Soil Sampling and NAPLANAL

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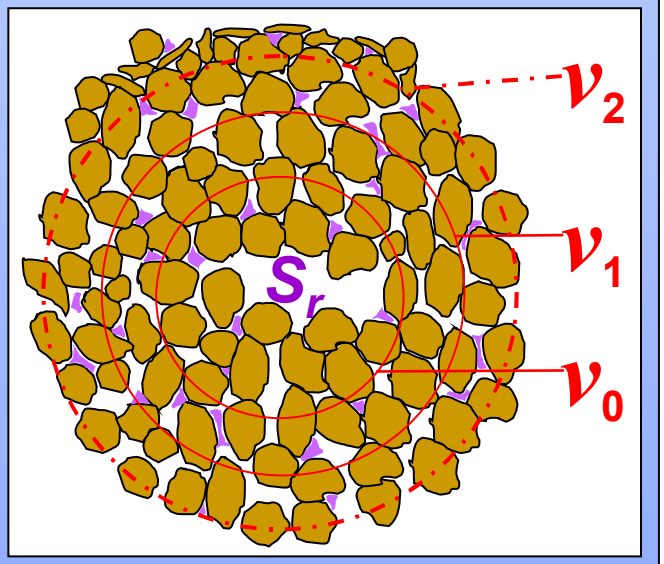
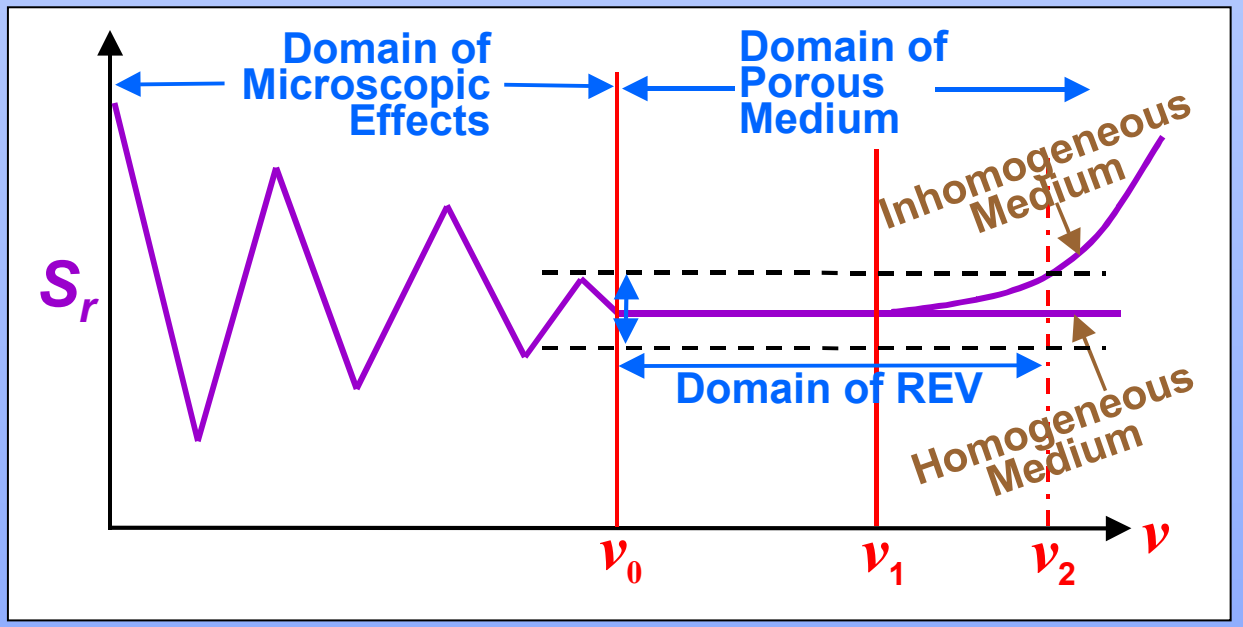
SEAR Workshop

Representative Elementary Volume (REV)





- Est. range of REV for NAPL in soil = $10\text{-}10^4$ cm^3
  = 0.0003 to 0.3 ft^3
- Volume of typical soil sample = $30\text{-}10^2$ cm
  = 0.001 to 0.01 ft^3

DNAPL in Soil from OU 2, Hill AFB, UT

DNAPL Soil Sampling Focus

Average Saturation

$$S_N = \frac{\text{volume of NAPL within REV}}{\text{total pore volume within REV}}$$

Calculating Saturation

- Feenstra et al. (1991)
  - Assesses whether NAPL is present
- Mott (1995): SOILCALC
  - Assesses presence of NAPL
  - Estimates NAPL composition
  - Assumes NAPL does not occupy pore space, can't calculate S_N
- Mariner et al. (1997): NAPLANAL

NAPLANAL

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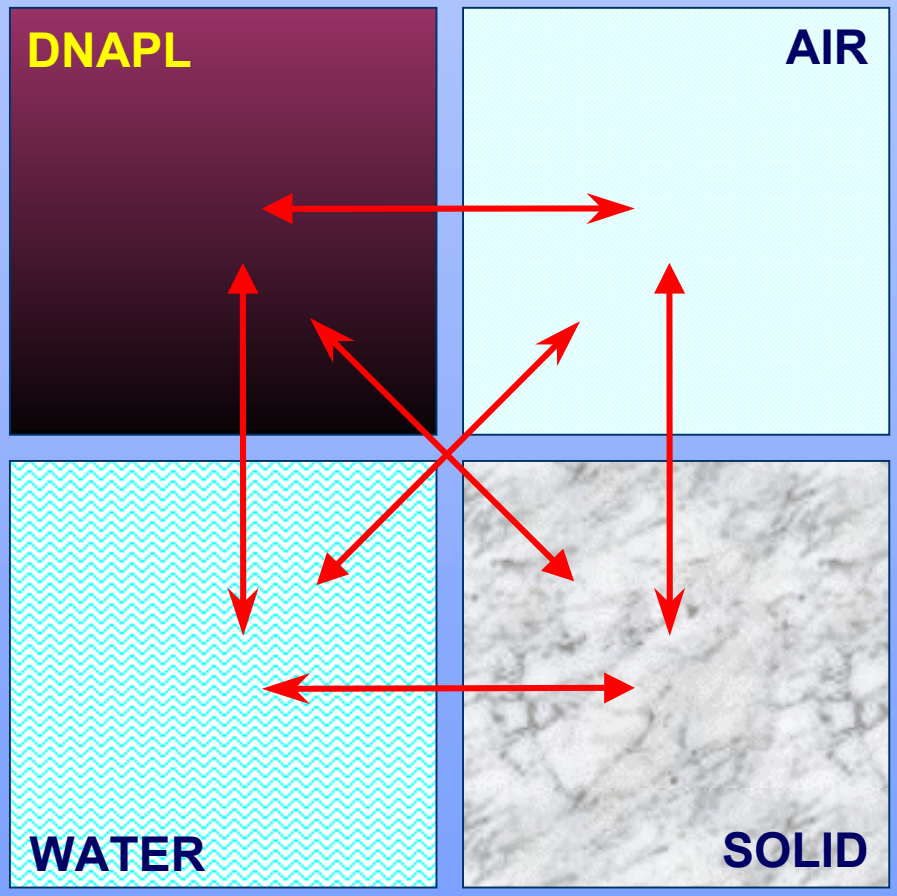
NOT

ˈna-pl - ā -ˌnel

Partitioning Theory



NAPLANAL Calculates:

- NAPL saturation
- NAPL composition
- VOC concentrations in each phase
- NAPL composition and volume in water-NAPL emulsions ($\phi_s = 0$)

Conservation of Mass

Mass of *i* = sum of mass of I in all phases:

$$\rho_t C_t^i = \phi_w C_w^i + \phi_a C_a^i + \phi_n C_n^i + \phi_{s\,s} C_s^i$$

Total density = weighted average of all densities:

$$\rho_t = \phi_w \rho_w + \phi_a \rho_a + \phi_n \rho_n + \phi_s \rho_s$$

NAPLANAL Needs

FIELD

- Total concentrations for each component
- Volumetric water content
- Soil porosity
- f_{oc}

DATABASE

- K_{oc} for each component
- K_H for each component
- Molecular weight of each component
- Densities
  - Soil, water, air, NAPL

How to Sample

- Objective: Recover all the sediment and the interstitial fluids!
- Types of samplers
  - Solinst Cohesionless Sediment Sampler
    - Fine-grained soils
  - Split Spoon
    - Coarse-grained soils
  - CME Continuous Tube (wireline)
  - Cryogenic sampler (USGS)

Soil Sampling Methods

- Continuous sampling **throughout** the zone of interest:
  - Get samples from critical zones
  - But you can save $$ if you do not need upper zone sampled

Soil Sampling Methods (cont.)

Direct push

- Geoprobe® with plastic tube sample liners
- Advantage
  - Low cost if conditions are well suited
- Limitations
  - Depth and coarse-grained or resistant sediments

Soil Sampling Methods (cont.)

Things to avoid

- Wash rigs (lots of water flooding)
- Air rigs (lots of SVE)
- Miscommunication with the driller

How to Sample

Things to do (EPA Method 5035)

- Use in-the-field preservation (methanol)
  - "...volatilization losses can randomly reduce VOC concentrations by one to three orders of magnitude."
    Hewitt et al., 1995
- EnCore sampler

Soil Sampling Protocols

Procedure

- Prepare
- Core
- Sub-sample
- Screen (PID)
- Log
- Photograph
- Weigh and record

Preparation

- Get Amber jars, methanol, scale (2,000 gm)
- Permanent ID (methanol dissolves labels and ink!)
- Tare jars
- Fill jars (50 mL for coarse sediment)
- Weigh and record
- Don’t forget replicates and blanks!

Sample

- Fast!
- 2 parts methanol to 1 part soil (make a dummy)
- Don’t splash!
- Clean threads and tighten lids
- Put on ice
- Tighten lids

Ship

- Weigh and record
- Pack well and use adsorbent
- Label and ship properly
  - Flammable
  - Numbers
  - 24-hr phone

NAPLANAL Input

NAPLANAL Field	Example Input
• Sample name/ID	• LC34B10-15
• Vadose or saturated zone	• Saturated
• Porosity or water content	• Porosity ~ 30%
• f_{oc}	• f_{oc} = 0.001
• Number of NAPL components	• 4 components – *c*-DCE, PCE, TCE, *t*-DCE

NAPLANAL Input (cont.)

Target analytes expressed in the form: $\frac{mg_{contaminant}}{kg_{soil}}$

Sample	Depth ft bgs	c-DCE mg/kg	PCE mg/kg	TCE mg/kg	t-DCE mg/kg
LC34B10-01	21.0	0.08	0.69	1.42	0.0
LC34B10-02	22.5	2.38	0.06	154.54	0.03
LC34B10-03	23.5	3.4	0.01	316.05	0.06
LC34B10-04	24.5	1.97	0.0	242.034	0.03
LC34B10-05	25.5	2.33	0.0	361.96	0.04
LC34B10-06	26.5	1.74	0.0	156.29	0.03
LC34B10-07	27.5	2.3	0.0	330.47	0.02
LC34B10-08	28.5	1.93	0.0	260.35	0.01
LC34B10-09	29.5	1.79	0.0	292.48	
LC34B10-10	40.5	1.33	0.14	1976.7	0.02
LC34B10-11	41.5	0.62	0.00	324.16	
LC34B10-12	42.5	2.03	0.36	4473.12	0.02
LC34B10-13	43.5	0.44	0.0	332.07	
LC34B10-14	44.5	0.52	0.09	1058.94	
LC34B10-15	**45.6**	**4.89**	**0.28**	**12345.0**	**0.1**
LC34B10-16	46.0	1.27	0.01	1024.82	

NAPLANAL Solves

- In saturated zone, ϕ_a and $C_a = 0$
- User picks ϕ or ϕ_w as unknown
- In vadose zone, you need to know ϕ_w
- Water sample: porosity = 1.0

NAPLANAL Output

Sample Name Identification: LC34B10-15
Model used: Liquid saturated & porosity known
Porosity (Volume Frac.): 0.3
Fraction organic carbon (f_{oc}): 0.001

NAPLANAL ANALYSIS RESULTS:

Name	Total Mass (mg/kg)*	Mass in Water (mg/kg)*	Mass in Soil (mg/kg)*	Mass in NAPL (mg/kg)*	Conc. in Water (mg/L)	Sorbed in Soil (mg/kg)^	Conc. in NAPL (kg/L)	Mole Fraction in NAPL
c-DCE	4.89	0.4335	0.245	4.2115	3.3227	0.2858	0.0005	0.0005
PCE	0.28	0.0006	0.0014	0.2781	0.0043	0.0016	0	0.0000
TCE	12345	180.571	149.561	12014.9	1384.2	174.41	1.4594	0.9995
t-DCE	0.1	0.0059	0.0023	0.0918	0.0454	0.0027	0	0.0000

(mg/kg)* = mg per kg of soil sample (wet soil)
(mg/kg)^ = mg per kg of solid (dry soil)

Water Volume Frac. (L/L)	0.28219	Bulk Density (kg/L)	2.1632
NAPL Volume Frac. (L/L)	0.01781	NAPL Density (kg/L)	1.4599
Soil Volume Frac. (L/L)	0.7		
Porosity (Volume Frac.)	0.3	NAPL Saturation (%)	5.9364

Presence of DNAPL in Soil

- For OU 2, Hill AFB soil with:
  - f_{oc} = .0001
  - ϕ = 0.28
  - moisture content = .09
- TCE > 345 mg/kg
- TCA > 62 mg/kg
- PCE > 23 mg/kg

Other Soil Data

- Total VOC concentration
- Bulk density
- Soil f_{oc}: TOC - minus VOCs!
- Porosity
- Grain size
- XRD: Clay minerals
- Wettability
- Capillary desaturation

Characterizing Capillary Barriers

- Clay type (XRD)
- Entry pressure
  - Mercury intrusion
  - Centrifuge
  - Pressure cell
- Gamma logging contacts
- Cone penetrometer data

Any Questions?