Remediation strategy for a waste rock dump at a former uranium leach operation

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Abstract

The Schüsselgrund mine waste dump at Wismut's Königstein mine site (Saxony, Germany) has been in operation since 1965. Due to the acidity of the leached mine waste as well as the acid generation potential of the sulfide bearing non-leached low-grade ore, the dump shows acidic seepage. Since the dump does not contain a liner at its base, groundwater monitoring shows significant influence of the dump at the underlying cretaceous aquifer regarding radio nuclide and trace metal concentrations. With regard to the remediation strategy neither relocation nor construction of a simple cover system turned out to be appropriate remediation options for the dump. Therefore, an optimized cover approach was chosen in order to both minimize the infiltration rate and improve the seepage quality. First measurement results of soil moisture and hydrochemical observation systems at the cover show positive effects regarding both the water balance and the seepage quality.

Introduction

The Schüsselgrund mine waste dump at Wismut's Königstein mine site is located in the Elbe Sandstone Mountains in the immediate vicinity of the Saxon Switzerland National Park. Established upon development of the Königstein uranium deposit in 1965 and extending across two dry valleys, the dump holds a total of some 4.5 million m^3. In the area of valley fill its maximum thickness amounts to ca. 45 m. The dumped material inventory includes waste rock, low-grade ore both acid-leached and non-leached, as well as water treatment sludges, both dewatered and undewatered. The largest mobile contaminant potential is found both in leached and non-leached low-grade ore. Seepage exhibits low pH, strongly oxidising conditions as well as elevated levels of Cl, SO_4, U, Zn, Ni, Co, Cu and Ra. Contaminant mobilisation is by sulphide oxidation processes and by residual acid remaining in the leached low grade ore from heap leaching operations.

In addition to the clay-lined floors of the dry valleys, the mine dump also overlies sandstone rocks of the first cretaceous aquifer. The dump has no base sealing. Average groundwater recharge in the area of the dump is 41 % of the corrected precipitation (ca. 350 mm/a). Via hydraulically permeable sandstones the seepage finds its way into the cretaceous water-bearing horizon (see Figure1). There are three more cretaceous sandstone aquifers in the footwall of the first aquifer. Impacts by seepage from the dump have been ascertained for aquifers one to three, where elevated levels of heavy metals and radionuclides, which are typically present in dumps of that type, were recorded in some monitoring wells. Due to the presence of high levels of SO_4, Zn and U this implies restrictions on the use of water from aquifers two and three.

***Table 1** Average water balance for the Schüsselgrund mine dump (period 1994 through 2011)*

Water balance quantity	mm/y (% of corrected precipitation)
Corrected precipitation	839 (100)
Real evapotranspiration	392 (47)
Surface and near-surface runoff	102 (12)
Groundwater recharge	349 (41)

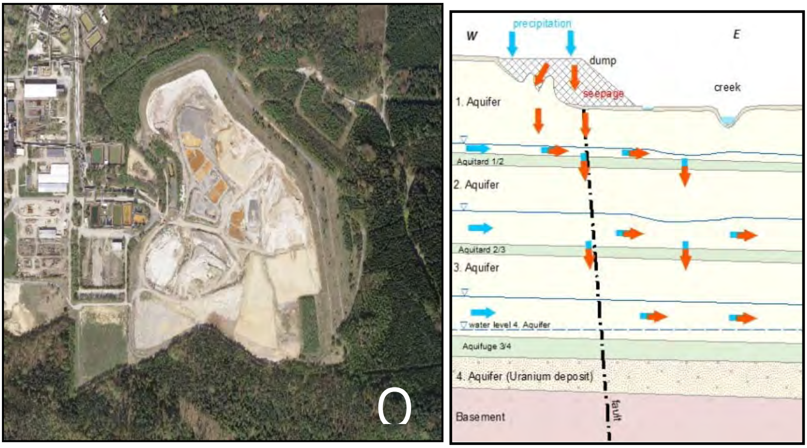

***Figure 1** Above: Aerial view of Schüsselgrund mine dump, 2011; Below: schematic cross-section of Schüsselgrund mine dump*

Selection and Optimisation of a combined cover system for the Schüsselgrund mine dump

The Schüsselgrund mine dump represents a typical uranium mining spoil heap that has no base sealing. Due to its contaminant inventory (residues of leach operations) the dump produces acid leachates which contain elevated levels of contaminants which are carried into the groundwater. With a view to minimising a further mobilisation of contaminants and their release to the groundwater via the seepage pathway, the subsequent remedial options were basically available:

- Relocation of the dump
- Conventional covering of the dump
- Combined covering using reactive material.

Disproportionately high haulage costs, lack of alternative on-site storage locations, and the need to blend the newly constructed dump body into the Saxon Switzerland Protective Landscape Area made relocation impracticable. In the context of model-based optimisation considerations, the conventional surface covering (option 1: moisture storage layer; option 2: moisture storage layer and infiltration barrier) was step by step checked against a surface cover using reactive material (moisture storage layer plus reactive material). From a water balance perspective, preference should be given to the two-layer conventional cover system so as to benefit from reduced seepage rates (modelling result). When choosing that cover option, the mobile acid and contaminant potential will not be proportionately immobilized, but would instead be released in a time-delayed manner. For that reason, placement of a reactive layer was preferred in order to allow neutralising agents being percolated into the mine dump body. To ensure an optimum action of the reactive material on the mine dump body, a minimum percolation rate has to be achieved. Such rate is higher in a single layer cover as compared to a double-layer cover. In this way, a greater neutralisation potential is being introduced into the mine dump body to positively change the acid environment.

Laboratory investigation

Selection of the reactive material was carried out with due regard to the prevailing hydrochemical conditions in the mine dump and on the basis of hydrochemical model calculations as well as of materials testing. A series of column tests was devised to test a number of reactive materials for their impacts on the acid material in the dump (see Figure 2). In these tests, a mixture of white hydrated lime and barium hydroxide turned out to produce a favourable effect. Column testing of white hydrated lime and barium hydroxide in various mixtures were conducted for a period of two years to improve optimisation. Precipitation was simulated by supplying the columns with equivalent amounts of water. A granular reactive layer containing a portion of 5 % of barium hydroxide acted most efficiently. This mixture made the pH of the seepage from the waste rock move the scale from acidic up to basic. Compared to the control approach without reactive material, uranium release was down some 70 %. Heavy metal levels in seepage were below 3 % of initial concentrations.

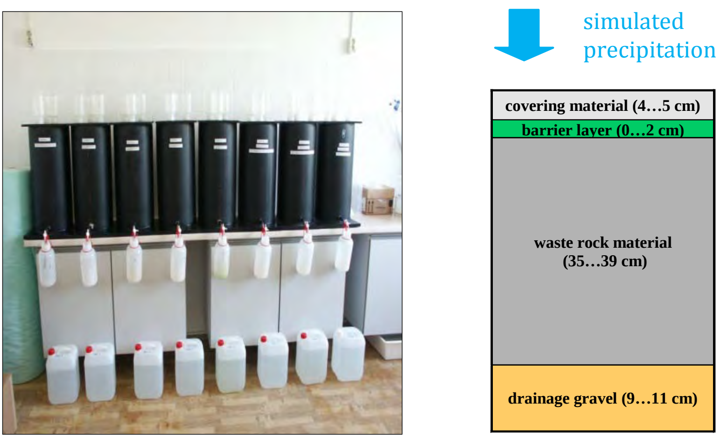

***Figure 2** Left: Column test to investigate the efficiency of reactive materials; Right: Schematic of column filling*

As a result of the column tests it could be reasonably ascertained that the reactive material had a favourable effect on the waste rock material by improving the hydrochemical conditions and reducing the migration of sulphate, iron, heavy metals, uranium and radionuclides. The application of barium hydroxide caused the fixation of Ra in the form of radiobarite (Ba, Ra) SO_4.

Full Scale application

Based on the results of water balance and hydrochemical model computations as well as on the findings of the column tests a single layer cover using reactive materials was identified as the optimum remedial options to apply to the Schüsselgrund mine dump.

Following licensing of the proposal, placement of this type of cover was initiated in a first construction lot in 2010. From bottom up, the layered system (see Figure 3) consists of:

- 1.0 m low-contaminated waste rock layer,
- 0.2 m reactive material layer,
- 1.0 m moisture storage layer.

With a view to verifying modelling and laboratory results, a total of nine soil probes and 6 lysimeters of identical fill pattern were incorporated into the cover during the second half of 2011. Probes and small-volume lysimeters are used to monitor soil moisture/soil tension and seepage rates and to perform periodical sampling. Trimestrial sampling is aimed at demonstrating the efficiency of the reactive materials. Initial data is now available after some six month of operation. Curve progression of seepage recharge is still determined by the system build-up (settlements, establishment of initial vegetation, to some extent impact by surface water) and exhibits the anticipated seasonal variations. Monitoring results from that brief period did not allow identification of hydrochemical developments.

Further soil hydrological/hydrochemical developments are continuously monitored. Reliable predictions on and trends for the cover system's efficiency will be derivable not until after one year of lysimeter and soil hydraulic measuring station operating. What may be expected is a declining seepage volume as the impact of vegetation is increasing (rise of evaporation portion).

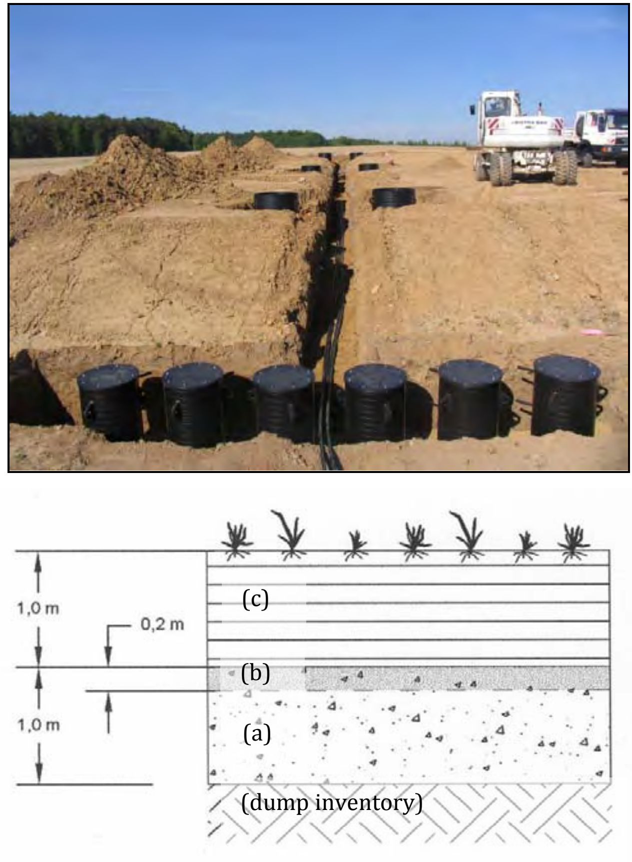

Figure 3 *Above: Lysimeter incorporation into mine dump cover; Below: Cross section of cover (a: low-contaminated waste rock layer; b: reactive material layer; c: moisture storage layer)*

Conclusions

Selection of rehabilitation options for a mine dump is determined by a variety of factors. Apart from technical and economic considerations, the crucial element in the case of the Schüsselgrund mine dump was its inventory of waste rock and residues from leach mining operations. Based on the results of investigations conducted on the dump inventory as well as on the results of hydrochemical and water balance modelling computations/optimisation analyses, the remediation option deducted was custom-tailored to the hydrochemical conditions of the dump. The cost-optimised cover system devised for the Schüsselgrund mine dump is aimed at both reducing the seepage volume and favourably impacting the contaminant source by hydrochemical means, i.e. permitting a treatment in situ. This combined cover system comprising a water storage layer plus an optimally selected reactive material was already put in place in the first construction lot.

Initial measurement and analytical data of the monitoring system exhibit the anticipated chemical and water balance effects of the cover system, even if not fully effective due to its recent placement. Upon establishment of vegetation (from fallow via meadow through to mixed woodland) an increase of the evapotranspiration rate and hence a decrease of the seepage rate is to be expected. Demonstration of the hydrochemical efficiency of the cover under real-size conditions will have to wait until a greater number of samples have been analysed.

References

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