Steam-Air Enhanced In-Situ Remediation of a Chlorinated Hydrocarbon Source under a Historical Building - from Planning to Successful Rehabilitation -

Introduction

Pilot Application (2005)
- remediation planning → site description
- thermally enhanced remediation → steam-air injection
- pilot; what for? → confirmation and design steam-air technology

Remediation concept

Remediation – Monitoring (2010/2012)
- remediation concept → sequential steam-air injection
- data monitoring → surveillance and process control
- Process operation → remediation progress and results

Realization of thermally enhanced remediation and aftercare

Site Karlsruhe Durlach

Impressions from the site in 2005
Contamination

Contaminant source PCE
Former dry cleaner: Leaking sewage system below the historical building
⇒ PCE in the unsaturated zone, capillary fringe and saturated zone (silt, clay 5 m b.g.s.)
⇒ PCE max. 3,800 mg/kg in vadose zone
⇒ 60 mg/l in groundwater

Groundwater contamination:
plume: > 300 m
PCE concentration up to 350 µg/L

Geology and remediation concept

S-A-injection:
7 - 8 m b. g.s. max. 200 kg/h
SVE:
100 - 150 m³/h
GW-pumping (cooling water)
1 - 3 m³/h
STEAM-AIR ENHANCED IN-SITU REMEDIATION OF A CHLORINATED HYDROCARBON SOURCE UNDER A HISTORICAL BUILDING - FROM PLANNING TO SUCCESSFUL REHABILITATION -
Summary of pilot application

- Steam propagation > 4 m radius
  - initial phase of maximum steam rate required
- time required is dominated by conductive heating of the silt layers
  - 4 – 6 weeks of reduced steam-air rate to heat up silt
- 440 kg PCE via SVE & 10 kg via GW removed:
  - "cold" SVE: 70 kg
  - air-sparging: 30 kg
  - steam-air: 340 kg
  - acceleration factor for steam-air of about 5
  - safe design and cost estimation for full site remediation

Remediation goal and concept full scale

- 1.600 m³ of soil to be treated in-situ
- 10 months of steam-air injection
- 300 kW of steam injection power

Implementation of full scale remediation

- same as pilot

(1) "cold" soil vapour extraction and groundwater pumping all compartments (1 week)
(2) air-sparging (each compartment)
(3) steam-air injection (6 weeks, each compartment)
(4) cooling phase: air-sparging and gw pumping 6 weeks

Remediation: implementation

- Site owner: Stadt Karlsruhe
- Remediation planning and contracting: consultant dplan (& VEGAS)
- Operation: Züblin Umwelttechnik
- Scientific assistance, monitoring and remediation control: VEGAS & dplan
- Advisory board: RP-Ka, City of KA, EPA (LUBW) of Baden-Württemberg

Steam injection under the building

- Injection wells
- Temperature monitoring
- Steam zone
- Steamed zone
- Soil vapour wells
- Combinedwell SVE and groundwater
- Groundwater
- Gas supply
- Fine sand
- Coarse sand
- Range of steam
- Steamed zone
- Building

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Remediation control and decision criteria

Control and balances
- Control of steam expansion and heat using 120 thermocouples in the subsurface
- Control and monitoring CHC and BTEX in soil vapour extraction (all lines, single wells and treatment)

Criteria of closure treatment of a compartment
1. Target temperature of 87°C to be achieved in saturated zone (azeotropic temperature TCE-PCE-water)
2. Concentration of contaminant in SVE falling short of 20 mg/m³ and remaining constant or falling
   - compartment successfully treated
   - switch to next field

Betrieb Mai - Juli 2010

Groundwater and soil vapour extraction, activated carbon filter

Exhaust chimney SVE

Extraction well and temperature measurement

Drilling works and wells construction

Exhaust chimny SVE

Extraction well and temperature measurement

Temperature development during remediation
Summary and some numbers of full scale remediation

- **Total duration** incl. drilling works 70 weeks
- **Duration of remediation** 42 weeks (ca. 30 weeks steam-air injection)
- **Contaminant removal mass** 50 kg CHC, (500 kg incl. pilot)
- **Remediation goals** achieved concerning CHC concentration (10 mg/m³ in soil vapour, << 10 µg/L in groundwater)
- **Impressive reduction of groundwater contamination**
  - before: 60,000 µg/L
  - two years after: < 5,0 µg/L bis n.n.

**Reduction of indoor contamination**
- before: CHC up to 10 mg/m³
- during and after: CHC = 0 mg/m³

**costs**
- total budget ca. 600,000 €
- 25% drilling and construction
- 25% consumables, energy (mainly gas for steam production)
- 50% for plants installation and operation
  ➔ specific costs: ~ 180 €/to soil

**Energy balance**
- 470 kWh/m³ soil (84% heat; 16% electric)
- total consumption: 780 MWh (thermical energy), 153 MWh electrical energy

**Summary and some numbers of full scale remediation**

.. at the very end..

**Thanks to all involved partners for the good and team work and cooperation**

**Thanks for your patience and your interest**

Any questions?

hans-peter.koschitzky@iws.uni-stuttgart.de
http://www.vegas.uni-stuttgart.de

Dr.-Ing. Hans-Peter Koschitzky & Oliver Trötschler
VEGAS, Versuchseinrichtung zur Grundwasser- und Altlastensanierung, Universität Stuttgart