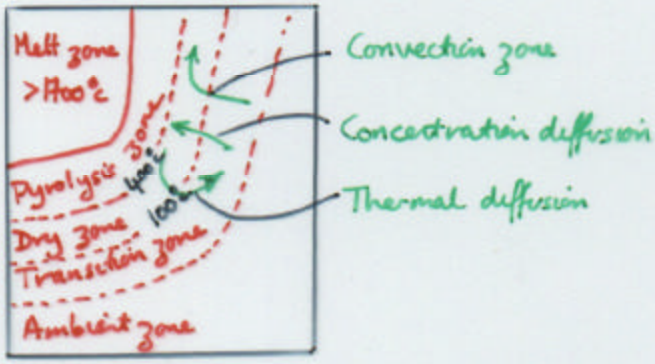
6.4 Vitrification

Joule resistance heating → melting → contaminant removal

Mechanisms: 1. Accelerated chemical reactions (melt and pyrolysis zone)
2. Organic vapor recovery in vacuum hood.
3. Pyrolysis of DNAPLs and vapors

1. Initial "starter" path of graphite added at surface between electrodes
2. Soil conductivity ↑ with melting (elect. cond.)
3. Soil temperatures 1600°c — 2000°c

Molten mass propagates ↓.



- DNAPLs boil as they transit the 100°c isotherm + dry.
- Dry zone acts as gas conduit
- Remaining compounds thermally decomposed in pyrolysis zone.

Cooled mass resembles obsidian. qu 5-10x concrete
high leach resistance.

Field Implementation

Molten soil mass — Heavy metals and radionuclides stabilized
DNAPLs pyrolized

50' dia. fugitive gas hood. Vacuum to $\frac{1}{2}$ - 1" H_2O
Electrodes fixed or moved down with melt
Square electrode array. 35' separation (max)
Depth of 19-25'.

Backfill subsidence. Mobilization between sites ~ 16 hr.

Applicability / Limitations

Originally developed for radionuclides — high cost.
Also applicable to DNAPLs

Limitation. Groundwater veils in soil with $K > 10^{-4}$ cm/s will stop melt progress.

Applicable to vadose soils only, and clays saturated.
Could be used with dewatering / containment
Useful in very heterogeneous soils.

Rule-of-thumb limitations:

- Metal concentration < 5–16% wt.
- No continuous metal traversing more than 90% of electrode spac
- Combustible organic concentration < 5–10% wt.
- Individual void volumes < 150 ft^3
- Drums and buried debris may short circuit (remaining at base of melt).

Hardware trailer mounted. Treat soil @ 10,000 lb/hr
Typical soils. 4 kW hr/lb → 4000 kW per application
About same consumption as average-sized city hotel

Cost / Availability

No full scale ISV below w/t
US DoE has patent
Not applicable for DNAPL below w/t
Useful for mixed wastes → $450/$yd^3$
Estimates $300–400 ton.

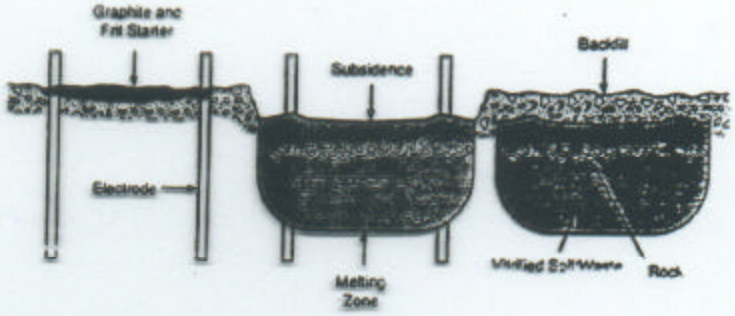


Figure 3.7.4.1 Schematic illustrating the in-situ vitrification (ISV) process [Smith and Hinchee, 1993].

TABLE 4.1.1. IN-SITU TECHNOLOGY COMPARISONS

IN SITU TECHNOLOGY	DESIGN BASIS	OPERATIONAL MECHANISM	APPLICABILITY	SCALE OF DEMONSTRATION	EXPECTED EFFICIENCY	COMMERCIAL AVAILABILITY	APPROX. COST RANGE ($/yd^3)
Aerobic Biodegradation	Theoretical	Treatment	Dissolved phase only	Pilot	Intermediate/High	Pilot/Available	15-60
Anaerobic Biodegradation	Theoretical	Treatment	Dissolved phase only	Pilot	Intermediate/High	Pilot/Available	15-60
Electro-Osmosis	Theoretical	Treatment/ Recovery	Dissolved phase only	Pilot	Low	Available	75-150
Electroacoustic Soil Decontamination	Empirical/ Theoretical	Treatment/ Recovery	Dissolved phase only	Laboratory	Low	Emerging	60-150
Slurry Walls	Empirical	Containment	Dissolved and separate phase	Full	High	Available	7-13/ft^2
Grouting	Empirical	Containment	Dissolved and separate phase	Full	Intermediate/High	Available	60-100
Hydraulic Gradient Control	Theoretical	Containment	Dissolved phase only	Full	Intermediate/High	Available	50-100
Stabilization/Solidification	Empirical	Containment	Dissolved and separate phase	Full	Intermediate/High	Available	SSM 26-65 DSM 130-260
Permeable Treatment Walls	Empirical/ Theoretical	Treatment	Dissolved phase only	Pilot	Intermediate/High	Pilot	50-100
Alkali Soil Washing	Theoretical	Recovery	Dissolved and separate phase	Pilot	Intermediate/High	Pilot/Available	75-125
Cosolvent Soil Washing	Theoretical	Recovery	Dissolved and separate phase	Laboratory	Intermediate	Emerging	75-125
Surfactant Soil Washing	Theoretical	Recovery	Dissolved and separate phase	Pilot	Intermediate/High	Pilot/Available	75-125
Water Flooding	Empirical/ Theoretical	Recovery	Dissolved and separate phase	Full	Low/Intermediate	Available	50-100
Air Sparging	Empirical	Recovery	Dissolved phase only	Full	Intermediate/High	Available	75-125
Vacuum Vaporizer Wells	Theoretical	Recovery	Dissolved phase only	Full	Intermediate	Available	50-100
CROW® Process	Theoretical	Recovery	Dissolved and separate phase	Pilot	Intermediate	Pilot	50-125
Steam Enhanced Extraction	Theoretical	Recovery	Dissolved and separate phase	Pilot	High	Pilot/Available	50-125
Radio Frequency Heating	Theoretical	Recovery	Dissolved and separate phase	Pilot (vadose zone)	Intermediate	Pilot	65-160
Vitrification	Empirical	Treatment/ Recovery	Vadose Zone only				400+

(see text for additional notes and explanations)