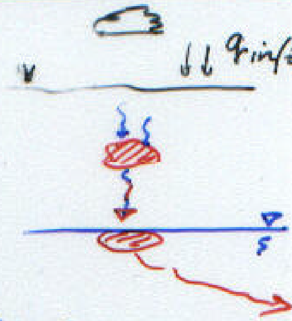
7.1.2 ADVECTION DUE TO INFILTRATION



① Assume steady vertical plug flow displacement

$$v_w^a = \frac{q_{inf}}{\theta_w}$$

q_{inf} = Infiltration amount
v_w^a = Advective velocity of water
θ_w = Volumetric moisture content

Resulting infiltration – advective flux

$$q_M = \underbrace{\theta_w v_w^a}_{\text{Darcy flux (velocity) } (q_w)} C_w$$

q_M = mass flux.

q_w = Darcy volumetric flux.

Note C_w max is solubility (aqueous).

Conservation of mass ⟹ Gaseous and Aqueous Transport
(Aqueous is carried by infiltration)

i.e. Net reduction of source volume by:

- Gaseous diffusion 
- Aqueous movement. 

$$R \frac{\partial c_g}{\partial t} = D_g^* \frac{\partial^2 c_g}{\partial x^2} - \underbrace{\frac{\theta_w}{\theta_g} \cdot \frac{1}{H}}_{} v_w^a \frac{\partial c_g}{\partial x}$$

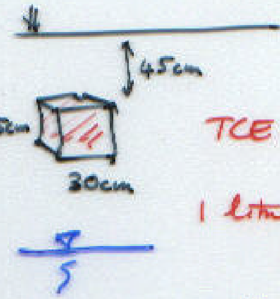
Partitioning of vapor into water – same as in R.

Neglects:

- Aqueous dispersion
- Gaseous advection.

Estimates of aqueous transport

e.g. Borden TCE experiment

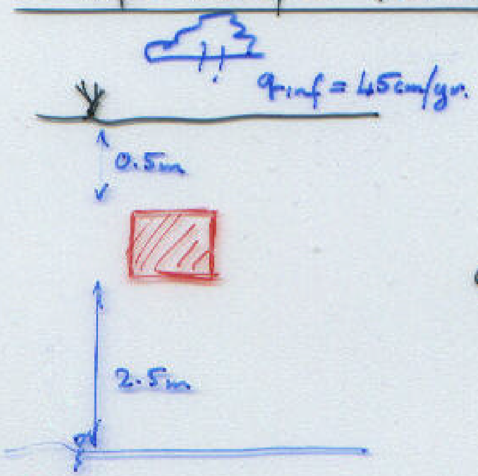


TCE @ residual sat.

1 litre of TCE over 45 x 30 cm area

~ 16 l/m³

No vapor transport (assume)



$\theta_w = 10\%$

Solubility, $S \equiv C_w = 1100$ mg/l

Questions?:

① How long to reach water table:

$$V_w^a = \frac{q_{inf}}{\theta_w} = \frac{.45\ m/yr}{.1} = 4.5\ m/yr$$

∴ 2.5 m travel ≃ ½ year.

(This ignores retardation).

② What loading from aqueous phase (i.e. q_M)

$$q_M = \theta_w V_w^a C_w = (0.1)(4.5)(1100\ mg/L)$$

Note 1 m/yr ≡ 1(m³/yr) per m²

$$q_M = 0.45\ m/yr\ (1100\ mg/L)$$

$.45\ m^3 = 450\ l$ ∴ $q_M = 450\ l \times 1100\ mg/l$

$\cong .5 \times 10^6\ mg$

$\simeq .5$ Kg/yr. per m²

Relatively small loading — removed from source.

LOADINGS MAY BE CHECKED USING MORE SOPHISTICATED MODEL

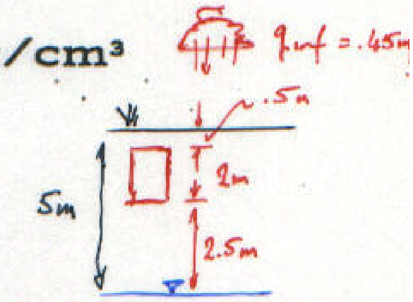
Transport Examples

porous medium:

very low sorption onto organic

θ_w = 10% f_{oc} = 0.01%

θ_s = 25% ρ_b = 1.65 g/cm³



q_{inf} = 45 cm/yr

depth to watertable 5 m

TCE @ 20°C:

D_g = 8.1 x 10^{-6} m²/sec   Gaseous diffusion coef.

H = 0.30

K_{oc} = 126 ml/g

P_v = 60 mm Hg (C_s = 7.9%)

S = 1100 mg/l

source:

height 2.0 m

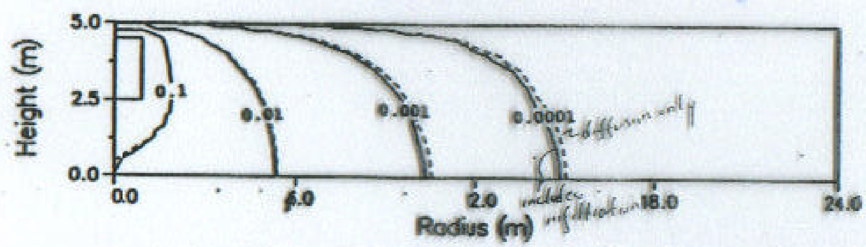
radius 1.0 m

depth to top 0.5 m

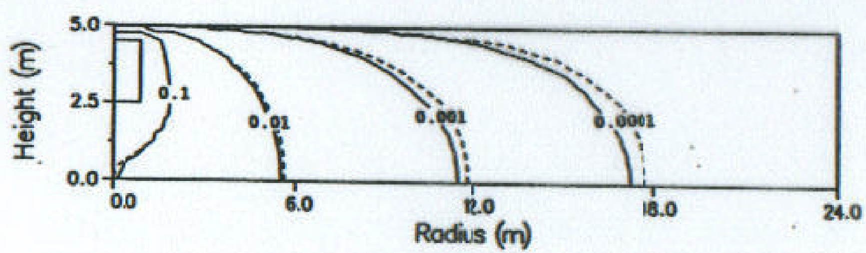
Gaseous and Aqueous Transport

Example

- uncovered ground surface
  - Passive remediation (good)
  - Infiltration to groundwater (bad)



5.75 kg to groundwater after 6 months

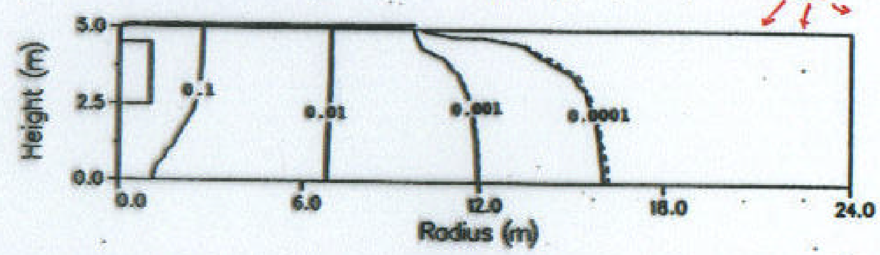


15.8 kg to groundwater after 1 year

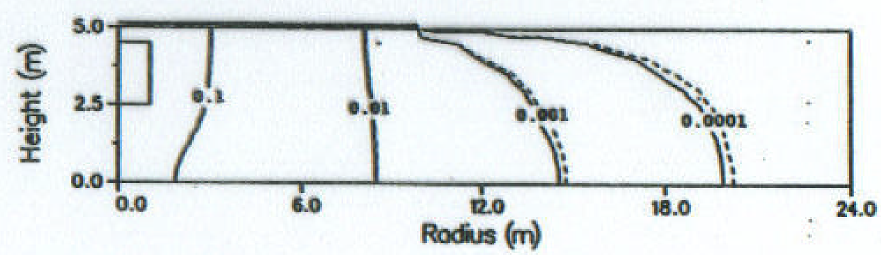
Gaseous and Aqueous Transport

Example

- covered ground surface ∴ No infiltration
  - Decreased passive remediation (bad?)
  - Decreased infiltration (good).



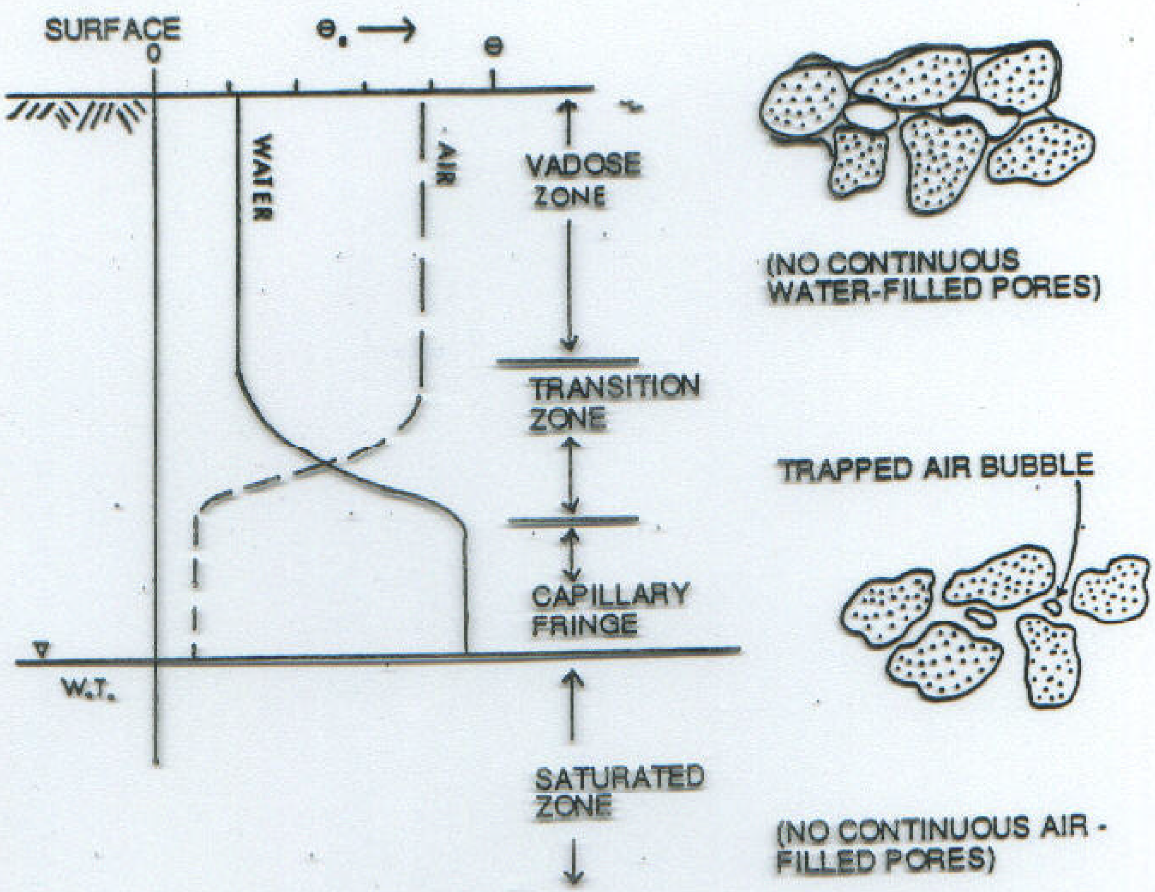
0.35 kg to groundwater after 6 months



2.95 kg to groundwater after 1 year

∧ INFILTRATION

Watertable (Capillary Fringe) Boundary



- very slow vapour transport in transition zone
- top of fringe impermeable to vapours

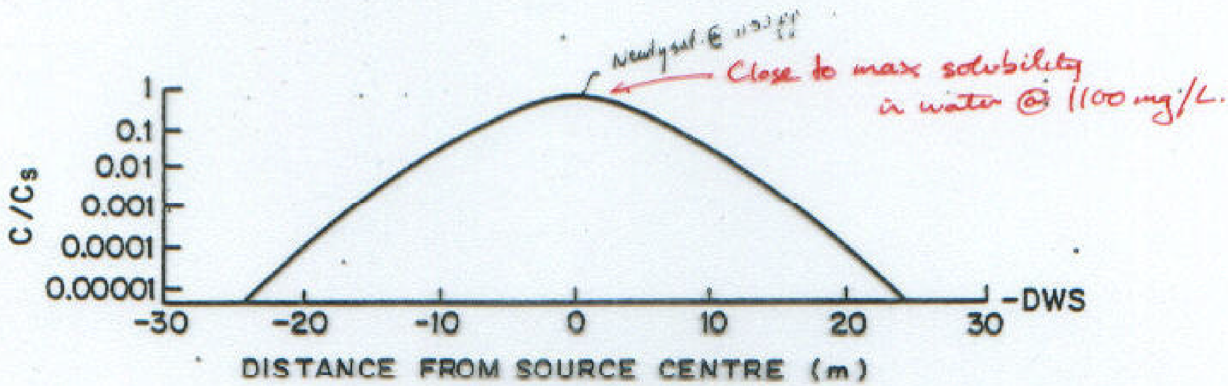
but, contaminants partition to water

Watertable Fluctuation

- contaminated soil moisture placed in saturated zone

- consider diffusive transport example

watertable concentration profile
(covered; after 6 months)



- a 50 cm rise in watertable elevation

→ 3.3 kg TCE placed in groundwater

This is an order of magnitude increase
in water table loading - from 0.35 kg.