Thermal treatment

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INTERREG IVB

What you can expect

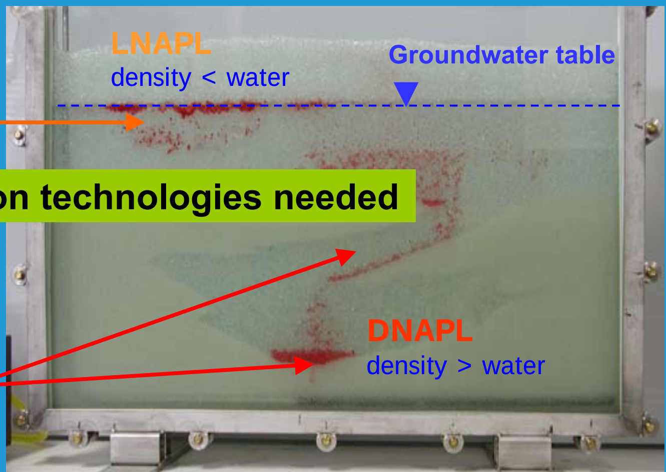
- Why in-situ thermal remediation, ISR ?
- Basics of thermal technologies
- Operating windows
- A successful example of steam-air-injection
- Therefore ISR - Conclusions

LNAP – DNAPL problem

LNAPL

Remediation technologies needed

DNAPL



NAPL = Non-aqueous phase liquid (not miscible with water)

Why thermal treatment ?

T_1 = 20°C

T_2 = 70°C

ca. 2 cm

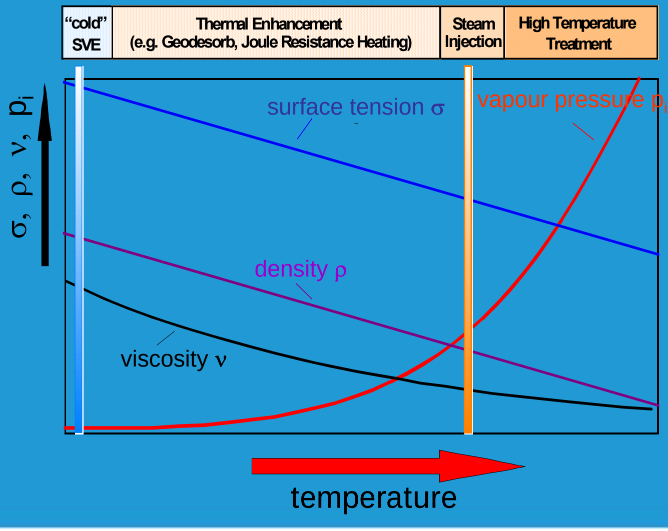
Photos: A. Winkler

Fluid properties - f(Temp)

T_1 = 20°C

T_2 = 70°C

Photos: A. Winkler



Steam distillation

Increasing temperature: 20°C → 80°C

and vapour pressure

- Water: factor 20
- PCE: factor 15
- Xylene: factor 19

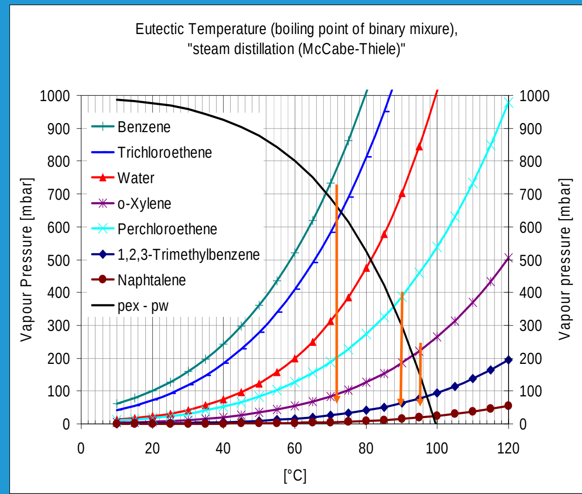
Reduction of boiling point by steam distillation (azeotropic point):

Benzene 80 → 69°C

TCE 87 → 74°C

PCE 121 → 87°C

m-Xylene 144 → 93°C

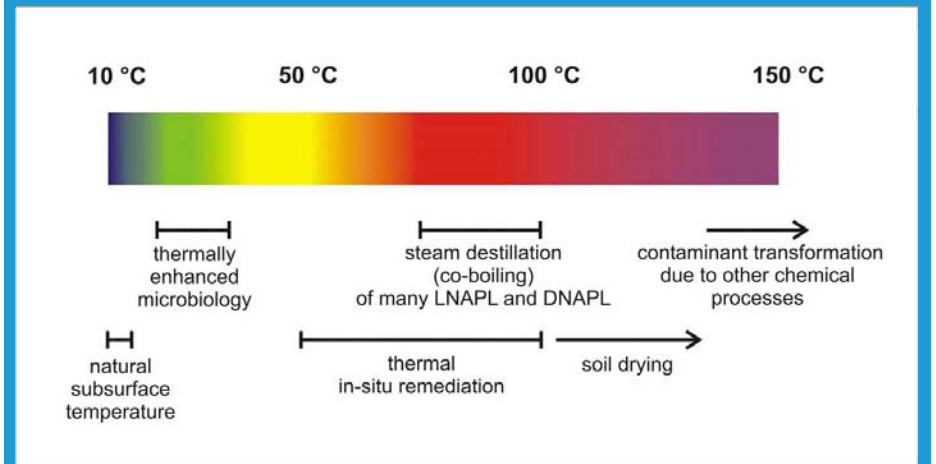


Thermal In-situ Technologies

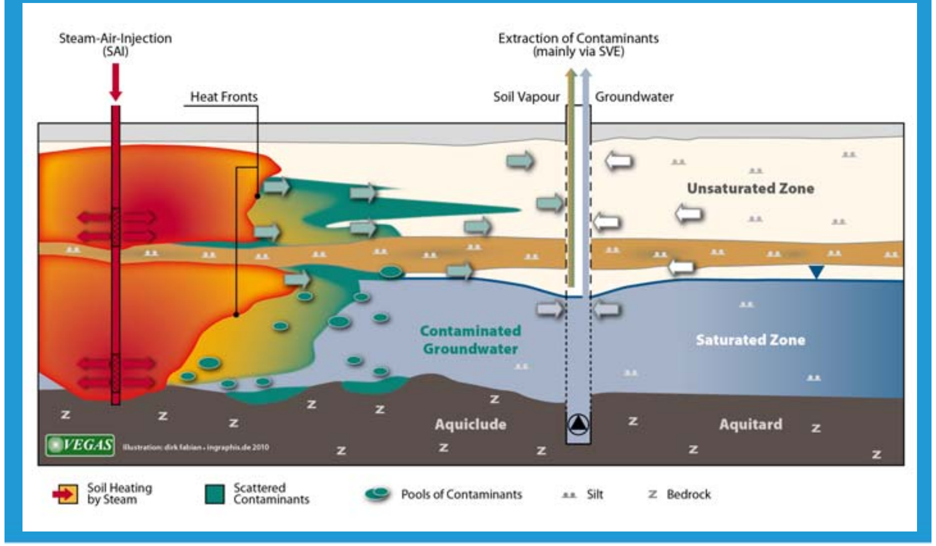
Convection →	Conduction	Ohm	di-electric
Steam- / Steam-Air -Injection	Conductive Heating, Thermal Wells (electric or hot gas)	Electric Resistance Heating	RF- / Radio-frequency Heating

- organic compounds (LNAPL & DNAPL)
- increase of vapor pressure of contaminant by heating of subsurface / steam distillation
  → by factors enhanced extraction rates
- **Extraction of contaminants as gas** (SVE Soil Vapour Extraction)
- fast and reliable (and controllable) remediation process
  → selection of technique dependent on site conditions and "composition" of contaminants (mixtures)
  → expert knowledge required

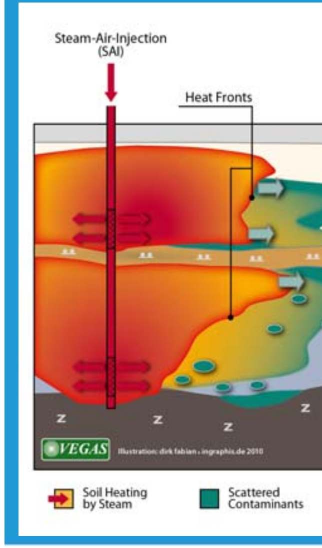
Operating Windows



Steam – Air – Injection (SAI)



Characteristics



Operation windows

DNAPL and LNAPL, light and medium volatile, boiling points < 180°C

UZ: Unconsolidated soil, mean to good permeability (silt → gravel)

GZ: Pore aquifer (sand to silt)
k_f: 5 x 10^{-5} to 1 x 10^{-3} m/s

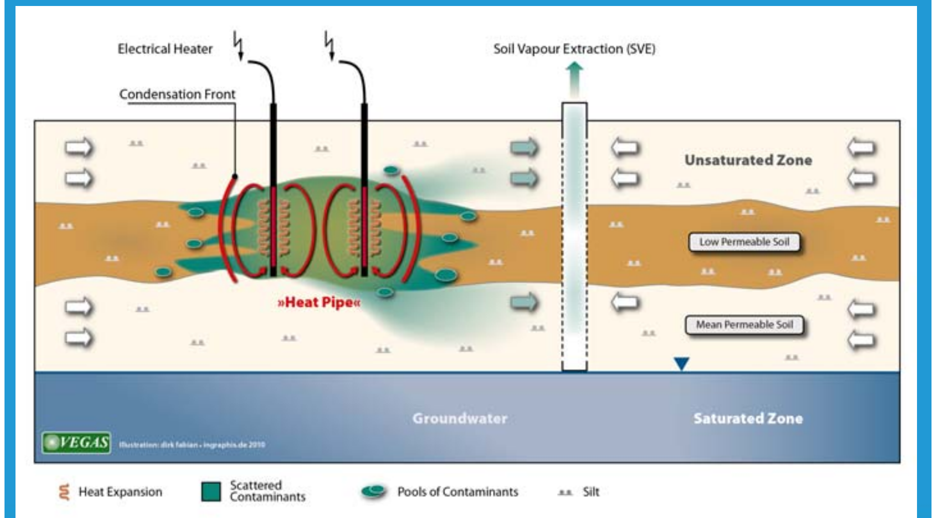
Thermal radius of influence (groundwater)

- Permeability: 0,5 – 5 x 10^{-4} m/s
- Steam propagation: 3 - 5 m radius for 150 kg/h steam
- Advantage: anisotropic soil structure

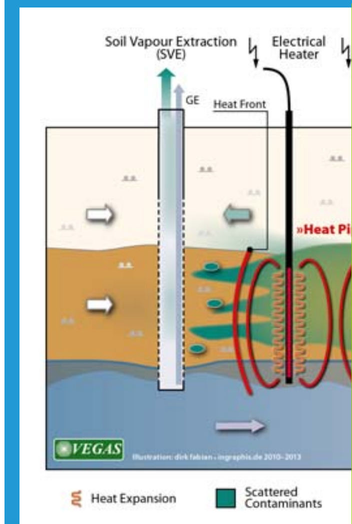
Features

- Simultaneous remediation of aquifer and unsaturated soil zone
- Possible structural changes in highly organic soil structures (peat layers) → settlements?

Conductive Heating (Thermal Wells)



Characteristics



Operation windows

DNAPL and LNAPL, light and heavy volatile, boiling points < 250°C

UZ: Low permeable soil layers (fine sediments, silt, clay, …), permeability up to 10^{-9} m/s

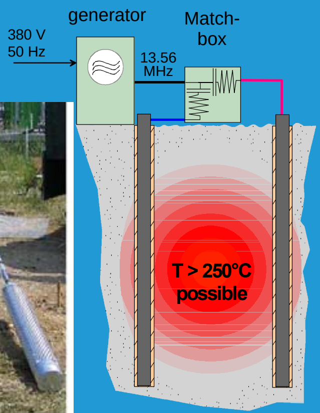
GZ: For special conditions feasible, to be proved by pilot investigations

Distance of heating elements in the range of meter (function of site)

Features

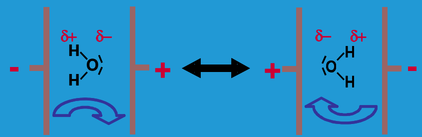
- During drying of the soil permeability for SVE can significantly increase
- Beware of possible settlements (clay layers,…)
- Low operating and maintenance costs

Radio Frequency / RF Heating



Principle of heating

- Comparable to Microwave oven
- Heating by internal friction
- Dipole (e.g. water) or other polare structures are activated by vibration



- Direct heat generation in the soil volume
- High flexibility (temperature programmes)
- Can be applied for dry and humid, sandy and tenaceous materials, e.g. soils

From Dr. Ulf Roland

HELMHOLTZ ZENTRUM FÜR UMWELTFORSCHUNG UFZ

Guidelines and tools

Tool for Design Steam-air-injection

Field case: Steam-Air-Injection

Site *Karlsruhe Durlach*

Slaughterhouse of 1574

➔ Dry cleaner

Historical City *Karlsruhe Durlach*

Contamination

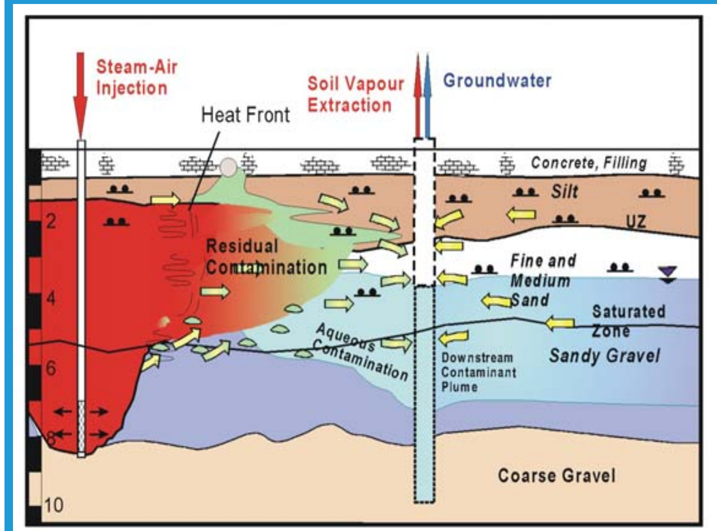
Groundwater contamination:
plume: > 300 m
PCE concentration up to 350 µg/L

O. Trötschler, H.-P. Koschitzky, Steffen Ochs, Stephan Denzel

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

Geology / remediation concept

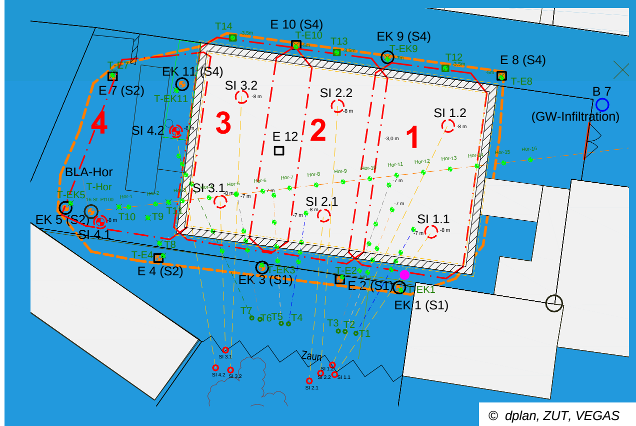


S-A-injection:
7- 8 m b. g.s.
max. 200 kg/h

SVE:
100 - 150 m³/h

GW-pumping (cooling water)
1- 3 m³/h

Remediation: implementation

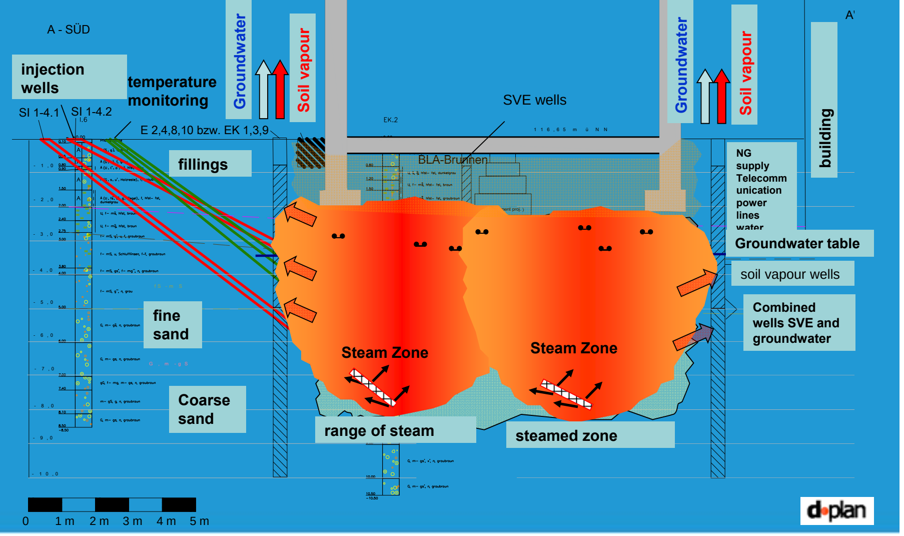


© dplan, ZUT, VEGAS

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

Stadt Karlsruhe Umwelt- u. Arbeitsschutz · dplan · ZÜBLIN · VEGAS

SAI below the building



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Drilling and installation of wells

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Field installation: remediation

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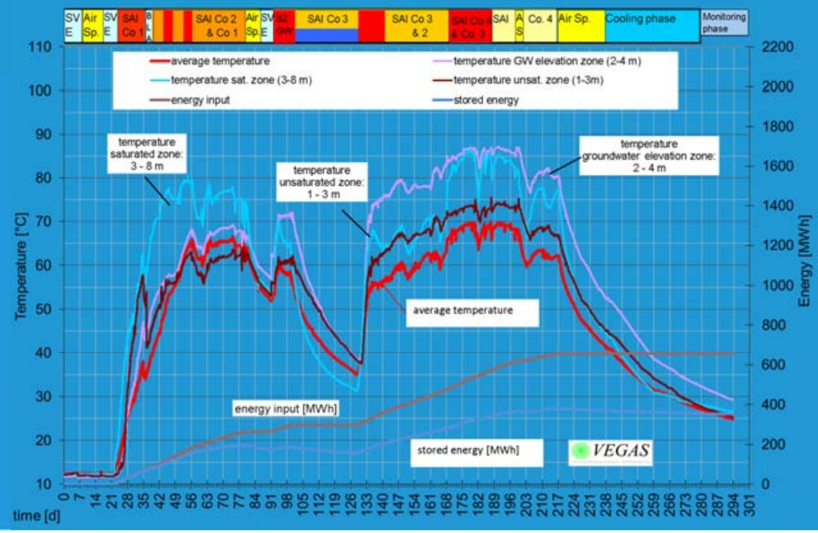
Temperature development during remediation



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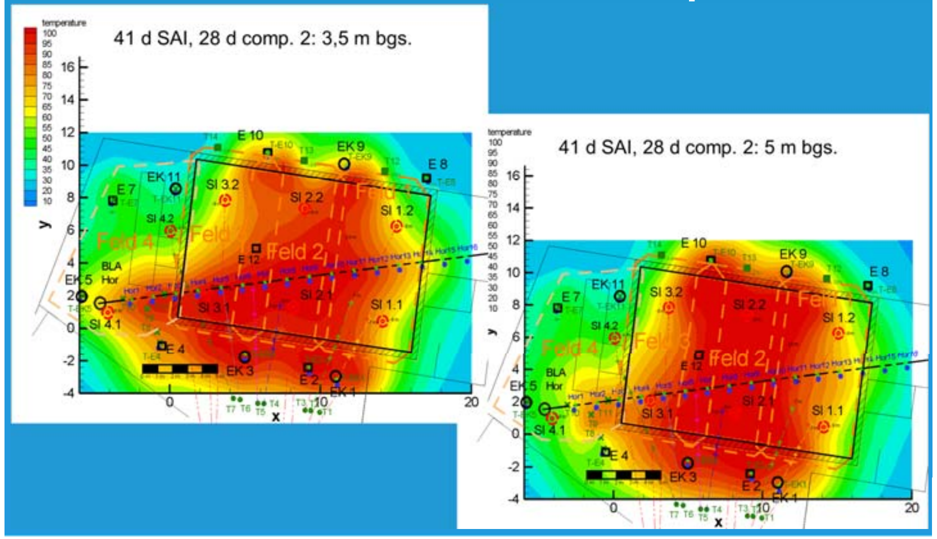
Heat propagation: compartment 2



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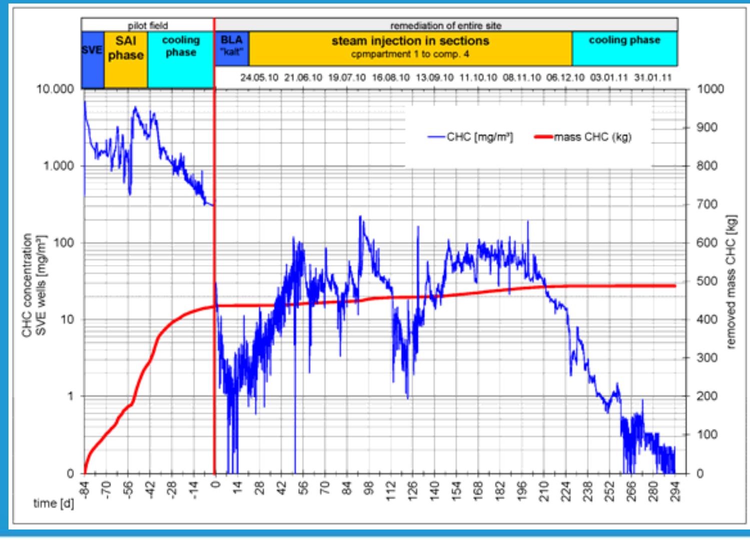
Contaminant removal by SVE



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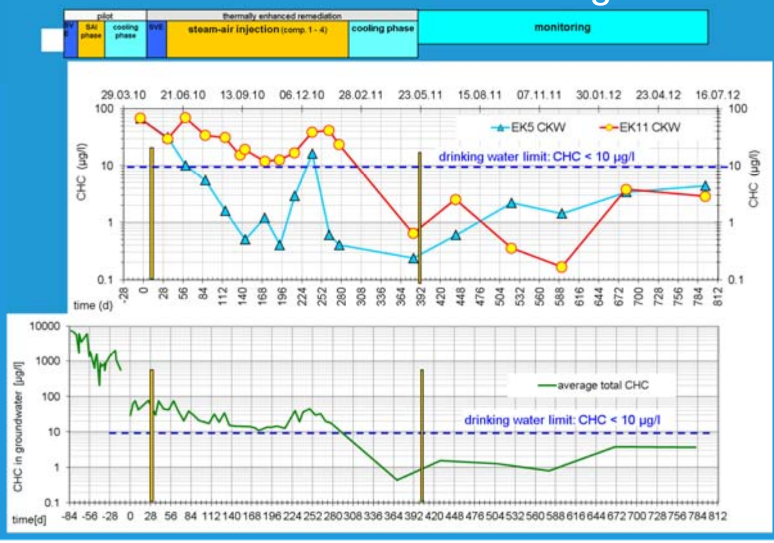
Development of CHC in groundwater



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Summary and some numbers of remediation (1)

- **Total duration** incl. drilling works 70 weeks
- **Duration of remediation** 42 weeks (ca. 30 weeks steam-air injection)
- **Contaminant removal mass** 500 kg CHC (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 down to not detectable

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Summary and some numbers of remediation (2)

- **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 (thermal energy)
  153 MWh (electrical energy)

The site after the remediation
(15.11.2011)

Therefore ISR

- **ISR can used under difficult and narrow conditions (even below buildings)**
- **ISR reduce remediation time at minimum by one order of magnitude**
- **ISR can reduce the total energy consumption by a factor 2**
- **Cost for subsurface heating and on site treatment (Soil vapour and groundwater) are approx. similar**

Conclusion

- **ISR can help to solve our contamination problems**
- **But - no "universal" remedy exists**
- **use ISR carefully → expert knowledge is needed**
- **Detailed site information is needed to chose an optimum solution**
- **Invest money in a serious site investigation**
- **Invest in (lab experiments, special problems) and pilots**

➔ Both will save money and at least led to a cost and eco efficient and sustainable solution

… at the very end

Thanks for your patience and your interest

Any questions ?

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