Crust Formation - The Meaning of Surface Reaction Research for Long-Term Aspects in Remediation

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Abstract

In Saxony uranium mining has taken place from the late forties to the late eighties of the past century. The sites of the early years were abandoned without real remediation measures before 1960 (old sites). The sites where uranium mining was still going on in the eighties are under remediation now (Wismut sites).

Because no remediation funding by the federal government for the old sites exists, they are of special interest for research work on natural attenuation processes.

At the abandoned old sites approximately 20 tailings ponds and several hundred waste rock piles from uranium and other ore mining are of interest. They are causing radiological (uranium-238 series, radionuclides) and toxic (arsenic, heavy metals) impacts to the surface and ground water. To minimize these impacts two possibilities can be envisaged:

1. to inhibit the release of contaminants at the source
2. to install conventional water treatment plants or passive water treatment methods

For the implementation of the first alternative it is important to have a good understanding of the climatic conditions of the site as well as of the hydrological and hydro-geochemical system, because these are the factors controlling the surface reactions and the formation of coatings or crusts.

Surface reactions that lead to crust formation have an essential effect on the development of

- the seepage and ground water quality,
- geomechanic stability, and
- the rate of radon emissions from the tailings or the waste rocks.

Crusts not only inhibit the release of contaminants, they also bind contaminants that are already in solution (e.g. into iron and manganese crusts).

For the active use of methods for stimulation of crust formation, there is a need for more site specific research in Saxony. Other European countries expressed interested in this topic as well. For this reason it is planned to implement a European research project.

Introduction

Saxony and Thuringia, situated in south-eastern Germany, belonged to the former GDR, which was the 3rd largest uranium producer in the world. After reunification uranium mining was stopped and the remediation of the sites started. The task was given to the former uranium producer Wismut GmbH, an enterprise now owned by the federal government.

At many smaller German sites uranium mining and milling already ended in the fifties and the sixties. These sites are not under legal responsibility of the federal government, and funding is not available for a state of the art remediation of the old sites. A similar situation exists in a number of European countries. As a consequence there is an urgent need for low cost remediation methods to inhibit or minimize radionuclide and conventional contaminant seepage as well as radon flux from waste rock piles and tailings ponds.

An overview of the wastes left behind by uranium mining and milling as well as the area affected by in situ leaching mines in Europe is given in tables 1 and 2.

In Europe there are approximately 15000 mines still in operation. Many of them are a permanent source of water contamination. The effluents from mines and mine wastes are contributing to the deterioration of the water and sediment quality to a degree that it cannot be neglected. Conventional water treatment for seepage from mines, waste rock and tailings is in most cases not an optimal approach, because it is cost intensive, energy consuming and produces additional wastes.

Therefore, low cost methods are of interest not only for uranium mining remediation, but also for other active and passive mining activities. One possibility to minimize emissions is to enhance natural processes of crust formation in mining and milling wastes and in the ore body resp. in the mining area.

Table 1 (From: http://www.antenna.nl/wise/uranium): Conventional uranium mines and related wastes

Country	Mines		Waste Rock		Heap Leach Waste	Mill Tailings
	No. of Mines	Total Prod. [t U]	No. of Heaps	Volume 10^6 m^3	Contents 10^6 t	Contents 10^6 t
Bulgaria	25	11,545	298	9		16
Czech Republic	20	90,948*		57.9		89
Estonia	1	65				4
Finland	1	30				0.04
France	31	73,982*			17.806	29.318
Germany	22	212,608	> 64	> 228	9.02	174.45
Hungary	1	18,221*		18	7.2	20.4
Poland	15	1,000				0.25
Portugal	4	3,443*				
Romania	7	17,554*	160			6.8
Russia	8	105,467*		> 130	36	> 56.85
Slovenia	1	382	3	1		0.7
Spain	25	4,451*			7.749	1.408
Sweden	1	200				1.5
Ukraine	4			4.11		89.5

Table 2 (From: http://www.antenna.nl/wise/uranium): Uranium In Situ Leach Mines (Europe)

Country	Surface Area ha	Contam. Groundwater Volume 10^6 m^3	Total Production [t U]
Bulgaria	1,862.04		5,175
Czech Republic	650	266	15,013*
Germany	150	1.8	5,257*
Portugal			250*
Russia			3,186*
Ukraine	276	12.29	

* as of end 1998
** as of end 1998, includes production from ISL facilities
*** estimate

Enhancing crust formation

By providing favourable conditions in waste rock piles and tailings ponds crusts can be expected to develop.
Crust formation is induced by alteration processes and driven by descending precipitation water or by ascending capillary water, which transports solutions towards the surface.
The process of crust formation takes place over a period of years.
The rate of crust formation can be stimulated by e.g.

- varying the rate of water delivery,
- increasing the temperature,
- increasing the rate of air convection (air pressure, wind velocity),
- decreasing the water the flow rate,
- covering with reactive solid materials or
- precipitating reactive fluid materials

in the waste body.

The type of crusts which develops on rock surfaces depends on the minerals in solution in the infiltrating or capillary waters. Very often iron-hydroxide, carbonate, sulphate crusts or a mixture of these are formed. Beside these a variety of other secondary minerals can be formed.
Iron-hydroxide crusts for example

- inhibit pyrite oxidation,
- co-precipitate radionuclides and heavy metals,
- have a large surface to immobilize radionuclides and heavy metals in water and
- are resistant to changes of hydro-geochemical conditions.

The formation of secondary carbonate or sulphate minerals also inhibits pyrite oxidation or the release of radionuclides and heavy me-tals. Under changing hydro-geochemical conditions gypsum and some carbonates may not be sufficiently stable, however Barite – similar to iron hydroxides - is expected to build products of long term stability.

Research needs and activities planned

At present there is no method for actively controllable immobilization of heavy metals, arsenic and radionuclides in the source. Several hydro-geochemical and mineralogical processes in mine wastes and on surfaces of cleavages and mine drifts – e.g. pyrite oxidation – are well known. Others, like the interaction between oxyhydroxide crusts and humic or fulvic acids are less well known but of potential interest. Also the processes that lead to formation of silicate or iron colloids are not sufficiently investigated yet. To achieve an effective long term fixation of heavy metals, arsenic and radionuclides on the surface of rocks, waste rocks and tailings is not a trivial task.
On the one hand, the thermodynamic and kinetic processes of water-rock interaction and redox processes leading to adsorption/ accumulation/mineral forming must be identified. On the other hand crust formation in tailings and waste rock piles have to be quantified. At first, laboratory studies have to demonstrate how much the rate of crust formation can be increased by milling the rock material to increase the reactive surface and by varying the rate of water delivery and by increasing the temperature. The results of the laboratory studies will be used to develop a concept for field and regional studies dealing with the problem.

Because of the legacy of the uranium and other ore mining in Saxony, the Saxon State Authority for Environment and Geology initiated a joint European research project on the above problems associated with mining.
The partner institutions participating in the joint project come from Canada, Czech Republic, France, Hungary, the Netherlands, Romania, Slovenia and Sweden.

References:

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