Groundwater Remediation in Germany
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standards and demands

- standard for radionuclides in drinking water according to drinking water regulation (Trinkwasserverordnung)
  - total dose 0.1 mSv/a

- water protection standards for uranium and non radiological contaminants
  - uranium standard according to drinking water regulation: 10 µg/l
  - other substances (increased in waters around german uranium mines): As 10 µg/l, Cd 3 µg/l, Ni 20 µg/l, Pb 10 µg/l

applicant for license has to prove, that remediation measures are appropriate to fulfil this demands
Территории для рекультивации последствий горнодобычи (Wismut GmbH) в Саксонии
post mining situation
underground mines

- groundwater was pumped out of the Koenigstein mine, because operation had just ended, in Aue flooding started in 1989/1990
- monitoring only for sulphate, chloride, uranium and radium
- water treatment was on a low level
- water was discharged to the Elbe river (Koenigstein) resp. to the Mulde river (Aue)
- first plans for the flooding of the Königstein mine
- first plans for a treatment plant in Aue © Wismut GmbH
Koenigstein mine
Aue mine
1800 m deep
post mining situation
Helmsdorf (Crossen) tailings pond

superfluous water from tailings pond was discharged without treatment to the Mulde river, As and U high, some monitoring for U, Ra, As, chloride and sulphate

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post mining situation
waste rock piles

seepage water partly leaked into the underground (mine) partly was discharged into the Mulde river, monitoring on a small level U, Ra, As, chloride, sulphate similar in Koenigstein, where seepage water from the waste rock pile mainly leaked into the groundwater

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current situation
underground mines

- underground mines Aue (1800 m deep) and Koenigstein (250 m deep; ISR) flooded to a level where no groundwater contamination is possible

- water treatment at both sites; uranium recovery from the treatment in Koenigstein; heat recovery planned for industrial estate Aue

- sophisticated monitoring programme and modelling of groundwater situation
current situation
Helmsdorf (Crossen) tailings pond

tailings pond water and seepage water discharged to Mulde after treatment

sophisticated monitoring programme and modelling of groundwater situation

tailings dewatered at the surface and partly covered
current situation
waste rock piles

covering in Aue nearly done (1 m)
cover in Koenigstein at the slopes (1 m) nearly done, started on the top (>1.5 m)

sophisticated groundwater monitoring programmes & modelling
mobility of contaminants
main processes

- climatic → precipitation, temperature

plus soil properties/cover designs → groundwater formation

- hydraulic → porosity of soils and aquifers

- hydrogeochemical/biogeochemical
  - pyrite oxidation/precipitation of minerals
  - activity of micro-organisms

→ solution conditions in groundwater (U-species)

- others
covers as soil substrate
evapotranspiration
evapotranspiration
loess soil (agricultural use)
soil humidity
annual variation

examples:
regional grassland
(two soil monitoring sites, different soils)

red arrows
left: flood of the century
right: dry summer
tailings, waste rock, covers, solution and precipitation

- processes in covers: see above (evapotranspiration) the older the covers the more pore space and small tunnels, caused by roots, worms, funghi and small animals are helping the water to drain through the covers

→ seepage water is draining through cover in tailings or waste rock → quantity of seepage water is increasing, → quality of seepage water is changing

→ seepage water is containing uranium (soluble due to oxygen/pyrite oxidation) and other contaminants but also carbonate and sulphate, etc.; depending on the specific circumstances these may precipitate (normally as gels) and seal the surfaces of the waste rock resp. cement the pores of the tailings

→ reduction of pyrite oxidation and contam. mobility, stabilization of tailings
mine water
redox situation/microorganisms

- before mining/natural state: normally reducing or at least low oxygen situation
  → no (or low) solubility (and mobility) of uranium, high radium concentrations in the vicinity of uranium deposits → no use as drinking water possible

- during mining/disturbed state: high oxygen input into system by pumping and lowering of the groundwater table
  → high solubility and mobility of uranium, low mobility of radium due to sulphate (co-precipitation)

- after mining: flooding minimises oxygen concentration in mine
  → uranium becomes less soluble, radium is in solution again

the role of microorganisms in the whole process is well investigated
to be improved/developed
e.g enhancing crust formation

CO2 may help to develop carbonate sealings in waste rock and tailings to minimize pyrite oxidation & contaminant mobility
first lab and field test in 2006
And the message?
What about the message?
understanding of processes regarding long-term effects on groundwater

- tailings- and waste rock covers:
  - is subject to natural soil forming processes and natural plant succession, if vegetation was planted it may underly a change due to this processes → effect on quantity of seepage water
  - tailings or waste rocks are subject to (bio-) hydrogeochemical processes that may stabilise (cementation) or destabilise (decomposition of clay minerals) them → effect on the mobility of contaminants

- mine floodings:
  - there is a need to understand the (bio) hydrogeochemical processes caused by the flooding of mines, i.e. dilution, change in pH and oxidation situation (Eh)
  - also consider the hydraulics

geochemical modelling may be helpful
obliged to

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