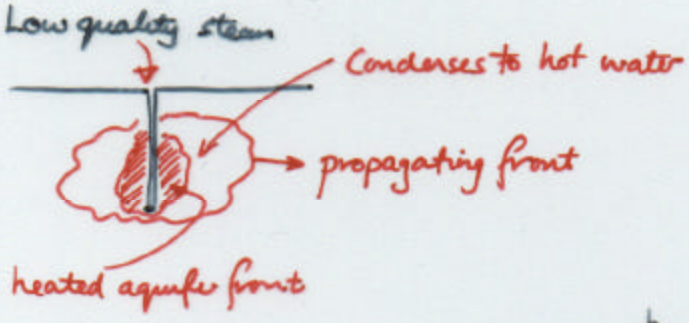
6.1 Contained Recovery of Oily Wastes CROW®

Low quality steam: 1. Flotation of NAPL by $\downarrow \rho$
2. Reduced μ and increased mobilization
- also surface tension changes.
3. Propagation of water front.

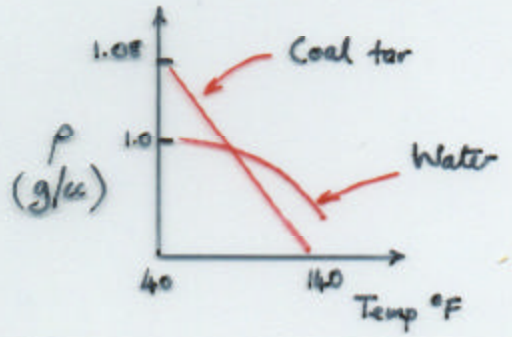
Secondary mechanisms: 1. Solubility enhancement of target NAPL
2. Enhanced in situ biodegradation.



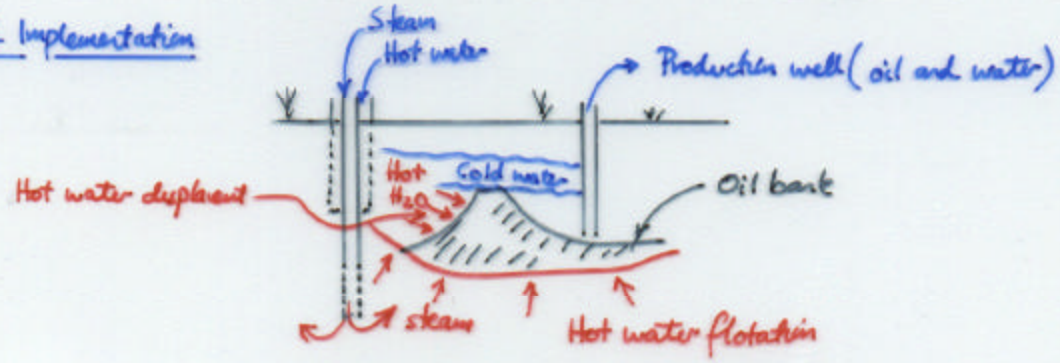
Steam → condenses to water
Water → (immiscible) plug displacement
Surfactants may be added.

$k_{rw} \uparrow$ by hot water due to viscosity $\downarrow$
$\mu \propto \frac{1}{\text{Temp}} \propto \frac{1}{\text{Kelvin}}$

Some DNAPLs may be transformed to LNAPL with temperature change



Field Implementation



Wells may inject: cold water, hot water, steam } at different levels.

remove: mixed water and NAPL → reinject water after treatment

- float DNAPL to surface and horizontal displacement
- Concentrate NAPL in "oil bank" for displacement by water
- ↓ S_{nw_0} due to ↓ interfacial tension
- Rear zone of solubilized NAPL due to hot water.

Cool water layer acts as confinement layer

May add surfactants to improve behavior.

Level of Demonstration

- Lab studies using columns (bead packs) for displacement } to determine potential
- Large reaction boxes 3×3×7ft

Pilot studies

Wood treatment plant (creosote)

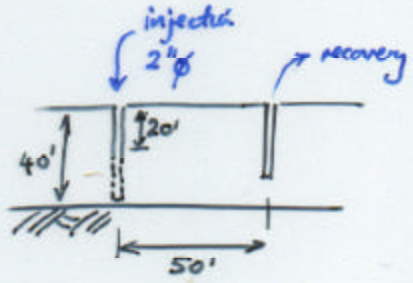
40 ft aquifer silty fine sands and gravels

30 day injection 4-5 gpm

147°F – 203°F

Uniform heating in 28 days.

Inject 193,000 gals; Extract 390,000 gals incl. 2000 gal NAPL



Samples of soil show: ~ 80% wt. reduction in hydrocarbons after 20 pore vol. flushings.

~ PCP concentration 2100 → 3.6 ppm.

Applicability / Limitations

LNAPLs and DNAPLs. Densities within 10–15% of water @ 20°C
(since ΔT will float product).

Residual saturation of NAPL controlled by N_B and N_C (by passing/short circuit).
and residual of 0.1–5 wt% remains
∴ need additional movement mechanism

Significant S_{nw_0} reductions, mixing, oxygenation → useful augmenting technique to bioremediation.

Cost / Availability

Depth of treatment dictates cost.
Planned treatment @ Shrewsbury, PA. 20 ft aquifer.

Good candidate for DNAPL removal.
Soil treatability studies (2 – 55 gal drums) $20,000
Pilot study $300,000
Full scale study $1.5 – 2.5 M ← capital costs for installing equipment
↑ include in situ biological treatment.
Operating/maintenance costs $50K – $60 K/year.