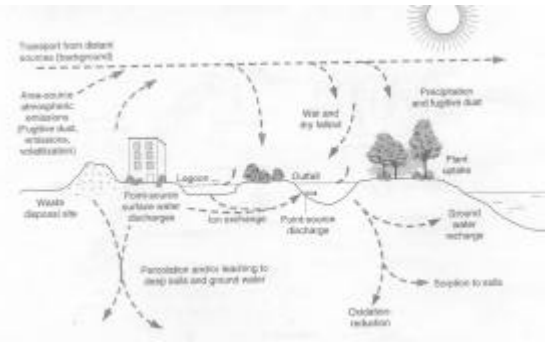
CVEN 4474/5474 Haz Waste Outline

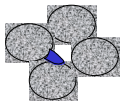
- Contaminant fate and transport
  - Soil and aquifer properties
  - Air dispersion

Contaminants can distribute through all phases in the environment:

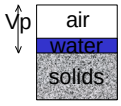
•Soil [including solids, pore water, pore air]
•Groundwater [including aquifer solids]
•Surface water [including sediments]
•Air [below grade; bulk atmosphere; global cycling]
•Biota [bioaccumulation; surface sorption]



Soil Properties



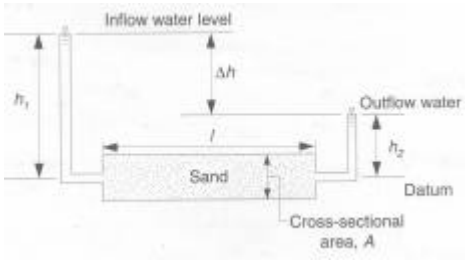
- Porosity
  - η = volume pores / volume total;
  - usually 0.25-0.50
- Saturation, s = vol w / vol pores = 0 - 1
- Solids Density = $\rho_s = Mass_s / Vol_s$
  ρ_s ~ 2.3-2.6 g/mL
- Bulk Density = $\rho_b = Mass_s / Vol_{total}$
  $\rho_b = Mass_s / V_s + V_w + V_a$
  $\rho_b = (1 - \eta)\ \rho_s < \rho_s$
- Permeability = k = cm^2



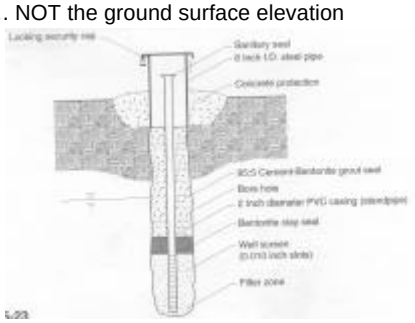
Fate and Transport of Contaminants in Groundwater

- Darcy's Law: Q = K i A
  Hydraulic gradient = i = dh/dl
  - dh = change in head in the direction of gw flow
  - dl = distance in direction of GW flow

  Hydraulic conductivity = K (cm/s)
  – Function of aquifer material AND fluid
  – Don't confuse with k
  – Interrelated: $K = k \rho g / \mu$
    - ρ = flowing fluid density; water ~ 1 g/cm^3
    - g = acceleration due to gravity ~ 9.81 m/s^2
    - μ = dynamic viscosity of fluid ~ 0.01 g/cm s
    - ρ and μ change with temp & pressure; g with elev.



Use free water rise level in well to measure head, h
Determine dh relative to a uniform datum [sea level]
…. NOT the ground surface elevation



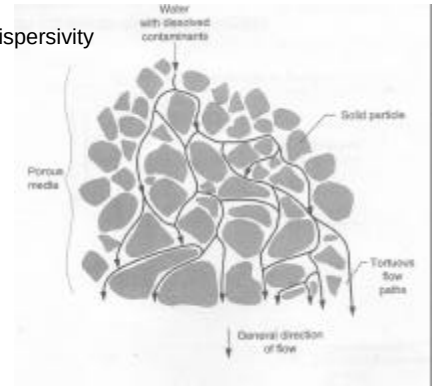
Fate and Transport of Contaminants in Groundwater

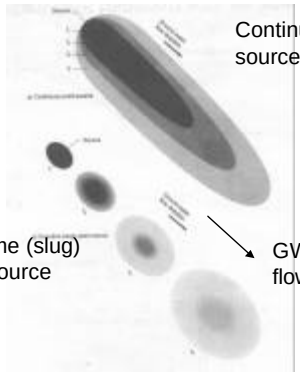
- Ave. Linear GW velocity = v = Q/A η_e
  - V = K i / η_e
  - η_e = effective porosity [contributes to flow]
- Contaminant movement
  - Dissolved organics will be retarded (move slower) than groundwater
  - Retardation Factor, R = ave v_{gw}/ave v_{contam} =
  - R = 1 + (ρ_b K_p/η) ~ 1 + (ρ_b f_{oc} K_{oc}/η)
  - R $\geq$ 1

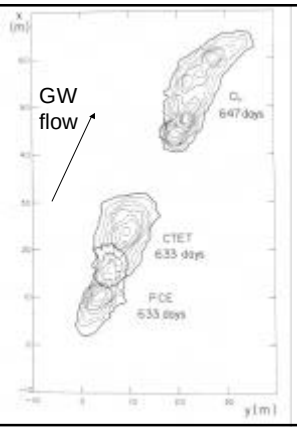
Contaminant Mvmt in Groundwater

- Retardation factor assumes linear sorption/desorption (may not be true)
- PLUME = extent of contaminant in groundwater, and is controlled by:
  - Advection with the groundwater flow
  - Diffusion (radial to achieve equal concentration; smaller cmpds larger diffusion; D)
  - Dispersion - spread due to tortuous flow around soil particles
    - Dispersivity = α (cm)
    - $\alpha_x > \alpha_y \geq \alpha_z$ results in non-spherical plumes
    - $\alpha_x \sim 10\ \alpha_y$

Dispersivity







Potential Transformation Processes in the Subsurface

- Biodegradation - bacteria transform contaminants
- Redox reactions transform contaminants - such as Cr+6 to Cr+3
- Humification - compound incorporated into humic structure of the soil
- Phytoremediation - plants uptake and/or transform contaminants

Example of contaminant movement

- If three contaminants leaked out of a landfill over 30 years at concentrations equal to 1% of their water solubility, estimate the plume location, size and concentrations of each contaminant today assuming that the average linear GW velocity is 10 m/yr.
  - Benzene, TCE, Cl-