







Remediation conducted in Hagfors

There has been two remediation actions (in soil) in Hagfors:

•1996, Soil Vapor Extraction (SVE)

•2003/2004, In Situ Steam Stripping (ISSS) (or Steam Enhanced SEV)

• The only ISSS remediation in Sweden, and one of few in Scandinavia

No groundwater remediation has been conducted.

NORDROCS 20-21 September 2006 Malmö, Sweden 1st Joint Nordic Meeting on Remediation of Contaminated S PCE remediation in Hagfors, Sweden













Effective time ·	Energy con	sumption -	Cost
Effective time:			
•Vacuum pump:	91 %		
•Compressor:	90 %		
•Steam:	83 %		
Energy consumpt	<u>ion :</u>		
Electrisity: Oil:	241 MWh 182 m3	45 MWh 100 m3	(+ 530%) (+ 180 %)
•PCE :	4 800 kg	1000 kg	(+480 %)
<u>Cost :</u>	Total cost app Cost per kg P Funded by the	orox. 10 MSEK CE: 2 100 SE e state	K/Kg
NORDROCS 20-21 September 2006 Ma	almö, Sweden	PCE remediation in Hagfors, Sw	
1st Joint Nordic Meeting on Remediation	of Contaminated Sites		



Problems

The following problems has been dealt with:

Problem with steering of the ground water cooling pump

Solved by switching to continues operation

Problem with water separation on the air ahead of the activated carbon filter.

Solved through rebuilding the air cooler

Problem PCE in indoor air after start of step 2c, steam injection in the upper level

• Adjustment of the steam injection. New SVE-well in the area of concern.

Problem with high temperatures on the floor (60 °C)

No solution at hand. The worker had a leave for some weeks. Isolation
of the floor had been possible- and favorable, but not easy due to traffic
with heavy trucks.

NORDROCS 20-21 September 2006 Malmö, Sweden 1st Joint Nordic Meeting on Remediation of Contaminated S PCE remediation in Hagfors, Sweden

Result PCE

Soil

- Soil contents up to 6 000 mg/kg TS was measured ahead of remediation
- After remediation 2003/2004 a soil sample from the most polluted area shows a content of 2 mg/kg TS. (The soil sampling was undertaken during the cooling period (about at 25 °C) and some PCE might have evaporated)
- RAO: 2,5 mg/kg TS in surface soil (proposal in the "Hållbar sanering" project)

Indoor air

- Prior to remediation tests showed 10 mg/m³ in the building and 240 mg/m³ in a badly vented area.
- During the period of steam injection 13 mg/m³ was measured (prior to the adjustment of steam injection in step 2c)
- Soon after the remediation 0,34 mg/m³ was measured (sept/nov 2004)
 Later the readings where 0,033 mg/m³ (January 2005)
- RAO: 0,1 ppm or 0,7 mg/m^{3.} (proposal in the "Hållbar sanering" project)

NORDROCS 20-21 September 2006 Malmö, Sweden 1st. Joint Nordic Meeting on Remediation of Contaminated Siles PCE remediation in Hagfors, Sweden

Lessons learned

•Groundwater pollution resist in spite of successful soil remediation

•PCE in GW is several mg/l. Solubility is 150 mg/l. PCE content thereby exceeds 1 % which indicates DNAPL PCE in saturated zone

•The amount of PCE transported off site in GW is of the same magnitude as the remediated PCE in soil

•It is imperative to set up proper RAOs ahead of remediation

•Welding and CHC, especially PCE - a high risk!

•The success of a remediation as complex as the ISSS remediation in Hagfors rely on adequate testing and design.

Hagfors an example in a "Hållbar sanering" project

SWECO, has, in cooperation with COWI och GeoSyntec worked with a Hållbar sanering project named: "Vägledning för efterbehandling av klorerade lösningsmedel i mark och grundvatten" (Remedial Alternatives Evaluation Process). Project leader is Peter Englöv, SWECO VIAK Malmö. Will soon be published.

•Tree remediation methods is considered applicable on PCE in soil in Hagfors

•7 remediation methods is considered applicable on PCE in groundwater

•The different methods is weighted an the best method is washed out for soil and groundwater

NORDROCS 20-21 September 2006 Malmö, Sweden 1st Joint Nordic Meeting on Remediation of Contaminated S PCE remediation in Hagfors, Sweden

Remedial action objectives (RAO) from "Hållbar sanering"
Primary RAO:
•PCE in indoor air < 0,1 ppm (= 700 μg/m³) due to risk of phosgene formation (when welding in PCE-atmosphere)
Secondary RAO:
•Reducing the concentration in shallow soils to 2,5 mg/kg TS (vegetables) in case of althering the land use to housing.
•Reducing the concentration in groundwater so that the concentration in the river Örbäcken does not exceed 3,5 µg/l (surface water)
•An RAO might concern the indoor air in houses situated over the plume. Another RAO could include the GW if drinking water is considered (Not investigated)

NORDROCS 20-21 September 2006 Malmö, Sweden

sweco 🛣

PCE and welding – a serious problem!

Electric welding in an atmosphere w form phosgene and trikloroacetylklor	ith PCE will Phosgene id (TCAC) in
equal parts.	the C. The bolisment of the
2 ppm PCE forms 1 ppm phosgene TCAC.	och 1 ppm
TGV (A maximum tolerable level me 15 minutes period of time) for phosg ppm which means that 0.1 ppm sho TGV for PCE under this conditions, a the RAO	asured over a ene is 0.05 uld be the and likevise
NGV (a tolerable level over a workin PCE is 10 ppm (100 times TGV calc	g day) for ulated above)
NORDROCS 20-21 September 2006 Malmö, Sweden	PCE remediation in Hagfors, Sweden

NORDROCS 20-21 September 2006 Malmö, Sweden 1st Joint Nordic Meeting on Remediation of Contaminated Site ‴sweco 첩

Evaluation of remediation methods for soil

Alternative 1 ineered Control b-slab Venting, CC Modification,	Alternative 2 Soil Vapor Extraction SVE Soil Vapor Extraction combined with Granulated Activated Cathons (GAC)	Alternative 3 Steam enhanced SVE ISSS Steam injection
ineered Control b-slab Venting, CC Modification,	Soil Vapor Extraction SVE	Steam enhanced SVE ISSS
b-slab Venting, AC Modification,	Soil Vapor Extraction combined with Granulated Activated Carbon (GAC)	Steam injection
indoor rui	filters	GAC-filters.
33	34	38
	33 rr 2006 Malmö, Sweden	33 34 r2006 Mamo, Sveden PCE renediati

Evaluation of remediation methods for groundwater							
	Alternative 1	Alternative 2	Alternative 3	Alternative 4	Alternative 5	Alternative 6	Alternative 7
	No Action	Physical Barrier (Slurry Wall/Sheet Pile)	Pump and treat (with Long-Term Monitoring)	Air spar- ging/SVE (with Long- Term Monitoring)	Anaerobic reductive dechlorination	In Situ Chemical Oxidation (with Long- Term Monitoring)	Permeable Reaktive Barrier with Fe ^o
Source Remediation	No Action (Investigations concerning leakage to the river is neded)	Hinder outflow from the source area, no mass reduction	Would adress the source in a long term operation	Not appliccable on the source	Aktiv, recirku- lation of soluble elektrodonors (e.g. Lactate)	Oxidant injection and groundwater recirculation in the source zone	Not appliccable on the source
Plume Remediation	No Action (Investigations concerning leakage to the river is neded)	No mass transport from source to plume	No mass transport from source to plume	Installation of a row of air sparging wells downstream ste source togheter with SVE wells	Passiv biobarrier whith injection of slow-release electron donors (such as emulsified edible oil)	Treatment of the source zone will reduce the flux to the plume	Installation of a passive reaktive barrier across the plume
Illustration of method		N.	·	E.	·		No.
Points (max 45)	18	29	34	33	40	39	34
							_
NORDROCS 20-21 September 2006 Malmö, Sweden PCE remediation in Hagfors, Sweden SWECO							



