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

Abstract

Elevated concentrations of heavy metals and radionuclide found in ore mining waste rock and coal dumps can resent a severe ground and surface water protection problem. Both heavy metals and radionuclide discharges via the water pathway as well as radon exhalation can lead to problems in water quality and to increased radiation doses to the population living close to such dumps. Conventional remediation methods, such as the construction of engineered covers, cannot be considered optimal solutions due to the relatively high costs and unproven long-term performance. The state of Saxony (Germany). EU accession countries and third countries having considerable mining liabilities believe there is an urgent need for sound remediation policy and protection standards, which are achievable at a reasonable cost and sustainable in the long-term. The development of alternative cost efficient remediation methods is essential for enabling these countries to remediate the mining liabilities.

In order to create a conceptual basis for such an alternative approach, our planned research project focuses on passive remediation methods utilizing natural processes acting on the surface of the waste rocks. Natural hardpan formation, i.e. the development of a natural coating on the waste rock due to secondary mineralization, leads to confinement of radionuclides and a decrease in porosity, thus reducing radon exhalation. The hardpan formation can be induced and enhanced by promoting specific hydro geochemical, microbiological and meteorological conditions. Most of the processes controlling hardpan formation are well known. However, nuclides by engineered hardpan formation will be tested on a technologically significant scale of waste rock dumps at 10 sites in Germany, the Czech Republic, Slovenia and Russia. The aim of these investigations is to develop a cost efficient technology for participating countries, thus providing feasible remedial solutions in compliance with European regulations.

Mine Residues in Europe

Saxony and Thuringia in southeastern Germany, belonged to the former GDR, whish was the third largest uranium producer in the world. After reunification uranium mining stopped and the remediation of the sites was started by 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 owned by the federal government. No funding for a state of the art remediation for the old sites exists. In many European countries a similar situation is given. As a consequence low cost remediation methods are needed to inhibit or minimize radionuclide and other contaminant seepage and rain flux from waste rock piles and tailings ponds.

An overview over the wastes of uranium, mining and milling as well as the influence area on in situ leaching mines in Europe is given in tables 1 and 2.

Conventional mine waste remediation (covering)

Table 1 (From: http://www.antenna.nl/wise.uranium):

Country	Mines No of Mines	Mines Total Prod. (t U)	Waste Rock No. of Heaps	Waste Rock Volume $10^6 m^3$	Heap Leach Contents 10^6 t	Mill Tailings Contents 10^6 t
Conventional uranium mines and related wastes (Europe)						
Bulgaria	25	11545	298	9	-	16
Czech Rep.	20	90948*	?	57.9	-	89
Estonia	1	65	?	?	?	4
Finland	1	30	?	?	?	0.04
France	31	73982*	?	?	17.806	29.318
Germany	22	212608	> 64	> 228	9.02	174.45
Hungary	1	18221	?	18	7.2	20.4
Poland	15	1000	?	?	-	0.25
Portugal	4	3443	?	?	-	?
Romania	7	17,554	160	?	-	6.8
Russia	8	105,467*	?	> 130	-	> 56.85
Slovenia	1	382	3	?	-	0.7
Spain	25	4.451*	?	?	-	1.408
Sweden	1	200	?	?	-	1.5
Ukraine	4	?	?	4.11	-	89.5

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

Table 2 (From: http://www.antenna.nl/wise.uranium):

Uranium In Situ Leach Facilities (Europe)			
Country	Surface Area ha	Contam. Groundwater Volume 10^6 m^3	Total Production [t U]
Bulgaria	1862.04	?	5175
Czech Rep.	650	266	15,013*
Germany	150	1.8	5,257*
Portugal	?	?	250*
Russia	?	?	3,186*
Ukraine	276	12.29	?

* as of end 1998

In Europe still about 15000 mines exist. 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 in a measure that cannot be neglected. Conventional water treatment for seepage from mine wastes in most cases in unsuitable, because it is cost intensive, energy consuming and produces new wastes.

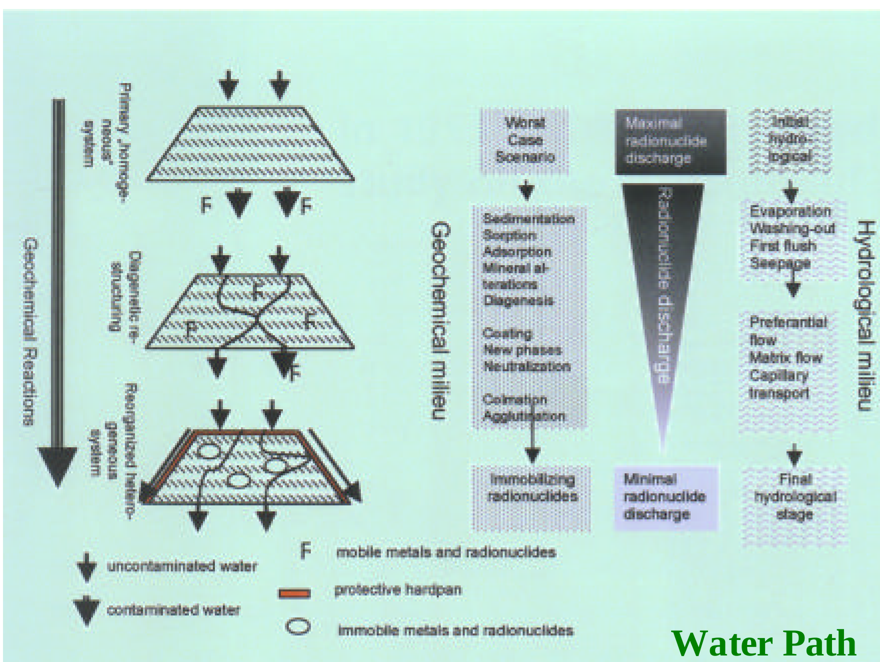
Therefore, low cost methods are not only for uranium mining remediation of interest, but also for other activities. One possibility to minimize emissions is to enhance natural processes of crust formation in mining and milling wastes and in the ore body rsp. the mining area.

Enhancing crust formation

Under favorable circumstances in waste rock piles and tailings ponds crusts are growing.

Crust formation is caused by alteration processes and driven by ascending capillary water, which transports solutions towards the surface, or by descending precipitation water.

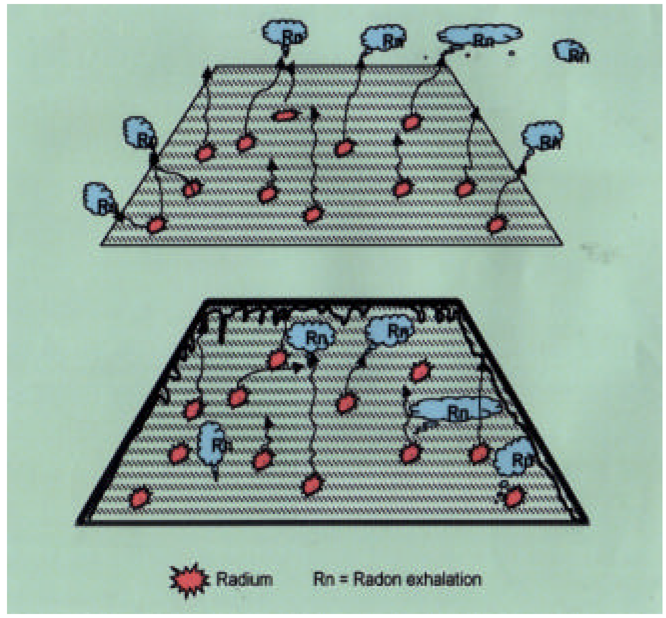
- varying rate of water delivery,
- increasing the temperature,



- increasing the percolation rate of air (air pressure, wind velocity),
- covering with reactive solid material or
- precipitating reactive fluid material.

The kind of crusts on rock surfaces depends on the minerals in solution in the in the precipitation or capillary waters. Very often iron-hydroxide, carbonate, sulphate or a mixture of them is formed. Iron-hydroxide crusts for example

- inhibit pyrite oxidation,
- co-precipitate radio nuclides and heavy metals,
- have a large surface to immobilize radionuclides and heavy metals in water and
- are very stable, when hydro-geochemical conditions are changing gypsum and some carbonates may not be very stable, while Barite – like iron hydroxides – is supposed to be long-term stable.



Radon barrier

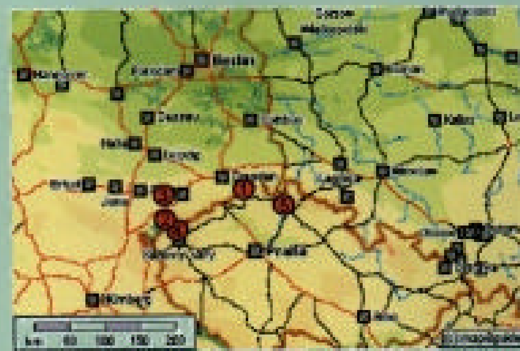
Need for research and planned activities

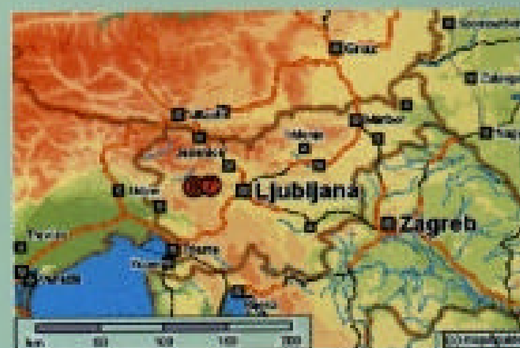
At present no actively controllable method for the immobilization of heavy metals, arsenic and radionuclides at the source itself exists. Some hydro-geochemical and mineralogical processes in mine wastes and on surfaces of cleavages and mine drifts – e.g. pyrite oxidation – are well known. Others, like the interaction between oxyhydroxide crusts and humic or fulvic acids are fairly unknown. Also the processes that lead to formation of silicate or iron colloids are not well investigated yet. The long-term effective fixation of heavy metals, arsenic and radionuclides on the surface of rocks, waste rock and tailings is not trivial to realize.

On one hand, the thermodynamic and kinetic processes of water rock interactions and redox processes leading to adsorption/accumulation/mineral forming must be identified. On the other hand specific materials to enhance hardpan formation in specific waste types must be found.

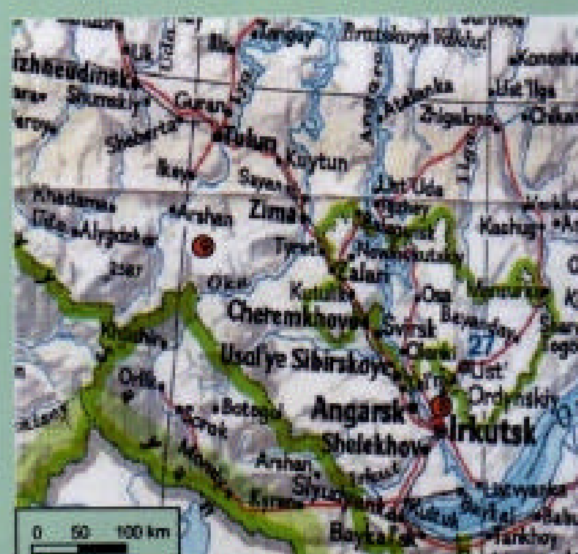
Because of the legacy fro uranium and other ore mining in Saxony the Saxon State Agency of Environment and Geology had been initiating a common European research project on the subject described above.
Partner institutions are from the Czech Republic, France, Russia, and Slovenia. A partner project of the University of Waterloo, Ontario, is planned.

Site	Geo-chemistry	Climate	Storage
1 Schüssel grund	acidic	720 mm/a	Coverage (start in 2005)
2 310 Aue	pH-neutral	860 mm/a	Remediation with low cost method
3 Reust	acidic	650 mm/a	Relocation
4 Abertamy	pH-neutral	850 mm/a	Remediation with low cost method
5 Straz Pod Ralskem	acidic		Since 1996 remediation
6 Jazpec	pH-neutral	1600-2400 mm/a	Coverage
7 P-1	pH-neutral	1600-2400 mm/a	Relocation starts in 2004





Site	Geo-chemistr	Climate	Storage
8 Irkutsk	Low^{y} alkaline	350-500 mm/a	Ash dumps
9 Belaya Zima	Low alkaline	450-500 mm/a	Dumping ground and tailings since early 60th
10 Irkutsk or Transbaikal region	Should be refined	Should be refined	Dumps or tailing of U-mine



Planned test sites