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EFFLUENTS FROM A WASTE ROCK DEPOSIT OF A FORMER URANIUM MINE IN SAXONY/GERMANY — MASS FLOW BALANCE OF WATER AND DISSOLVED SOLIDS

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Abstract. Soon after uranium mining had ceased in eastern Germany in 1990, work for remediation of several mining sites began. The Wismut GmbH, owner of the Mine of Dresden-Gittersee's waste rock dump, introduced the concept of reducing the impact to the environment via water and air paths by implementing a multi-layer soil cover. The deposit consists mainly of waste rock (clastic sediments of Döhlener Becken, deep metamorphic rocks) but also of low-grade ore (U-rich coal) and tailing materials. At the time when remediation started, the effluents completely infiltrated the underground. Because of previous surface exfiltration activities, they were already known to be very rich in dissolved solids, especially in sulphate and uranium. As demanded by the state authorities, the owner funded a vast hydrogeological study of the site. In testing the efficiency of surface sealing, the study indicated a mass flow balance of water and dissolved solids for the current situation, and predicted emissions into the water path which would occur after realisation of the proposed soil cover. The field investigation program consisted of:

— measurements of flow, of concentrations of dissolved solids (esp. U and Ra-226) and of contents of environmental isotopes in precipitation, surface runoff, seepage water and groundwater in the current condition of the dump
— the study of waste rock material (geochemistry, mineralogy)
— waste rock material elution tests
— underground investigation by drilling boreholes up to 270 m in depth

The resulting data allowed for:

— a hydrogeological conceptual model of the site
— a consistent mass flow balance for the current condition of the dump
— a prediction of concentrations in groundwater resulting after the realisation of a soil cover

The predictions show that the concentrations of dissolved solids in the contaminated groundwater would be significantly decreased. Furthermore it would be possible to reach the standards for drinking water with respect to uranium content. Based on the presented study the realisation of the proposed surface cover can be recommended.

1. INTRODUCTION

The area south of Dresden, Saxony was a coal mining district for decades. Partial natural enrichment of the coal with uranium wasn't discovered until the 1950's. For some time both coal and uranium were mined simultaneously. Starting in the end of the sixties, only uranium mining continued. Mining then was fully operated by the former Soviet-German mining company SDAG Wismut and lasted over a period of another 20 years. In conjunction with the reunification of Western and Eastern Germany into one state in 1989, uranium mining was haulted in the entire country including at Dresden-Gittersee. Close-down operations already started in 1990. Responsible for the closing-down of this mine is Wismut GmbH, a company fully owned by the federal government.

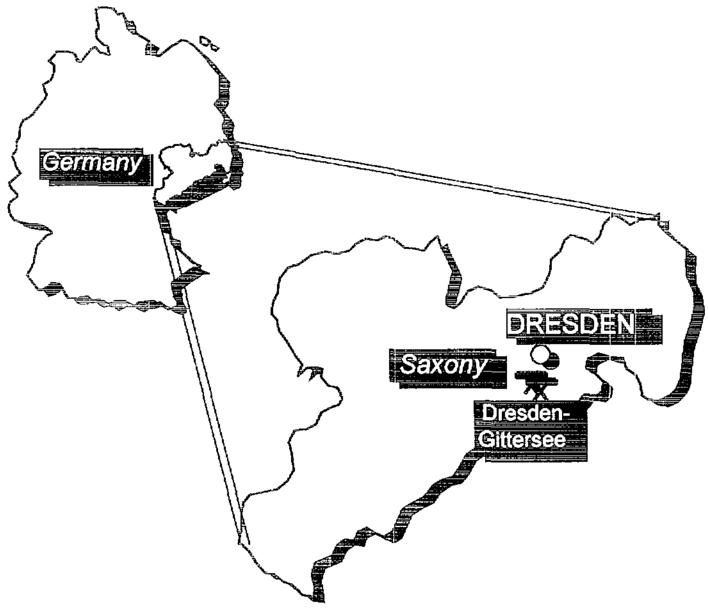

FIG. 1. Location of the mining site.

2. SITUATION AND PROBLEM

Several surficial deposits of mine waste exist in the area as remnants from the period of uranium mining. One of those, the dump of shafts 1 and 2, mainly consisting of waste rock is located in the immediate vicinity of the city of Dresden in a district named Gittersee (Fig. 1). In order to minimize the impact on the environment potentially caused by the release of contaminated effluents and the exhalation of radon, Wismut GmbH plans to implement a multi-layer soil cover on the dump. One important target of remediation are deep wells in the vicinity of the dump, which were used for drinking water supply at the time.

The project required the approval of the state authorities responsible for radiation protection. As a basis for its decisions, the authority demanded a hydrogeological study for the site, including a mass flow balance of water and dissolved solids in the current state of the dump, as well as predictions of effects due to the realisation of the project.

Using available documents and data, Colenco worked out a concept for the study which was based on field investigations and semi-quantitative analyses of data. The field investigation program consisted of:

- measurements of flow and piezometric head, determination of concentrations of dissolved solids (esp. Utot and Ra-226) and of contents of environmental isotopes in precipitation, surface runoff, effluents and groundwater;
- the study of waste rock material (geochemistry, mineralogy);
- performing waste rock material elution tests;
- underground investigation by drilling boreholes up to 270 m in depth.

The data analysis included:

- validation and interpretation of data
- development of a conceptual hydrogeological model
- evaluation of mass flow
- prediction of concentrations by simple analytical calculations

The work was done by a group consisting of Office Schmassmann (at that time a part of Colenco-Holinger AG), Wismut GmbH and BEAK Consultants GmbH.

3. SITE CHARACTERISATION

General information

Some general data on the dump site are given in Table 1.

TABLE I. GENERAL DATA OF DUMP (AFTER WISMUT 1994)

Waste rock dump Dresden-Gittersee, Saxony/Germany (state 1993)		
in operation		since 1950
Altitude		
- top (plateau)	m.a.s.l.	275
- lowermost point	m.a.s.l.	230
area (at bottom)	m^2	104'900
height of waste rock pile		
- maximum	m	30
- average	m	8
Volume	m^3	832'000
slope gradient		1:3
Content		
- waste rock: clastic sediments of Döhlen Basin and deep metamorphic rocks		
- low-grade ore: U-rich coal		
- tailing materials		

Geology and hydrogeology

As for the geological setting, the coal deposit is part of the Döhlen basin tectono-sedimentary structure which is filled with terrestrial clastic sediments of Lower Permian age, the so called "Rotliegendes".

The dump rests mostly on a thin layer of weathered rock and some soil, covering the underlying bedrock of the Lower Interstratified Formation. This Lower Interstratified Formation is a member of the "Rotliegendes" and consists of an inhomogeneous series of clastic sediments. Merely the uppermost part of the dump site is located on a thin sandstone formation of Cretaceous age.

The Lower Interstratified Formation is underlain by the Upper Breccious Conglomerate Formation, the Banded Silty Arkose Formation, the Lower Breccious Conglomerate Formation and the Niederhäslich-Schweinsdorfer Formation, all of which belong to the Lower Permian "Rotliegendes". As the names of its formations reveal, the "Rotliegendes" is composed of layers of conglomerates, sandstones and siltstones.

The Kaitzbach valley resembles a Quaternary gravel deposit.

From exposed rock faces and drilling observations one may roughly outline the hydrostratigraphy. It may be divided into coarse grained units like sandstones and conglomerates which function as aquifers and fine grained strata which represent aquicludes. Because the porosity of sandstones and conglomerates is very low, the permeability of the aquifers is controlled mainly by open fractures.

A detailed picture of the hydrostratigraphy evolved as the conceptual model of the local hydrogeology was developed. It consists of a complex system of aquifers with varying degrees of hydraulic communication (Fig. 2). At the top are the Upper Cretaceous sandstones, an unconfined aquifer with a freely fluctuating groundwater table. They are followed by the clastics of the inhomogeneous Lower Interstratified Formation. The available data is insufficient to derive an exact picture of ist internal structure. It is conceptualized as lenses of coarser material, i.e. local aquifers possibly with perched water tables, embedded in a less conductive matrix. Nevertheless, the Lower Interstratified Formation as a whole is considered as one of the three main aquifers of the "Rotliegendes", the other two being the Upper Breccious Conglomerate Formation and the Lower Breccious Conglomerate Formation.

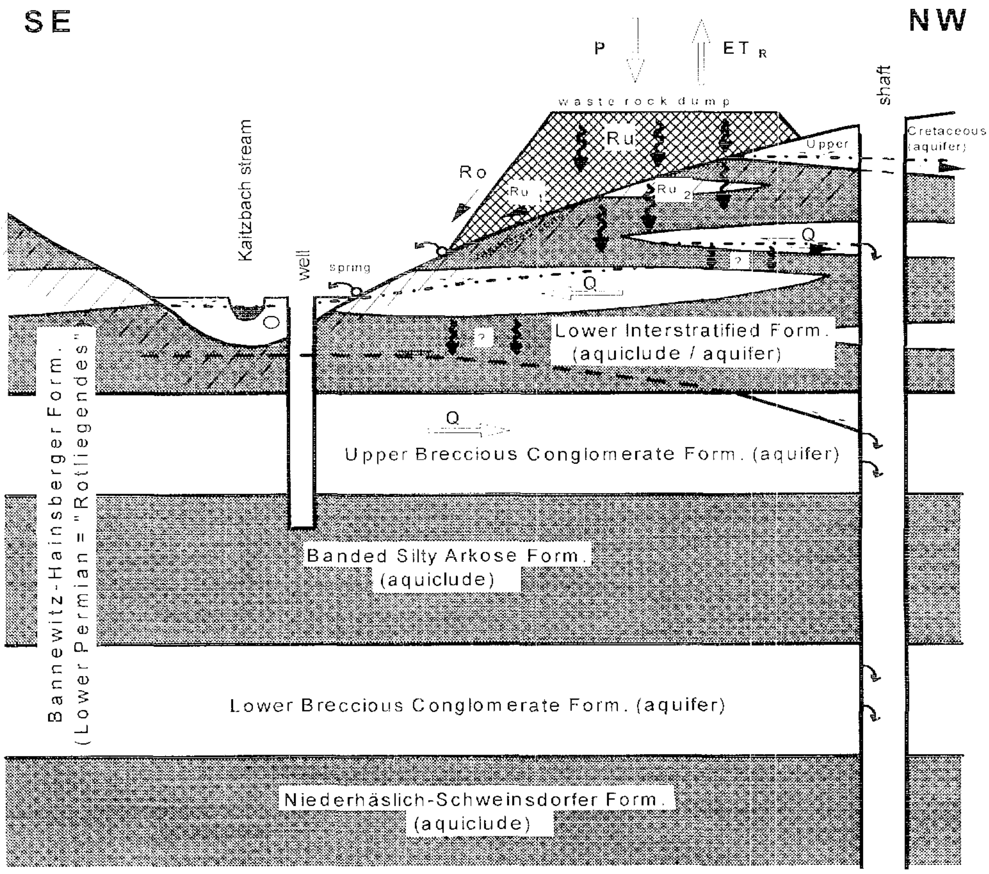

FIG. 2. Conceptual hydrogeological model.

The discharge of the Lower Interstratified Formation concentrates on one main spring, the Rotliegend-Quelle situated besides the Kaitzbach valley, with an average discharge rate of 1 L/s. One of the recharge areas of the Lower Breccious Conglomerate Formation aquifer is assumed to be located in the area of surficial outcrops in the Kaitzbach valley downstream of the dump whereas discharge occurs in the shafts of the former mine. For this reason groundwater flow in the two systems is of opposite direction. Several deep wells situated along the Kaitzbach stream use groundwater from the Lower Breccious Conglomerate Formation aquifer – one of them for drinking water supply.

Chemical analyses have shown significant contamination by effluents of the dump in the Upper Cretaceous sandstone aquifer and in the aquifers of the Lower Interstratified Formation but only weak influence on the deep system of the Lower Breccious Conglomerate Formation used by wells (see table 2).

TABLE II. SELECTED DATA OF OBSERVATION PERIOD 1995/96

		Sample Location	date	Cl mg/L	SO_4 mg/L	U mg/L	Ra-226 mBq/L
precipitation		Collector Cunnersdorf	average 1995/96	<1.08	6.09	n.a.	n.a.
Effluents		monitoring well UK10	31.10.95	241	1970	0.56	5.8±0.8
		effluent spring SQ2	03.11.95	129	1590	3.4	81±7
Groundwater	regional background	Kaitzbach spring	31.10.95	39	131	0.005	2.3±0.5
Groundwater	Upper Cretaceous	monitoring well GWMS 6508a/96	28.10.96	78	436	0.040	114±7
Groundwater	Lower Interstratified Formation	Rotliegend spring	31.10.95	183	1560	0.38	5.2±0.8
Groundwater	Quarternary of Kaitzbach valley	monitoring well P42	1.11.95	50	162	0.059	6.4±0.8
Groundwater	Lower Breccious Conglomerate	monitoring well GWMS 6501/95	3.11.95	42	105	0.014	5.5±0.6

n.a. – not analysed

4. ANALYSIS OF MASS FLOW

Methodology

The analysis of the mass flow was comprised of three steps:

1. generation of a mass flow balance consistent with current conditions at the dump
2. correction of mass flow balance for long-term effects
3. prediction of effects of sealing the dump with a soil cover

Database

A mass flow balance was generated for the current conditions at the dump site with its two components, the water balance and the distribution of dissolved solids (Table 3).

The water balance was investigated by BEAK based on measurements of precipitation and surface runoff, results of quantitative model calculations for the evaporation rates, and subsurface runoff rates for the dump site as determined from a climatic water balance for the current conditions at the dump site. Groundwater flow rates were determined from piezometric observations.

The dissolved solids content was determined for samples of meteoric water (precipitation) collected at Cunnersdorf, samples of surface runoff collected at different points of the waste rock pile, samples of effluents collected from a monitoring well and two effluent springs, as well as for formation water samples drawn from the various aquifers. A selection of four chemical constituents representative of the overall dissolved solids content is provided in Table 3. It is worth noting that the effluents show a neutral pH of 6.3 – 7.2.

TABLE III. DATABASE FOR MASS BALANCE

			flow rate*	Cl	SO_4	U	Ra-226
			L/s	mg/L	mg/L	mg/L	mBq/L
Dump	recharge		1.62	<1.1	6.1	0	0
	surficial runoff		0.19	10	287	0.05	14.2
	subsurface runoff		0.12	289	2364	2.5	100
Groundwater	Upper	*in*		*38*	*122*	*0.004*	*2.3*
	Cretaceous	out	0.30	78	436	0.04	
	Lower Interstratified	*in*		*52*	*176*	*<0.002*	*14.1*
	Formation	out	0.90	153	1297	0.31	4.4
	Quarternary of	*in*		*38*	*122*	*0.004*	*2.3*
	Kaitzbach valley	out	0.15	49	170	0.07	5.3
	Lower Breccious	*in*		*41*	*98*	*0.02*	*5.7*
	Conglomerate	out	0.50	60	276	0.03	17.6

* part of total flow that is potentially affected by effluents

Semi-quantitative analysis

A semi-quantitative analysis, i.e. without the use of numerical models, was conducted to study the long-term behaviour for cases with and without soil cover. The following assumptions were applied in the analysis:

- the quality of the effluent is stable,
- in the long term the groundwater flow increases by a factor about equal to the factor of increase in precipitation,
- the effluent outflow is reduced by a factor equal to the reduction of permeability of the cover material.

It is supposed that there will be no change of geochemical milieu (especially no acidification) in the long term so that the quality of the effluent may be considered stable.

The comparison of measured precipitation rates to long-term monitoring data from surrounding stations in the area led to the long-term rate of 56 mm/a (9% of P) or 0,19 L/s. It is assumed that the application of the soil cover reduces the overall permeability of the waste rock pile by at least two orders of magnitude. The subsurface runoff is therefore reduced at least to 1/100 of the current rate. In turn, the infiltration rate is reduced to 0.56 mm/a or 0,002 L/s.

It was then attempted to calculate predictive values for contaminant concentrations in the groundwater for the situation after the soil cover has been applied by adjusting the mass flow data and background data accordingly.

5. RESULTS

The observed concentrations of sulphate and chloride in groundwater may not be explained by the currently observed subsurface runoff concentrations of dump. It is presumed that there is another source of these indicative contaminants located below the dump site (see Fig. 3). A possible explanation would be a residual, historic contamination with mine water which is stored and released from micropores in the bedrock. In contrast, the uranium balance shows an equilibrium, i.e. the calculated freight rates in groundwater are equal to those in the effluent (Fig. 3).

The radium balance shows a depletion in the underground, in other words the freight rates are lower in the groundwater than in the effluent.

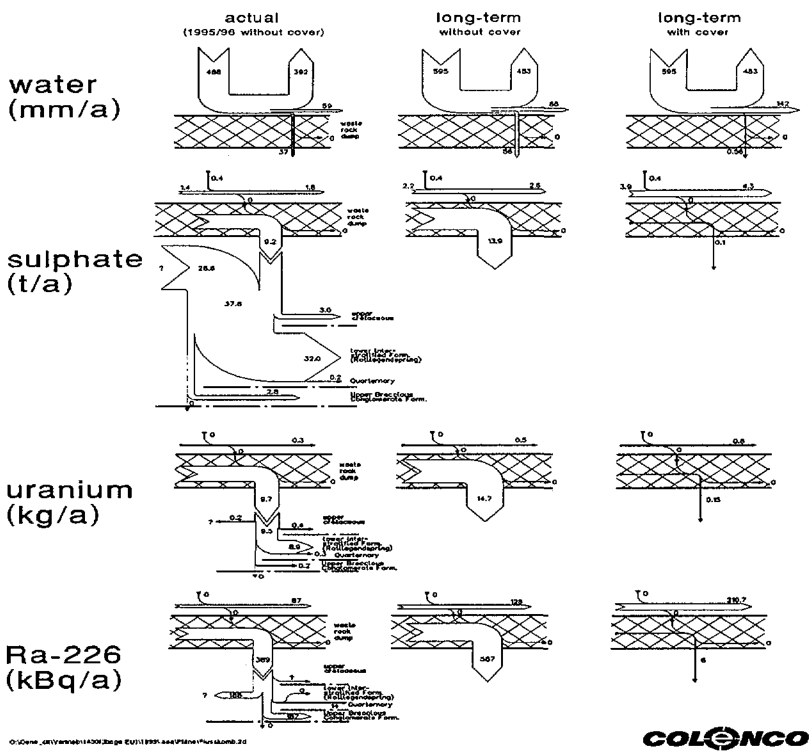

FIG. 3. Results of mass flow analysis for different states of dump (note: masses derived from groundwater background are not shown!).

In summary it becomes apparent that a reduction of emission rates out of the waste rock dump has a significant effect in the case of radium and uranium but not in the case of chlorine and sulphate (see Fig. 4). The goal is to reach the standard maximum allowable concentrations for drinking water for uranium already over a mid-term period for the water sources currently most affected. Radium has dropped already below these maximum allowable concentrations (Fig. 4).

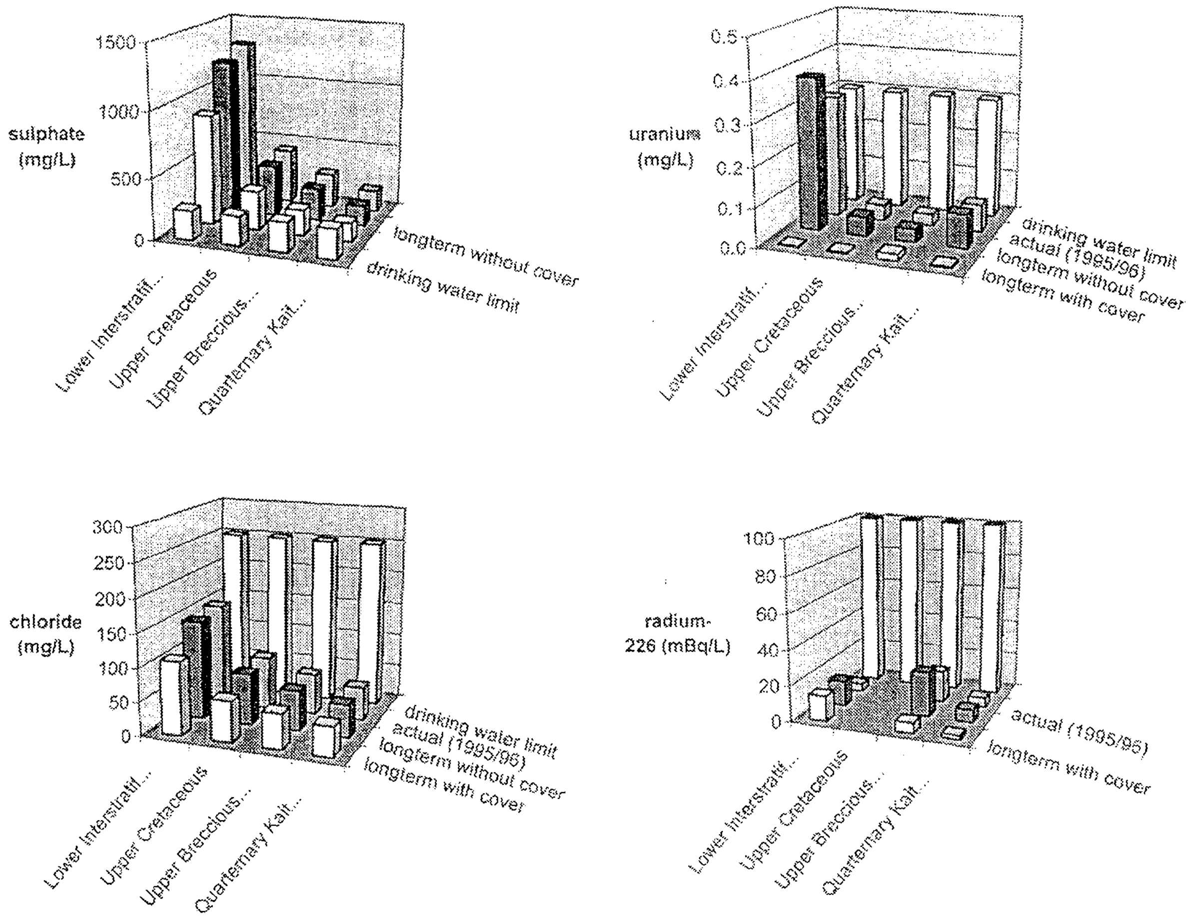

FIG. 4. Predicted concentrations of contaminants in groundwater.

6. CONCLUSIONS

Based on the results of this study the implementation of the proposed surface cover may be recommended. The expected effects include a significant reduction of uranium emissions into the groundwater. Less notable reductions in the concentrations in the groundwater are expected for sulphate and chloride as these are influenced by a secondary source in the bedrock in addition to the effluent emissions from the waste rock dump. On the other hand dump derived Radium seems to be fixed in the bedrock in significant amounts.

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