground and pore water, which are released in the rivers nearby, will become the most important aqueous pathway for the migration of radioactive and toxic contaminants. In order to evaluate the radionuclide potential and to specify the current and future environmental impact of the disposal site, investigations of environmental and radioactive isotopes have been performed as part of a hydrogeological and hydrochemical case study.

Description of Aue Mine Dump

Site characterisation

Aue Mine Dump 371 is is situated in the south west of Saxonia, Germany, next to the city of Aue. The study site (see Figure 1) receives an average annual precipitation of 800 mm with maxima in March, April and August.

Aue Mine Dump 371 is the most voluminous dump of the Aue dump complex and reaches a thickness up to 30 m, in maximum 60 m. It was filled from 1946 to 1990 with rocky mining waste of the shaft 371. Aue Mine Dump 371/I contains 9,9 mil m³, Aue Mine Dump 371/II 3,7 mil m³ mining waste consisting of rock material of the mining process and mining residues. The deposited mining waste includes 642 t uranium, 10.692 GBq radium and 7036 t arsenic. The 371 Mine was closed in 1990 (Meyer et al 1998). The flooding of the pit started in 1999. All belonging dumps will be covered with mineral soil and replanted.

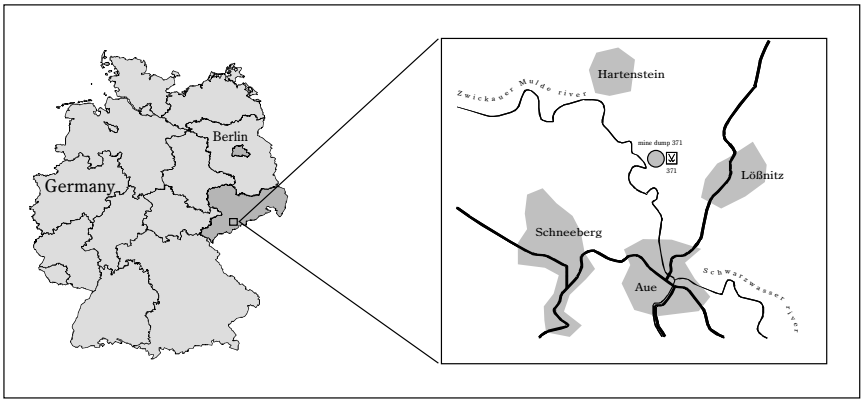

Fig.1: Map showing the location of Aue Mine Dump.

Geological and hydrogeological setting

The Aue area is characterised by paleozoic micas and phyllites, which were formed during the variscic orogenesis. The rock is fractured and clayey weathered from the surface into a depth of 2 to 30 m. Upstream and downstream the dumps monitoring wells were installed. These wells describe the water flowing in the rock aquifer and the weathering zone of the phyllites. Referring to pumping tests, the mean hydraulic conductivities of the unweathered rock zone range from 10^{-7} to 10^{-8} m/s, with elevated values of 10^{-5} m/s in tectonic structures. The weathered loamy

zone has a permeability of 10^{-6} m/s. The dump material reaches a high permeability up to 10^{-2} m/s, locally. The phyllite aquifer can be described as fracture aquifer. Recharge takes place throughout the study area by infiltration of precipitation and vertical leakage. An artesic ground water table has formed In the loamy weathering zone, locally.

Aue Dump 371/I is partly covering the former Kohlungbach river valley, Aue Dump 371/II the former Wiesenbach river valley, which are overfilled. The rivers are flowing into the dump material upstream and crop out of the dump material downstream. About 500 m underneath the dumps the rivers are entering the main river Zwickauer Mulde. Water saturation within the dump is maintained only at the bottom with an extension of about 2 m. In most parts of the dump, an impermeable basement is missing. Consequently, percolating dump waters can directly enter the phyllite.

Investigations Methods

Following topic was investigated in detail at Aue Mine Dump 371:

- hydrological and hydrochemical characterisation including water balance of the dump and dump catchment,
- isotopic and hydrochemical composition of the pore, surface and groundwater to characterise the longterm contaminant potential,
- hydraulic and hydrogeological characterisation of the dump, the underlaying weathering zone, the fracture aquifer und the nearby rivers,
- water residence times and water recharge rates.

The water balance was calculated based on hydrological data of field measurements. Following equipment was installed:

- ground water wells,
- various runoff weir plants using continiuos data collecting units,
- climatological station,
- lysimeters for the evaluation of pore water recharge.

According to the complex hydraulic situation of the site following isotope analysis were performed:

- oxygen-18 analysis of the surface and ground water to analyse the annual variation of mean residence time and evaporation effects,
- tritium (^{3}H, ^{85}Kr) analysis of groundwater to evaluate the residence time of the older component,
- investigation of heavy runoff events (including measurements of runoff, conductivity, oxygen-18).

The neutralisation potential towards acid mine drainage was investigated by the $^{32/34}S$ method.

Results

Hydrochemical analysis of ground and surface waters

The hydrochemical data base of about 40 surface and ground water monitoring locations contains about 800 analytical data sets. All data were analysed using statistical methods.

The natural ground and surface waters refer to the HCO_3-SO_4-type. Due to the natural HCO_3-content, the dump waters are characterised by neutral pH-values and no acidification potential. The natural mineralisation reaches 0.4 mS/cm. The main contaminants of the pore waters are uranium (0,8-2,5 mg/L) and arsenic (28-270 µg/L). In addition, contaminants such as zinc and sulphate are present in the pore water. In contaminated surface waters uranium concentrations range from 0,5-1,5 mg/L, arsenic concentrations from 80-560 µg/L. Radium-226 activity reaches 90 mBq/L, locally.

The radionuclide concentrations in the dump pore waters are 10 times higher than at the natural inflow of Kohlungbach (MP 067) and Wiesenbach (MP 094), see figures 2 and 3. Due to the deposited mining waste containing arsenic ore the arsenic concentrations of Aue Dump 371/II are about ten times higher than in Aue Dump 371/II. The uranium concentrations in the pore waters of Aue Dump 371/I are reaching three times higher values than the pore waters of Aue Dump 371/II. Contaminated pore water was analysed in the groundwater in the narrow strips of faulted rock beneath both dumps reaching Zwickauer Mulde River.

Water balance and recharge

The water balances of Aue Mine dump 371 can be deduced from values of about 0 to 100 mm infiltration into the underlying weathering zone to be very variable depending on local precipitation situation.

Investigation of stable isotopes

The mean residence time of those waters percolating the dump is about 2 to 5 months. The ^{3}H and ^{85}Kr contents in the groundwater of the first aquifer yield a mean residence time of about 10 to 20 years. The pore waters of the dump refer to a mixing system of precipitation and an older component. The results of the ^{34}S contents show no significant acidification potential of the dump material. Dump waters drain into the nearby rivers by interflow processes as indicated by stable isotopes, partly. The results of the isotopic and hydrochemical investigations are summarised in figures 2 and 3.

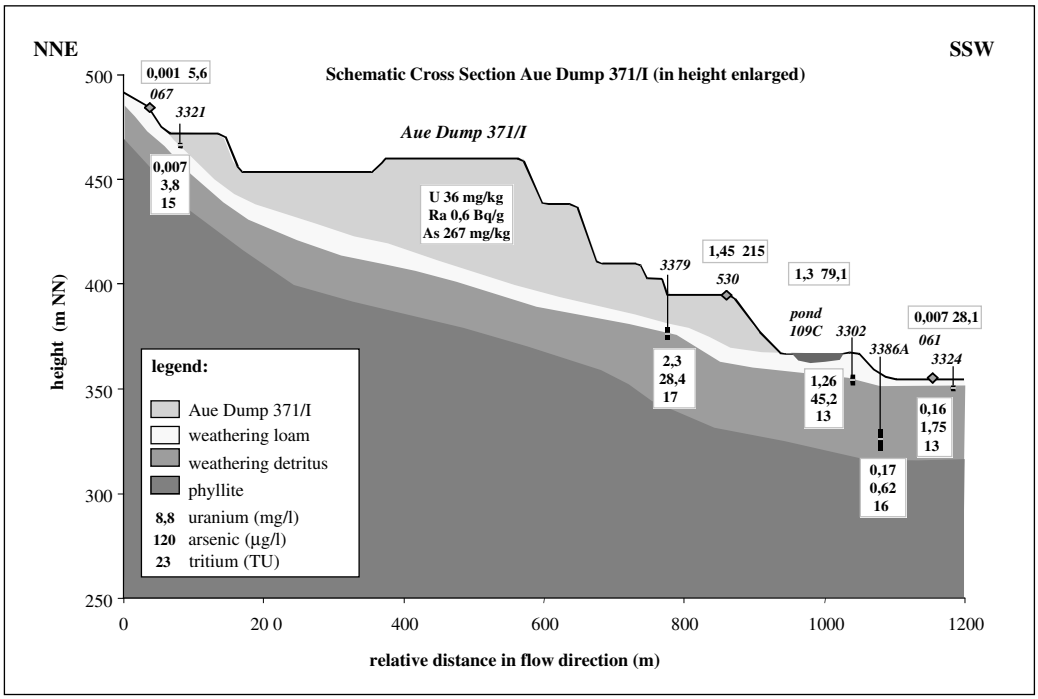

Fig.2: Schematic cross section of Aue Dump 371/I due to investigation results.

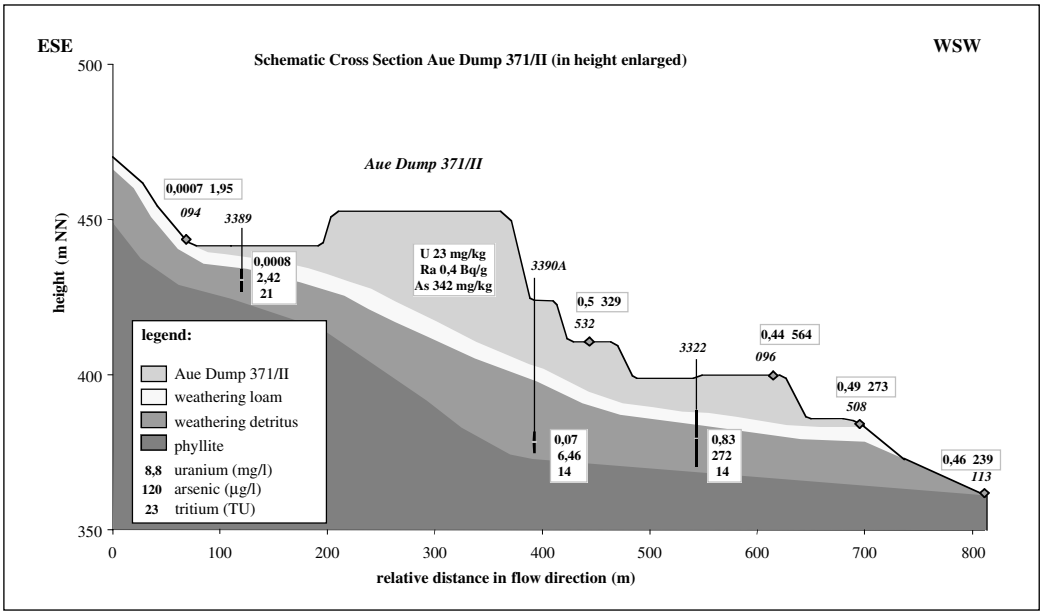

Fig.3: Schematic cross section of Aue Dump 371/II due to investigation results.

Conclusions

The impact of Aue Mine Dump 371 on the aquatic environment is determined by the evolution of the contaminants dissolved in the dump water and the amount of water released from the dump per year. Precipitation will infiltrate into the mostly uncovered dump body and eluate contaminants. Due to the heterogeneous structure of the dump, preferential flow paths for percolating waters are assumed to be responsible for the dominating water with low residence times, indicated by variations in $\delta^{18}O$ and recent ^{3}H values. Subsurface water is bound to the weathering zone, mainly.

References

Meyer J, Jenk U, Schuppan W, Knappik R (1998) Hydrogeochemical Aspects of the Aue pit Flooding. In: Merkel B, Helling C (eds.): Uranium-Mining and Hydrogeology, GeoCongress II, S. 124-129, Verlag Sven von Loga, Köln.