Steam-Air-Injection: In-Situ-Remediation of a CHC Contamination below a historical Building

Oliver Trötschler, Hans-Peter Koschitzky

Universität Stuttgart
Germany

Situation

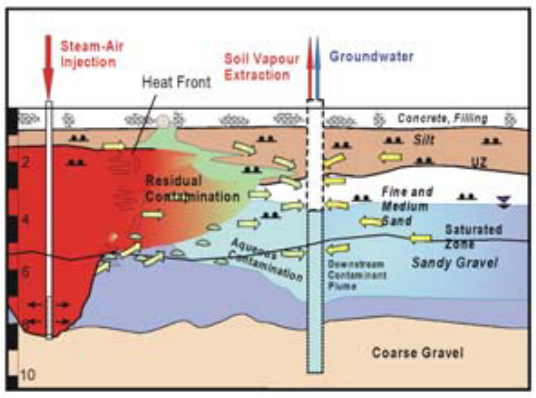
A contaminant source of chlorinated hydrocarbons (CHC, mainly PCE) under an old historical building caused by a former dry-cleaner in the unsaturated and saturated zone leads to a long persistant contaminant plume.
The groundwater level is in the range of 3 - 3.5 m b.g.s..

- vertical expansion of the contamination approx. 6 - 7 m b.g.s.
- unsaturatted zone: concentrations of PCE in the soil samples up to 3800 mg/kg soil (1 - 2.5 m b.g.s)
- saturated zone (3-4 m b.g.s.), concentrations up to 850 mg/kg, as well as 70 mg/kg (4-5 m), and 6 mg/kg (5-6 m)
- CHC concentration up to 40 - 60 mg/l of CHC in the groundwater indicate residual NAPL in the near field of the sampling location (source zone).

Historical building "source zone"

Principle of Remediation Technology and local situation

TSVE can be applied for organic contaminants with boiling points lower than 180°C and aquifers of medium permeability, e.g. sands and silty sands.
In case of a DNAPL contamination the risk of a downward migration due to the accumulation of the organic phase in front of the steam front has to be prevented. Therefore, steam-air injection is advised. The injected air functions as an inert gas to transport the evaporated organic phase to prevent accumulation, the steam serves as the energy-transfer medium.



Scheme of TSVE (Thermally Enhanced Soil Vapour Extraction) in Karlsruhe

- 1.5 m: replenishments
- 2.5 m: sandy soil with fine silt layers (k_f < 1 x 10^{-5} m/s)
- 4 m: fine silty sand (k_f ~ 5 x 10^{-5} m/s)
- 7 m: fine and medium sand (k_f ~ 0.8 - 3 x 10^{-4} m/s)
- 8 m: medium sand with gravel (k_f ~ 0.5 - 2 x 10^{-3} m/s)
- 10 m: gravel (k_f ~ 3 - 8 x 10^{-3} m/s)

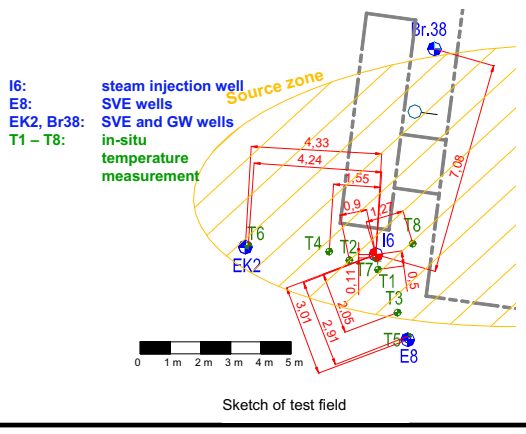
A mixture of steam-air is injected into the contaminated zones to evaporate organic contaminants by active convective heating of the soil to steam-air temperature. The contaminants are carried by the amount of hot air towards the soil-vapour extraction wells. The extracted soil-vapour is treated conventionally on-site.

Pilot - Test

On behalf of the environmental agency of the city of Karlsruhe, a pilot remediation test was carried out using one injection well for the steam-air mixture with parallel soil-vapour and groundwater extraction.
The pilot was accompanied by the numerical simulation of the steam propagation. The goal was to determine the range of the steam propagation in the saturated zone, as well as to verify the site-specific applicability and efficiency of the remediation technology in order to design the full scale application.

Top view of test field

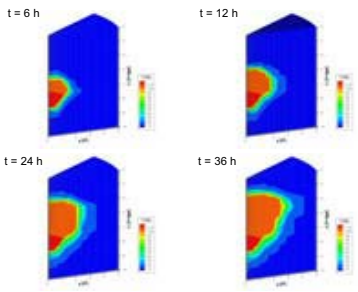
On-Site Treatment Installation



Sketch of test field

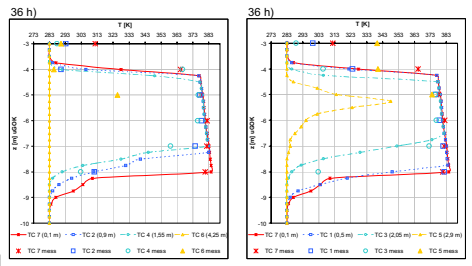
Numerical Simulation

The accompanying numerical simulation for the determination „of the thermal radius" as a basis for the design of the full scale remediation (distance of injection wells, determination of the mass flows) requires a detailed investigation of the subsurface (vertical distribution of k_f-values). The anisotropy of the layered aquifer plays a significant role in steam propagation.



Numerical simulation of steam propagation (S. Ochs, IWS, Universität Stuttgart)

The numerical simulation almost matches perfectly the field data for an anisotropy (k_h/k_v) of 3. For distances larger than 3 m the simulation underestimates the steam propagation. This may be addressed to inhomogeneities of the subsurface or a lower permeable soil compared to the simulation.



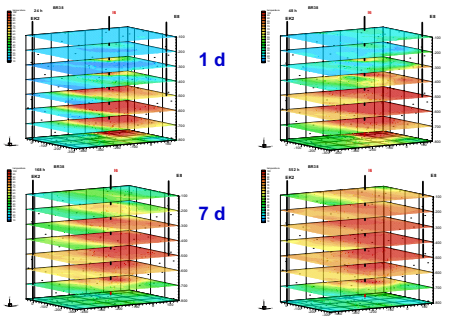
Comparison of temperature distribution: simulation and field measurements (S. Ochs, IWS, Universität Stuttgart)

Results

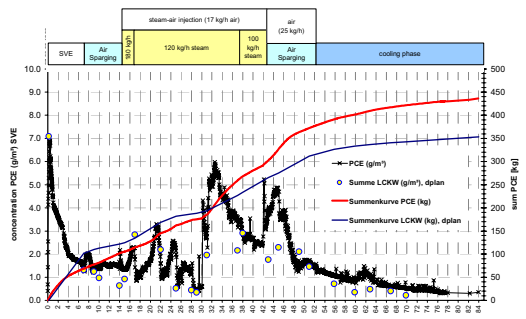
Steps of the pilot injection:

(1) One week groundwater and soil-vapour extraction to achieve constant conditions; ➔ PCE extraction: 70 kg
(2) One week Air-Sparging: injection of approx. 20 m³/h air through the injection well; ➔ PCE extraction: 33 kg
(3) Four weeks injection of a steam-air mixture (105 - 110°C), decreasing rates from 200 to 120 kg/h; ➔ PCE extraction: 200 kg
(4) Six weeks cooling phase: starting with one week of air sparging accompanied by soil-vapour and groundwater extraction; ➔ PCE extraction: 135 kg.

➔ **Total extraction of more than 440 kg PCE confirmed the efficiency of the steam air injection at the location**



Steam propagation in the target zone

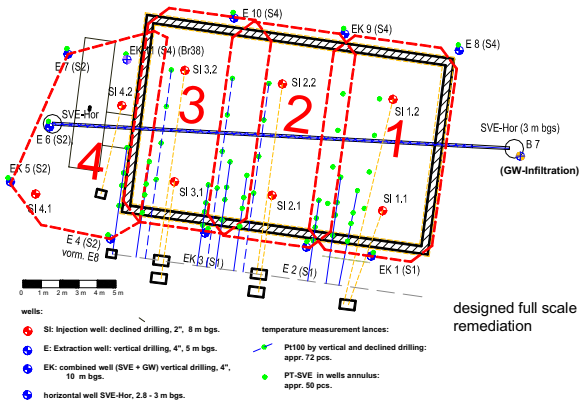


Mass balance based on SVE

- steam extension radius > 3 m within some days (200 kg/h steam-air)
- steam zone extension maintained with an injection of 120 kg/h - 140 kg/h to heat up highly contaminated silt layer by conduction (steam override),
- fast heat propagation during the first two days in the medium permeable sand layers below 5 m (temperatures between 80 and 100°C),
- after approximately 20 days, the subsurface between 2 - 7 m bgs. was effectively heated (> 90°C) with 3 m radius, most of the pollutants were evaporized and extracted (> 99,5 % mass removal due to soil sampling)

Full Scale Remediation Design

Based on the results of the pilot the full scale remediation was designed, the time frame (less than 1 year) and the costs (515 k€, ~ 300 € p. m³ soil) were estimated. Declined and horizontal drilling is required to install injection and extraction wells due to local situation (historical building).



designed full scale remediation

- The site is to be divided into 4 areas to be remediated stepwise by the injection of 350 kg/h steam-air.
- Groundwater is extracted with 2 m³/h and after treatment infiltrated upstream the source zone.
- In total 300 m³/h of soil vapour are to be extracted.

Partners and Acknowledgement

The pilot application was funded by the environmental agency of Karlsruhe. The consultant dplan, Karlsruhe was responsible project director and controller.

VEGAS
Versuchseinrichtung zur Grundwasser- und Altlastensanierung

Universität Stuttgart, *VEGAS*
Pfaffenwaldring 61
D-70550 Stuttgart (Germany)
http://www.vegasinfo.de

Contact:
Hans-Peter Koschitzky, Oliver Trötschler
hans-peter.Koschitzky@iws.uni-stuttgart.de
Oliver.troetschler@iws.uni-stuttgart.de

d·plan