Natural Attenuation of an urban CHC-plume – Prediction results

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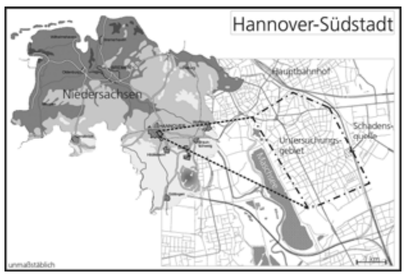
Site & Objective

The site is located in the North German Lowlands in Hannover, the state capital of Lower Saxony. It is characterized by dense urbanization, scattered small industry and intense water management due to subway-construction from 1979 to 1992.

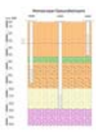
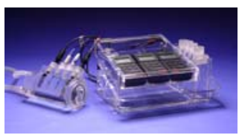
- Source characteristics:
- Chemical wholesale dealer since WW II
- Pollutants: CHC, BTEX, acids (H_2SO_4, HCl)
- DNAPL contamination mass: ≥ 250 tons
- DNAPL recovery: ≈ 200 tons
- Active source: 1945 – 1988
- Slurry wall construction & water management: from 1993
- Remediation costs (2003): M€ 13 (source remediation, P&T)
- Problem owner: City of Hanover (CHC-plume)

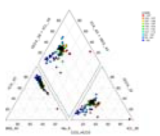


Q1: Identify natural attenuation (Nat-Att) processes in the aquifer
Q2: Quantify natural attenuation processes
Q3: Model based advice on the future handling of the site

Procedure & Tools

- Testing, verifying and extending the municipal GW-sampling network with 60 2" wells (in 20 groups) and short filterscreens (≤ 3 m)
- GW-sampling campaigns from 2003 to 2006 for CHC's, gases and inorganic water quality
- Headspace-analysis of CHC's (ethenes, ethanes) with GC-FID/ECD-detection
- Open Source GIS environment with GRASS, PostgreSQL and ParaView to interpolate data into 3D-voxel-grids & visualize and calculate mass of dissolved contaminants
- Assessing the properties of the aquifer (e.g. TOC, Fe(III), FeS_2) together with GW-monitoring data to derive hydrogeochemical reaction zones
- Column tracer experiments with aquifer for site-specific sorption parameters
- Setting up a 3D-subsurface model using 150 drill-logs and shearwave seismic data
- Setting up a reactive transport model with two-site sorption and reaction zones

Groundwater Monitoring & Evaluation

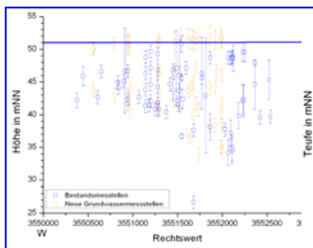


Fig. Improved monitoring network, wells with length of filter screen, old (blue), new 2" wells (orange)

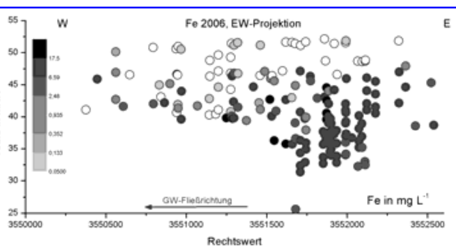


Fig. Vertical zoning of diss. Fe in the aquifer forming a „wedge" of reduced groundwater on the upstream side

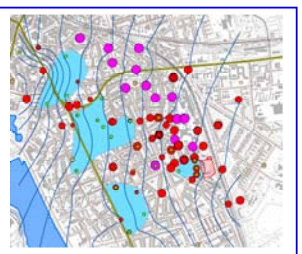
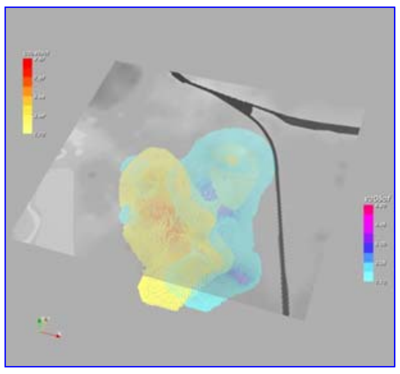


Fig. Thematic map of diss. Fe concentration in the plume (green ≈. n.d., magenta > p95)



Monitoring with an emphasis on the vertical distribution of CHC-metabolites & electron acceptors was carried out. Hydrochemical results were complemented by geochemical and petrographical investigations of aquifer-cores. In spite of only 0.075 wt.% TOC, significant tailing was found in column desorption experiments. 3D-modeling of monitoring results with GRASS GIS provided the current dissolved ***mass of contaminants.*** It allowed to delineate hydrogeochemical reaction zones with ***reducing*** (VC, Fe (r.)) and ***oxidizing*** degradation path-ways (cDCE, TCE (l.)) further downstream in the plume.

Fig. Plume 2006: cDCE (yellow) and VC (blue) concentration data, DTM for reference; Visualization: ParaView

Modeling & Prediction Results

Based on a drill-database, new drill holes and results from shear-wave seismic measurements, a subsurface model (u.r.) has been developed. Spatial coupling of reducing and oxidizing processes in a numerical ***reactive transport model*** allowed to describe transport of metabolites through these zones. ***Kinetic desorption***, combined with thermodynamic desorption from two different types of sorption sites (e.g. Van Genuchten, 1982) was taken to represent interaction between contaminants in solution and the matrix. The degradation rate for dissolved CHC was found to be higher than the release rate from the aquifer. The apparent ***longterm immobility*** of the plume can be reproduced well, which therefore is a dynamic equilibrium. CHC-sorption onto dispersed coal-type kerogens in the aquifer plays an essential role for the future development of the plume. Several runs of the 3D reactive transport model (FeFLOW™) showed (m.r.), that the characteristic immobility of the plume will persist into the future, while contamination levels will decrease within approx. 30 more years down to permissible regulatory levels. This is due to the fact that although only 2 tons of metabolites are currently dissolved in the plume, up to 16 tons of contaminants are still sorbed on the matrix - coal particles - of the aquifer (botrom r.).

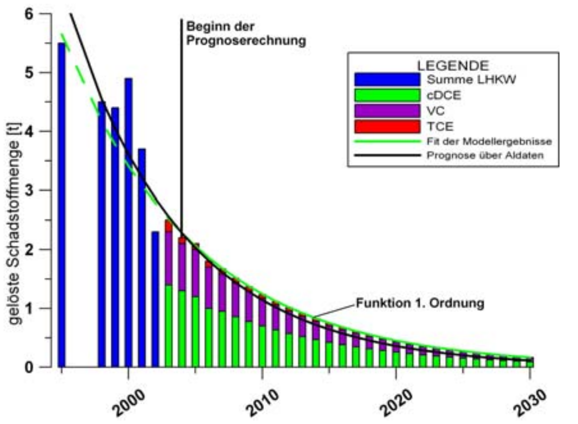


Fig. Prediction of Nat-Att. with transport, reaction and kinetic desorption from coal till 2030 for mass of diss. TCE, cDCE and VC (source: [2)]M & P)

Controlling factor: Coals in the sand size fraction of the aquifer are responsible for kinetic desorption properties leading to a long term release of CHC-contaminants.

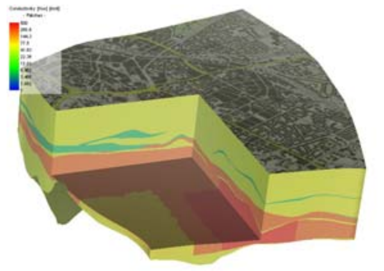


Fig. Subsurface model of the unconfined aquifer of glacio-fluviatile origin (gravel, sand, silt-beds)

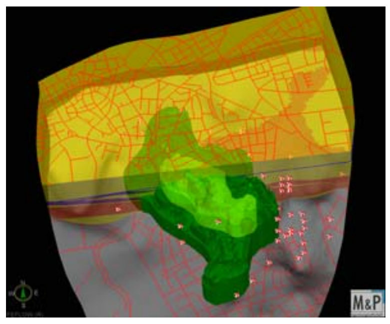


Fig. Model result: cDCE-plume will shrink from the border and concentration will fall but plume holds position (source: [2)]M & P, u.r. and m.r.)

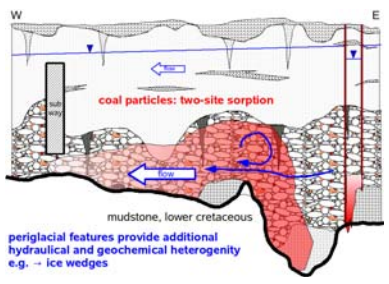
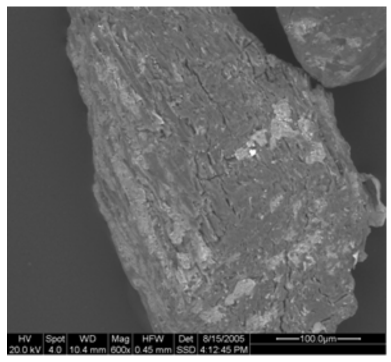


Fig. EW-schematic section to explain controlling processes in the CHC-plume of Hannover-Südstadt.



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