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Technical Communication

Remediating 700 years of Mining in Saxony: A Heritage from Ore Mining

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Saxony is located in the eastern part of Germany, adjoining the Czech Republic to the south and Poland to the east. The southern part of Saxony is especially rich in mineral resources. The mountainous region covering the southwestern part of Saxony and the northwestern part of the Czech Republic is appropriately named Erzgebirge (Ore Mountains).

Mining began with the discovery of silver in the 12th century. The silver content of the rocks were profitable enough to allow the construction of extensive surface and subsurface infrastructures. In the mid-16th century, Georg Agricola summarized the technological achievements in his famous compendium 'de re metallica' – a fundamental text on the science of mining. Several elements derive their names from the Saxonian mining area, e.g., cobalt and nickel. The first systematic treatise in mineralogy was written in Saxony at an academic institution that in 1765 became the Freiberg School of Mines. In 1789, M. Klaproth discovered a new element that he decided to name Uranium after the planet Uranus. In 1863, Reich and Richter discovered Indium in a Saxonian zinc blend, and in 1886, Winkler discovered Germanium.

Figure 1 provides an overview of the uranium as well as lignite mining areas in Saxony. Saxony has 4.7 million inhabitants in an area of 18,338 km^2, and the Saxonian mining sites are close to densely populated areas. Even though the population density is inhomogeneous, there are no uninhabited areas. Thus, the relics of mining activities influence the activities of a large amount of people.

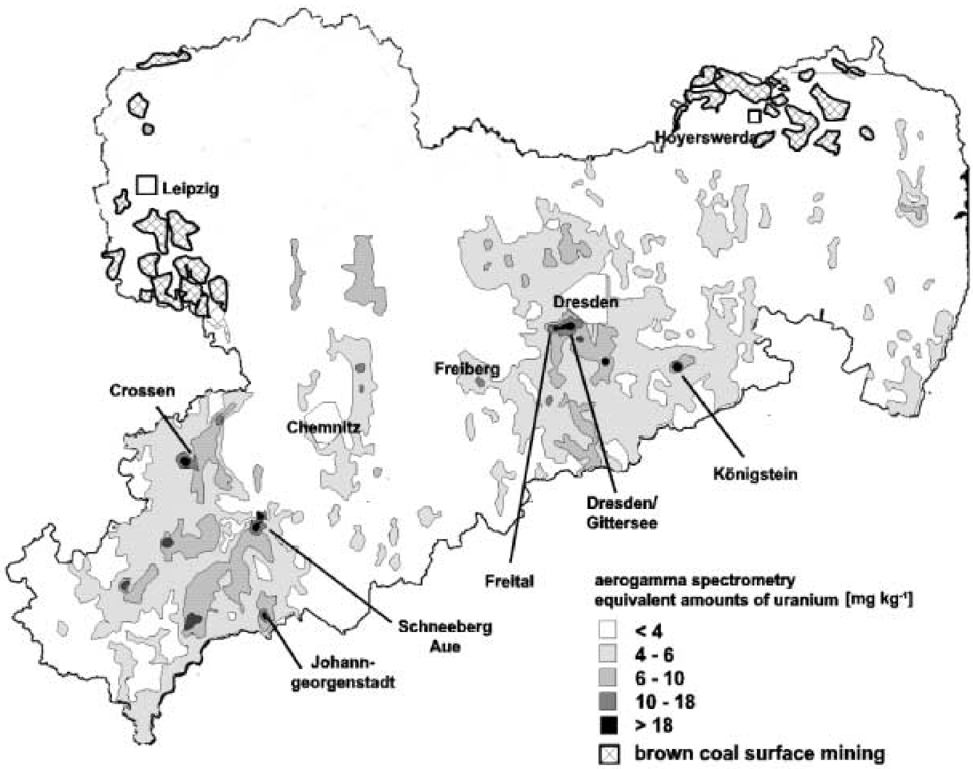

Figure 1. Sites of uranium and lignite mining in Saxony presented together with aerogamma spectrometric data of Saxony (based on information from the Saxonian Agency of Environment and Geology)

Mineral resources have been exploited continuously in Saxony for more than 600 years. After 1945, the uranium resources became of strategic interest for the former Soviet Union. The exploitation of this element took place all over Saxony between 1945 and 1991 in 27 deposits of mainly four types: veins, sandstone, volcanic and coal. Old mines in the Ore Mountains were reactivated and new deposits were found. In total, 231,000 tons of uranium were produced, making the former German Democratic Republic the world's third largest uranium producer. In total, 1200 million tons of ore and rocks were moved, of which 1000 million tons were deposited in waste rock piles and tailings ponds. Two hunderd million tons were transported to treatment and processing plants. An average of 45,000 workers worked in this industry, most around-the-clock in three shifts in the mines.

Outside the Ore Erzgebirge region, surface lignite mining takes place in two larger areas: in the north-eastern Lausitz region and the western Leipzig-Halle district. Lignite surface mining is, compared to rock mining, a younger activity, starting in the mid-19th century and continuing until today. Taking an illustrative figure from 1988, 505 million tons of material have been moved in the Lausitz district, with 220 million tons of lignite mined. As a result, an area of 2100 km^2 has no groundwater within 80 m of the land surface. A deficit in static ground water of $13 \cdot 10^9$ m^3 has resulted from ground water pumping. The Halle-Leipzig district figures are similarily impressive: 110 million m^3 of materials have been moved with 110 million tons of lignite mined. This has resulted in an area of 1,100 km^2 without ground water within 80 m of the surface and a calculated deficit in static ground water of $8.1 \cdot 10^9$ m^3.

The scars left from these activities are still widely visible at the surface. The former uranium producer 'WISMUT SDAG' (SDAG = a Soviet-German joint stock company) has been transformed into a remediation company after German reunification in 1990. With a capital budget of 6.5 billion Euro, the sustainable remediation or at least mitigation of the adverse effects of exploitation of the uranium resources is now underway. Environmental remediation and mitigation activities on this scale posed new challenges for both WISMUT and the governmental authorities responsible for licensing the remediation activities.

Radon emissions from mines and waste heaps was and still is an issue for workers as well as for the population close to the sites. Radon from waste heaps can be stopped by covering the heaps, but radon from underground mines can enter houses and cause lung cancer to the inhabitants. The German federal authority for radiation protection and the Saxonian ministry of environment and agriculture have been measuring radon in houses and funding radon redevelopment of houses in Saxony since 1990.

Another issue of long-term significance is the quality of seepage and mine waters. Waste piles in Saxony normally do not release seepage on the surface. However, at waste piles situated in a former valley, where a creek once existed, seepage water is running off in high quantities. The seepage water of waste piles and tailings ponds as a rule show high uranium concentrations (ca. 1 ppm). The concentrations of other radionuclides are close to background concentrations. Mine water running out of a gallery to the surface first showed high concentrations in radionuclides and heavy metals. However, uranium concentrations decreased over time, though radium concentrations in the mine water remain high.

This has occurred because the initial flooding involved water with relatively high oxygen concentrations, resulting from the ventilation of the mine in the time before it was flooded. After inundation, oxygen concentrations in the water decreased because of redox processes. These processes also dissolved secondary minerals that were produced during the oxygen-rich time when the mine was ventilated. Uranium is more soluble in oxygen-rich waters and nearly insoluble under reducing conditions. Altogether, mineralisation is close to background at present.

Uranium mining seepage waters (or better, waste-rock covered creeks) show high concentrations of uranium (0.5 to 1 ppm) and low concentrations of radium because they normally are saturated in oxygen. Unfortunately, they are also highly mineralized, mainly due to high sulphate concentrations. Additionally, arsenic concentrations are often elevated as well.

Restoration of lignite surface mining sites by flooding has to take into account the changing geological and ground water hydraulic systems and boundary conditions. Lake-side landscapes will form that did not exist before mining. Undesireable processes may occur: acidification of lake waters by pyrite and marcasite oxidation, increase in iron, alumina and sulfate burdens in the neighboring ground water aquifers, loss of minerals in the sediments and walls (i.e., carbonates), hydrogeochemical formation of new minerals like iron hydroxides and gypsum, and acidic elution and material transport from other sites and industrial areas by the restoration of the ground water levels.

If the mine water or seepage water is needed as drinking water, or if the runoff flows into a fishing area, measures have to be found to remove the radium and, sometimes also the arsenic, out of the water. However, conventional methods of doing this have high long-term costs and produces wastes that have to be disposed of. Passive treatment methods are being assessed. For passive water treatment to be effective, the hydrogeochemical system and the water chemistry have to be known very well. The potential benefits of natural attenuation processes also have to be considered.

Predicting the natural development of mine or seepage water quality is a challenge to all of the scientists and engineers involved. There have been very few studies of the long-term development of mine and seepage waters at sites similar to the Saxony mines. Hydrogeological data from older and younger mines should be collected systematically and published in a kind of catalogue or guide; this would aid in the validation of hydrogeochemical models.

Another weak point in hydrogeochemical modeling for prognostic reasons is the lack of an internationally standardized thermodynamic data bank. Predicting the consequences of both mining and remediation is therefore important in designing and licensing mining and remediation actions. In the same situation, recognizing limitations in the predictive capabilities is crucial. The use of different data by different consultants leads to results that cannot be compared.

In Saxony, the water draining from nearly all of the uranium mining sites flow into the Mulde River, which is a tributary to the Elbe River. The aim of the Saxonian regulatory authorities is to minimize the radionuclide concentrations in the Mulde, its sediments, and its meadowlands. Therefore, an alternative treatment method must be developed in the catchment area of the Mulde, at least until the mines have been flushed 6 to 8 times.

Finally it should be pointed out that radiological problems in Saxonian waters are not only associated with the uranium mining sites. Saxonian water authorities have found that in those areas in Saxony where lignite deposits exist, uranium concentrations are also elevated (up to 0.3 ppm) in ground and surface waters. Lignite was and still is being mined in huge open pits. The hydrogeochemical behaviour of waters close to lignite deposits under natural and anthropogenically changed conditions are generally well understood. However, the behaviour of uranium at such sites has not been studied. For that reason, a research project on the solubility of uranium in lignite has been started by the Saxonian state authority of environment and geology. Preliminary results will be available in 2002.

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