Groundwater–Surface Water Interaction
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Methods and Case Studies

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Groundwater–Surface Water Interaction is a process relevant for ...

- Salinisation of fresh groundwater due to sea water intrusion
- Intrusion of contaminated groundwaters into surface water
- Development of pit lakes highly contaminated and acidified by lignite mining
- Groundwater un-covered by gravel production
1. Sea water intrusion

- **Problem:**
  Over-exploitation of coastal-near groundwater reservoirs causes intrusion of sea water

- **Measures:**
  Accurate ascertainment of the groundwater reservoir to avoid over-exploitation

- **Tools:**
  - Monitoring of hydrochemical evolution
  - Definition of size of reservoir with environmental isotopes
1. Sea water intrusion areas
1 Tools

- Stable isotopes ($^{2}$H, $^{18}$O) of water → Information about the origin of water
- Tritium ($^{3}$H) of water and $^{3}$He of dissolved gases → Information about the residence time of water
- Noble gas temperature → Distinction between sea and juvenile waters

...study in progress...
2 Contaminated groundwater

- **Problem:** Groundwater highly contaminated with heavy metals infiltrates into surface water (inverse to river bank filtration)
- **Measures:** Under discussion yet, but at first Determination of the flow system as basis of further steps
- **Tools:** Hydrochemical monitoring Detection of inflow by temperature
Concept

High Groundwater Discharge

Medium Groundwater Discharge

Low Groundwater Discharge

Vertical Flow can be obtained from a simple one-dimensional analytical solution of the heat diffusion advection equation.
Measurements

Assumption: Observed streambed temperatures represent spatial differences of groundwater discharge.

Streambed temperatures are measured by temporarily inserting a probe into streambed.
Results

Flow direction

Stream

Distance 220m

Streambed

Depth

Zones of high groundwater discharge

Temperature in °C

12 14 16 18 20
Results

Temperature profil can be converted to a water-influx profil
3 Mining lakes

- **Problem:** Flooding of holes from lignite mining activity are acidified (down to pH = 2) and contaminated with heavy metals
- **Measures:** Development of remediation strategies dependent on groundwater-lake water interaction
- **Tools:**
  - Inflow/outflow balance with environmental isotopes
  - Detection of inflow by $^{222}$Rn and stable isotopes
  - Governing biogeochemical cycles at benthos
3 Test site RL 111

- **Quartär**
- **angeschnittene Tertiärsedimente**
- **Förderbrückenkuppe**
- **Quartärhalde**
- **Kippenböschung**
- **Grundwasserfließrichtung**

- **Messstelle**
- **Quelle**
- **Probenahmepunkt See**

- **Length** 900 m
- **Width** 180 m
- **Depth** 10 m
- **Area** 110,000 m²
3 Determination of fluxes

high-resolution concentration profiles

→ Millimeter scale

micro sensors

concentration

(R. Stellmacher 2006)
3 Determination of fluxes

In situ sediment incubation provides information about fluxes and biogeochemical processes. "Direct" flux determination with simulated flow changes the concentration with time.
3 Determination of fluxes

high-resolution concentration profiles

→ Decimeter scale

DET (Gel Peeper)

front view

diffusive equilibrium

side view

Dialysis pore water sampler (DPS)

(R. Stellmacher 2006)
RL 111: DP sampler

Groundwater flow direction

Position of DPS

(K. Knöller and S. Weise 2006)
Radon is a naturally occurring radioactive gas, with a non-reactive nature and a short half-life ($t_{1/2} = 3.83$ d).

Radon concentrations of groundwater are very large enriched to surface water (often 1000-fold or more).

Radon is an excellent tracer to identify and quantify significant groundwater discharge.

The approach for quantifying gw discharge is a steady-state system with a consideration of all $^{222}$Rn sources and sinks related to the lake.

(Axel Schmidt, UFZ, Dept. Analytical Chemistry)
Using $^{222}$Rn to detect groundwater inflow into a lake

Example: Tagebaurestloch RL 107, Plessa

- area: 125,000 m², medium depth: ~3 m
- pH = 2.4; Fe = 400-840 mg/l; SO$_4^{2-}$ = 1.8-3.7 g/l

Data:

$$\text{Flux}_{\text{atm}} = 2 \pm 0.16 \ [\text{Bq m}^{-3}]$$
$$\text{Inventory} = 75 \pm 1.8 \ [\text{Bq m}^{-2}]$$
$$\text{Diffusion} = 0.2 \ [\text{Bq m}^{-3}]$$
$$\text{Radonflux} = 414 \pm 9.9 \ [\text{Bq/m}^2\cdot\text{d}]$$

Groundwater discharge:

$$0.182 \pm 0.057 \ \text{cm d}^{-1}$$

Radon is an excellent tracer to quantify groundwater discharge

(Axel Schmidt, UFZ, Dept. Analytical Chemistry)
RL 111: Isotopic balance

Basic input:
- annual variation in isotopic composition of lake water
- isotopic composition and amount of precipitation
- isotopic composition of groundwater
- surface in- and output
- (estimates of) evaporation

annual groundwater inflow: 23700m³
annual groundwater outflow: 15700m³

(K. Knöller 2001)
RL 111: Ground- and dump water (isotope-) geochemistry

SO4 vary between 40 and 700 mg/L in the aquifers
SO4 reaches 4300 mg/L at max. in dump water

δ³⁴S: –9.9 to +23 %o in GW
δ³⁴S: +7 and +32%o in dump water
RL 111: Results of isotope geochemical investigations

• Sulfate from mining dumps is reduced in the aquifer west of RL 111.

• In the dump, oxidation of pyrite and mobilisation still provides a permanent sulphate input into the lake.

• Consequently, for remediation measures the groundwater inflow from dumps have to be taken into account.
Mining lakes: Perspective...

from mining landscape...

...to recreation landscape

Cospuden mining area (south of Leipzig)
4 Gravel production

• dis-covers high-productive aquifers and
• connects a groundwater flow system with lake water.

Issues:
• What is the intensity of groundwater-lake connection?
• What is the effect on groundwater quality?
4 Case study *Lake Leis*

**Lake Leis:**
- Surface area: 116,000 m²
- Depth: 21 m (in average)
- Annual turnover

**Aquifer:**
- Geology: Quaternary gravel and sands
- Groundwater flow velocity: 0.5 – 2 m/d

(S. Weise, W. Stichler, B. Bertleff 2001)
4 Lake Leis: Tritium "age"

- Tritium content [TU]
- Years before date of sampling

- Apparent age
- $^3$H in precipitation corrected for decay
- $^3$H range of deeper ground- and Lake Leis waters
4 Lake Leis: $^3$He/$^3$H "age"

exchange with atmosphere (degassing) resets $^3$He/$^3$H "age" close to zero

“age” of about 20 years though the lake turns over every year

Lake Leis
16.10.1997

apparent $^3$He/$^3$H age [years]

Depth [m]
4 Case study *Lake Leis*

Results from $^3$He/$^3$H investigations:

- groundwater inflow is about $2000 \text{ m}^3/\text{d}$.
- regarding known hydraulic conductivities, the area effective for inflow is between $500$ and $7500 \text{ m}^2$, consistent with lake's cross-section area of about $6000 \text{ m}^2$.
- Lake Leis must be extremely good incorporated into the regional ground water flow regime.
Thank you for attention!

Mining lakes Merseburg Ost