Handout for Chapter 5 Water pollution—Part II Ground water

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What you have to know after this course:

- Define Stratification Effect、BOD、COD…..
- Understand common pollutants in water
- Estimate BOD values
- Derive the oxygen sag curve
- Darcy's law
- Three major controlling processes for contaminant transport in groundwater
- Groundwater equilibrium equations
- Remediation technologies （Introduction）

※Reading materials: (Parts of homework assignments)

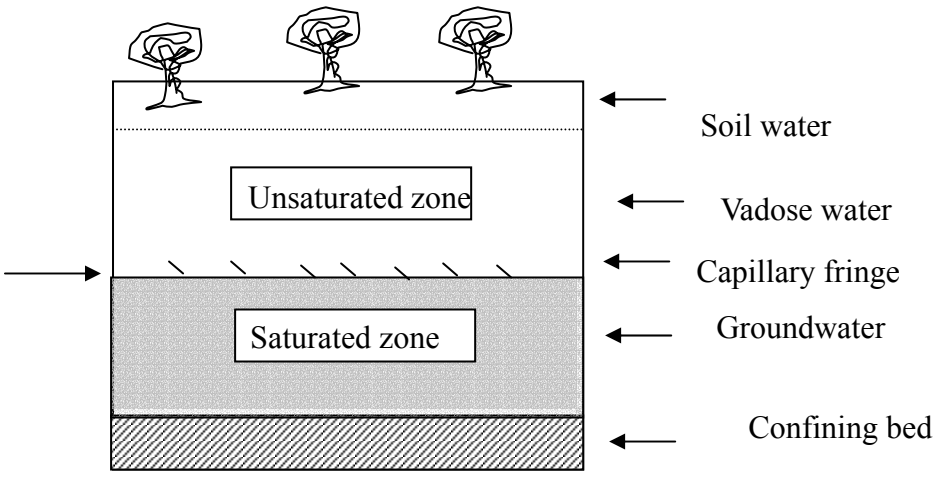
Chapter 5 section 5.7 Page 207-220.

※Homework assignment #3

※5.5, 5.18, 5.27, 5.35, modified 5.41

※modified 5.41: (c) Assuming a retardation factor of 2, how long would it take to travel a distance of 1000m?

1. Identification of subsurface regions (Unconfined aquifer)



Aquifer (含水層)：a saturated geologic layer that is permeable enough to allow water to flow fairly easily through it.

Confined aquifer

Unconfined aquifer

2. Porosity（_____）

$$\eta = \frac{\text{Volume of voids}}{\text{Total volume of solids and voids}}$$

Specific yield (effective porosity)：The volume of water that can actually be drained from an unconfined aquifer per unit of area per unit decline in water table

3. Hydraulic gradient

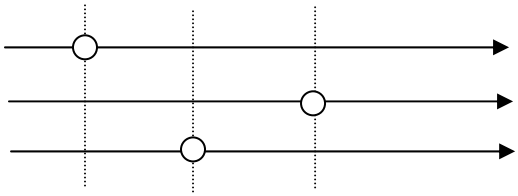
Hydraulic head（_____）

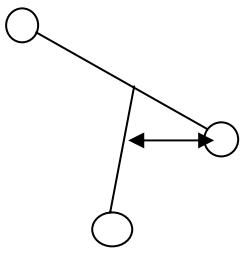
$$\text{Hydraulic gradient} = \frac{\text{Change in head}}{\text{Horizontal distance}} = \text{-----}$$

Equipotential lines

Stream lines

How to determine the groundwater flow?





4. Darcy's law（_____）

$Q = KA(dh/dL)$

v （Darcy velocity）= K dh/dL

v' （Average linear velocity, seepage velocity）=Darcy velocity /porosity

5. Equilibrium formula for unconfined aquifer.

Assumptions:

i. Pumping has been steady for a long enough time (_____)

ii. The original water table is _horizontal _____.

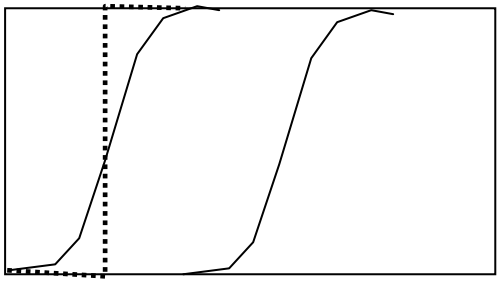
iii. The flow to the well is _____ horizontal ___and ____radical____.

Q = K2πrh*dh/dr

6. Contaminant transport: Diffusion, Dispersion, Retardation

Transport in the environment (General form):

$$\frac{\partial C}{\partial t} = -v\frac{\partial C}{\partial x} - R\frac{\partial C}{\partial x} + D\frac{\partial^2 C}{\partial x^2} - kC \pm S_d$$



Diffusion term:

Dispersion term:

Retardation term:

Decay term:

Diffusion: (Fick's law): the rate of mass transport by diffusion across an element of area is proportional to the concentration gradient of the diffusing sbustrance.

Retardation:

Cause by _____

Retardation factor:

$$R = \text{----------} = \left(1 + K_{ad}\frac{\rho_b}{\eta}\right) \geq 1 \quad \text{（dimensionless）}$$

ρ_b = bulk density of the porous medium.

7. Remediation technologies

i. Targets: heavy metals, NAPLs （nonaqueous-phase liquids）, DNAPLs, LNAPLs

ii. Bioremediation vs. physiochemical processes

In situ vs *ex situ* and on site

iii. Examples: pump-and treat, Soil vapor extraction (SVH), Bioventing (air sparging), *in situ* bioremediation, Permeable reactive barriers (PRBs), Solvent flushing, chemical injection (e.g., $KMnO_4$).