Reactive Membrane Barriers for Containment of Subsurface Contamination

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Build a Better Barrier

- Waste containment
- Diffusion through polymer membrane can be significant
- Incorporation of reactive material will delay contaminant breakthrough

Objectives

- Test polyvinyl alcohol membranes with iron metal and crystalline silicotitanate particles
  - Fe(0) reduces metals, chlorinated solvents
  - CST is selective for Cs^+
  - PVA gives short experiments, rapid assays

Objectives, cont'd

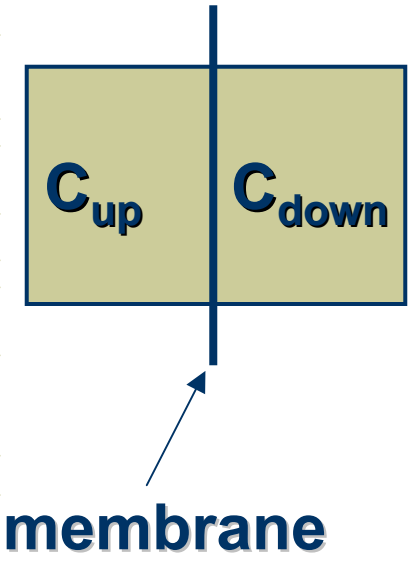
- Test polyethylene membranes with iron metal and crystalline silicotitanate particles
  - HDPE used for geomembranes
- Test effect of groundwater chemistry
- Develop numerical model

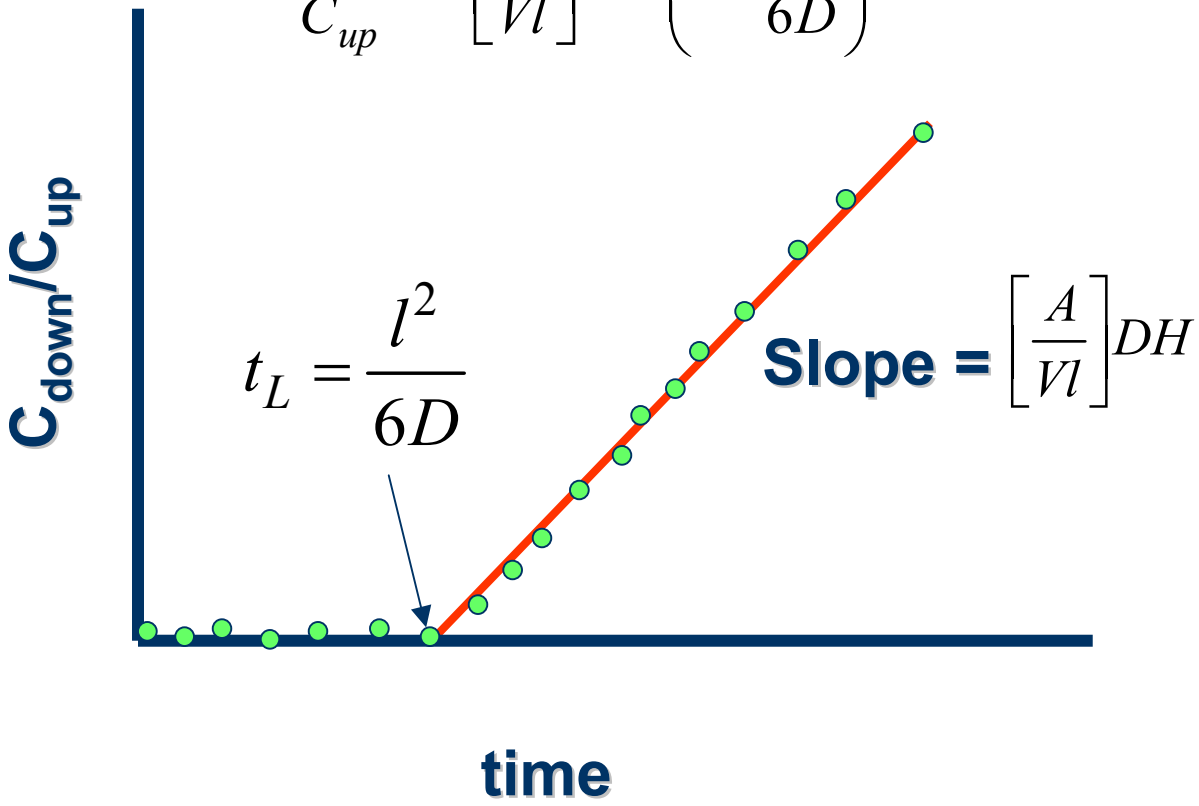
Applicability to DOE

- Fe(0) containing membranes
  - Hanford-Prevent vadose zone transport of CCl_4; barrier for CrO_4^{2-} to protect Columbia River
  - Savannah River-Isolation of PCE/TCE hot spots
- CST containing membranes
  - Isolation of ^{137}Cs and ^{90}Sr

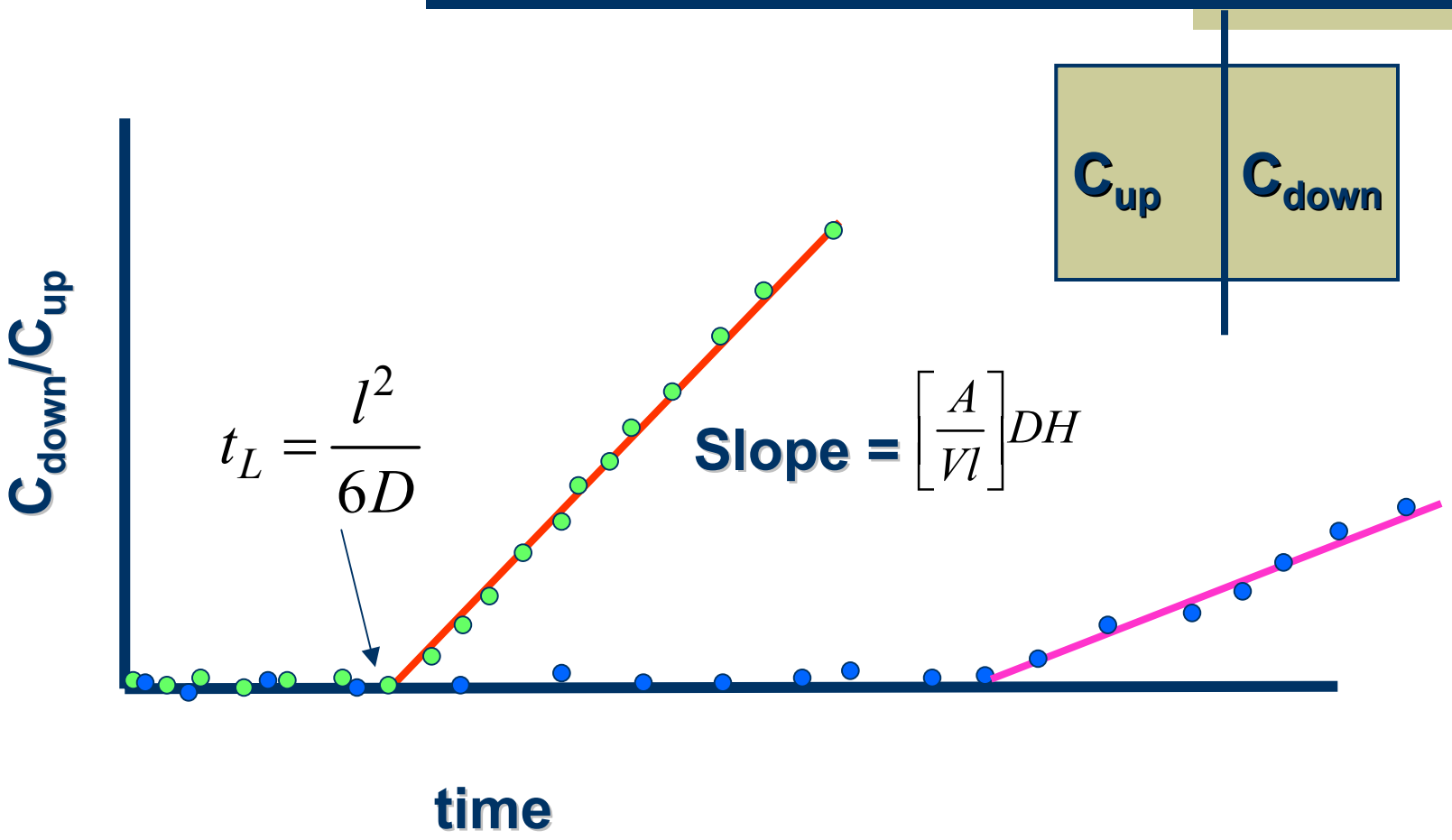
Theory

$$\frac{C_{down}}{C_{up}} = \left[\frac{A}{Vl}\right] DH\left(t - \frac{l^2}{6D}\right)$$



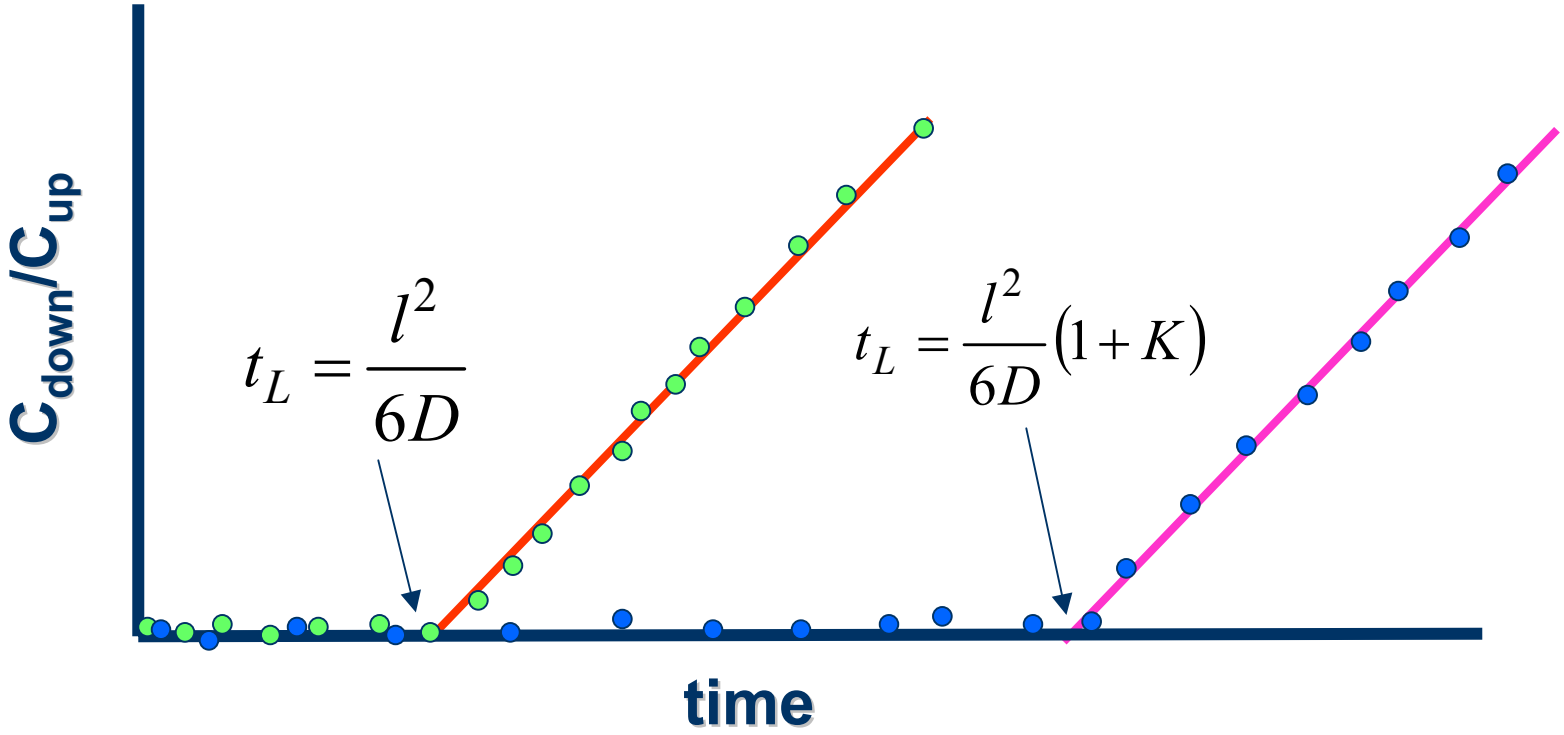


Improved performance



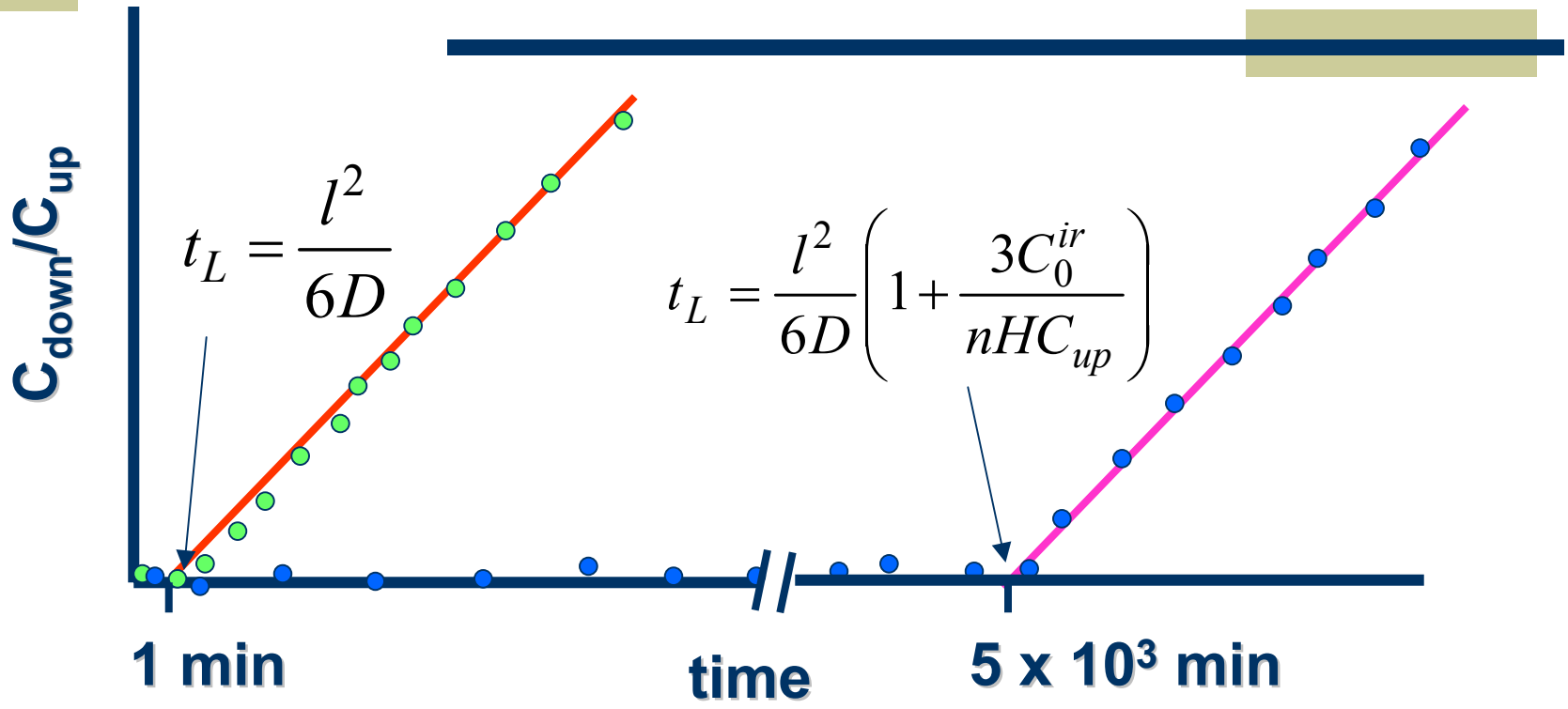
Sorption

- Instantaneous, reversible reaction



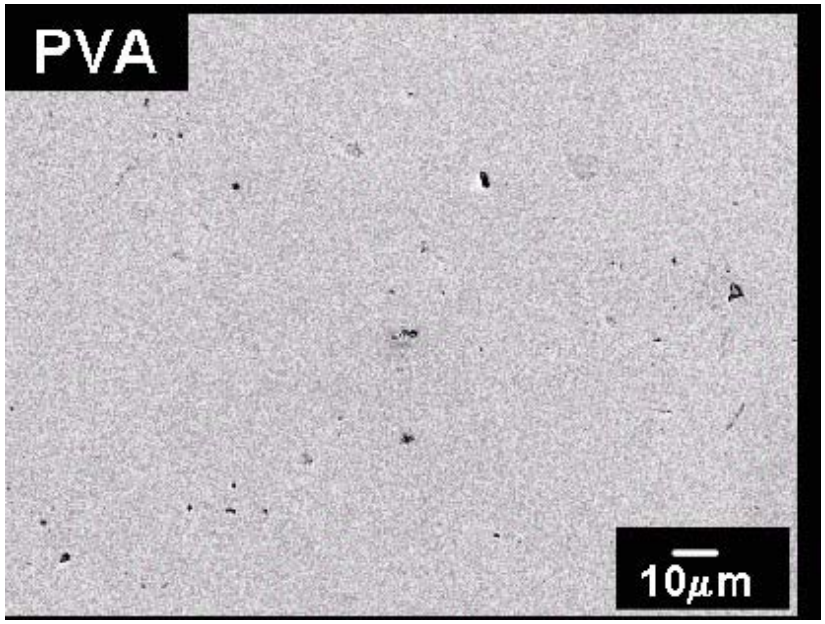
- Paul (1969); Paul and Koros (1976)

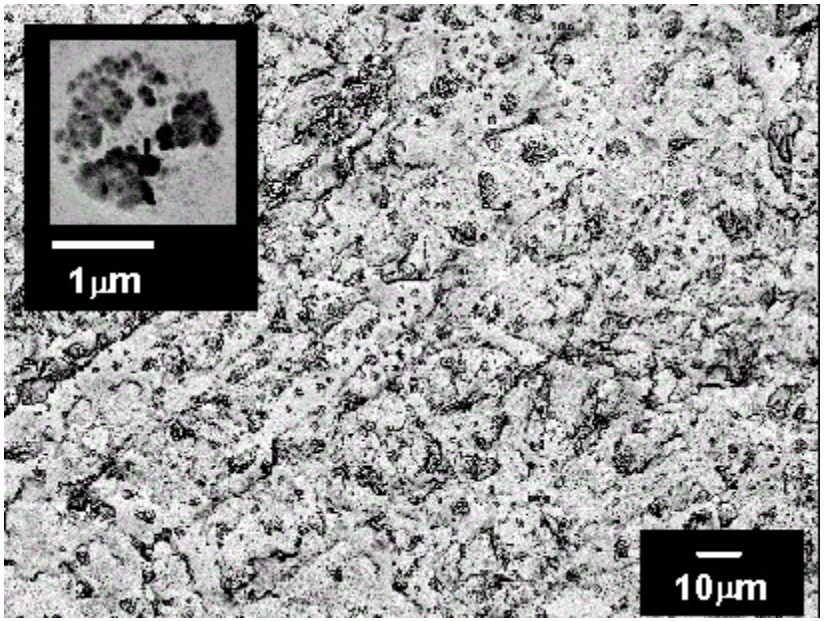
Immobilized Reagent



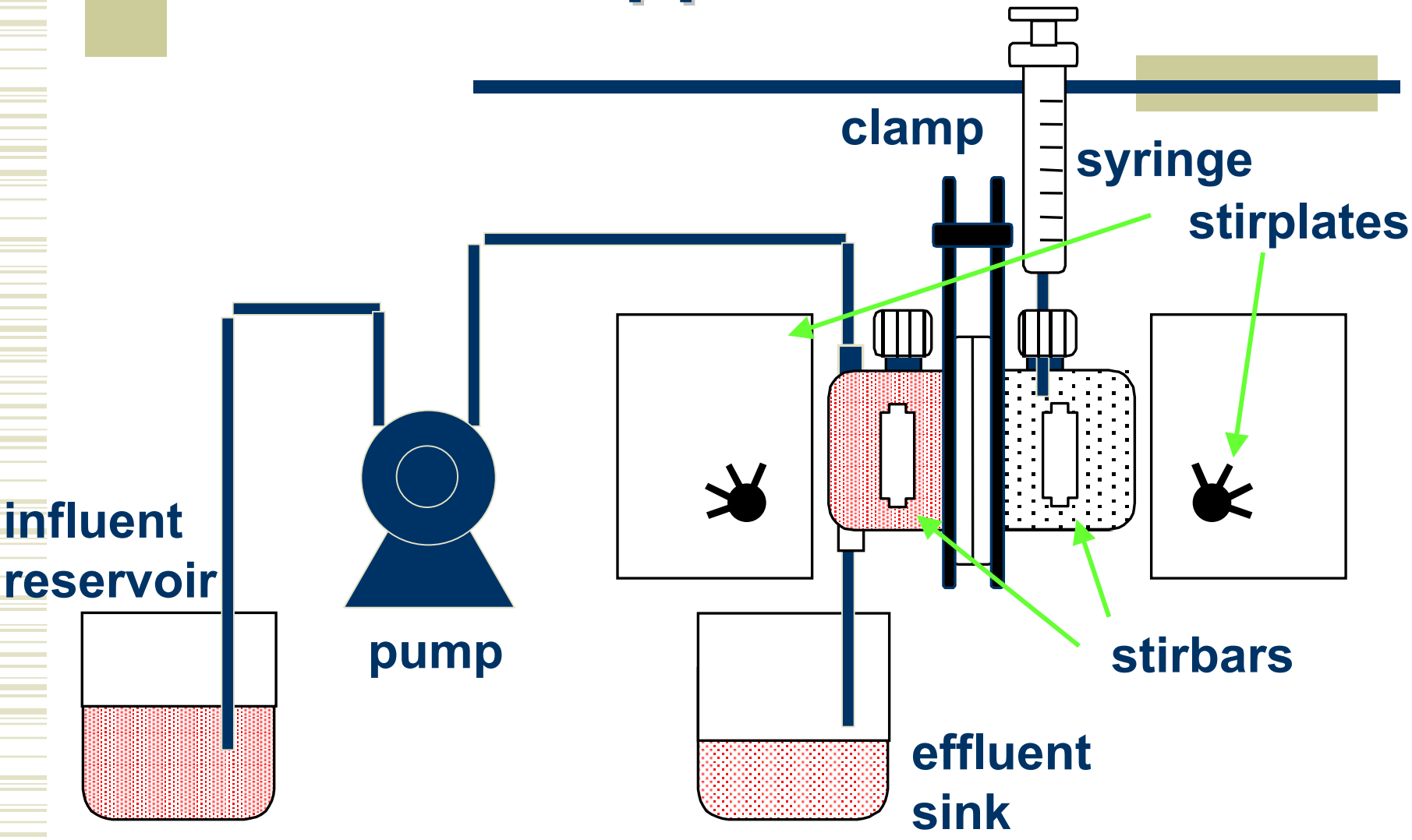
- Predicted CCl_4 diffusion for PVA and Fe(0)/PVA
- Instantaneous, second order with finite immobilized reagent (Yang et al. 2001)

Fe(0)-PVA membranes

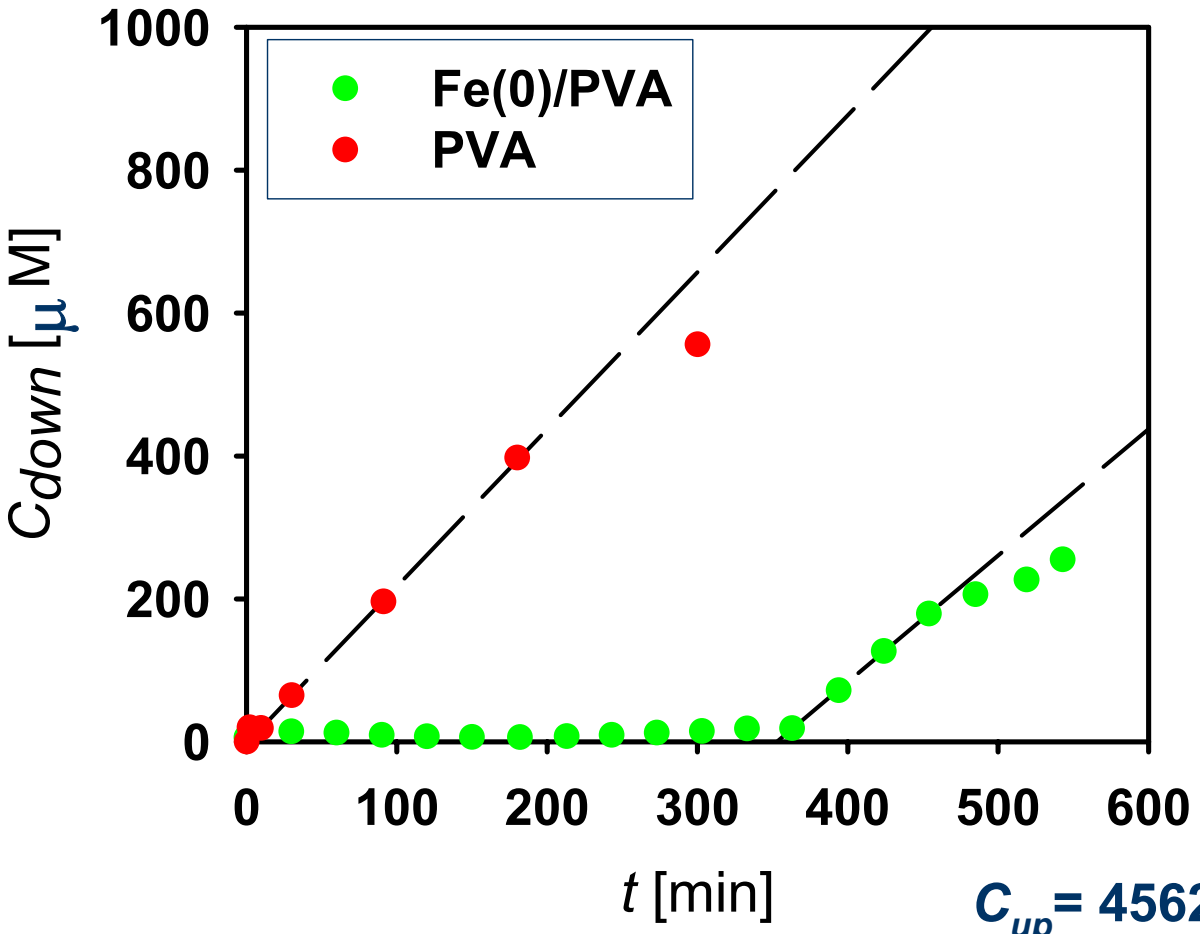




Apparatus


clamp
syringe
stirplates
influent
reservoir
pump
stirbars
effluent
sink

Carbon Tetrachloride



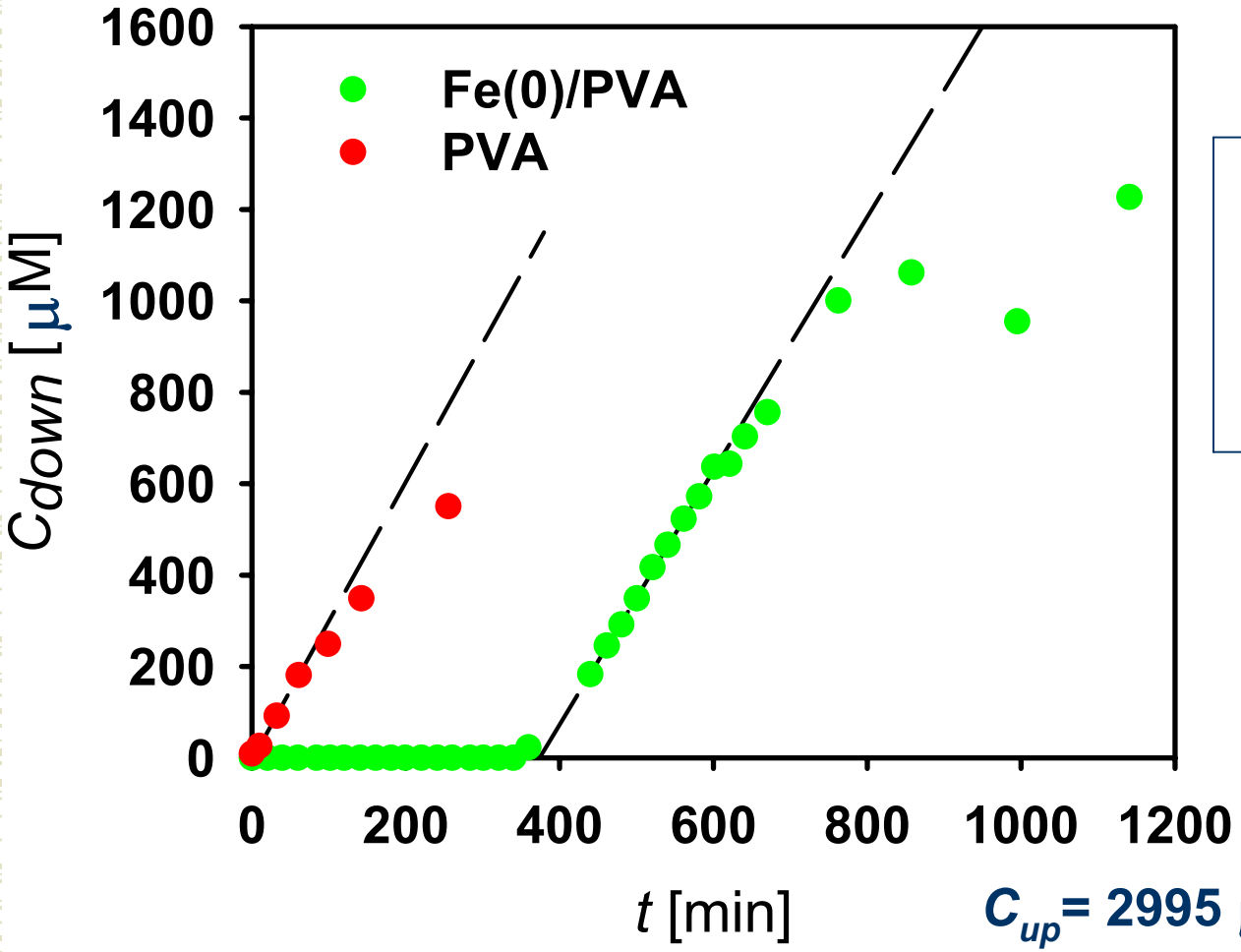
t_{lag}

PVA: 1.2 min

Fe(0)/PVA: 353 min

C_{up} = 4562 μM, L = 212 μm

Copper



t_{lag}

PVA: 1.8 min

Fe(0)/PVA: 374 min

C_{up}= 2995 μM, L = 102 μm

Lag Time Prediction

$$t_{lag} = \frac{L^2}{2nP}\frac{C_{Fe}}{C_{up}}$$

Assumptions

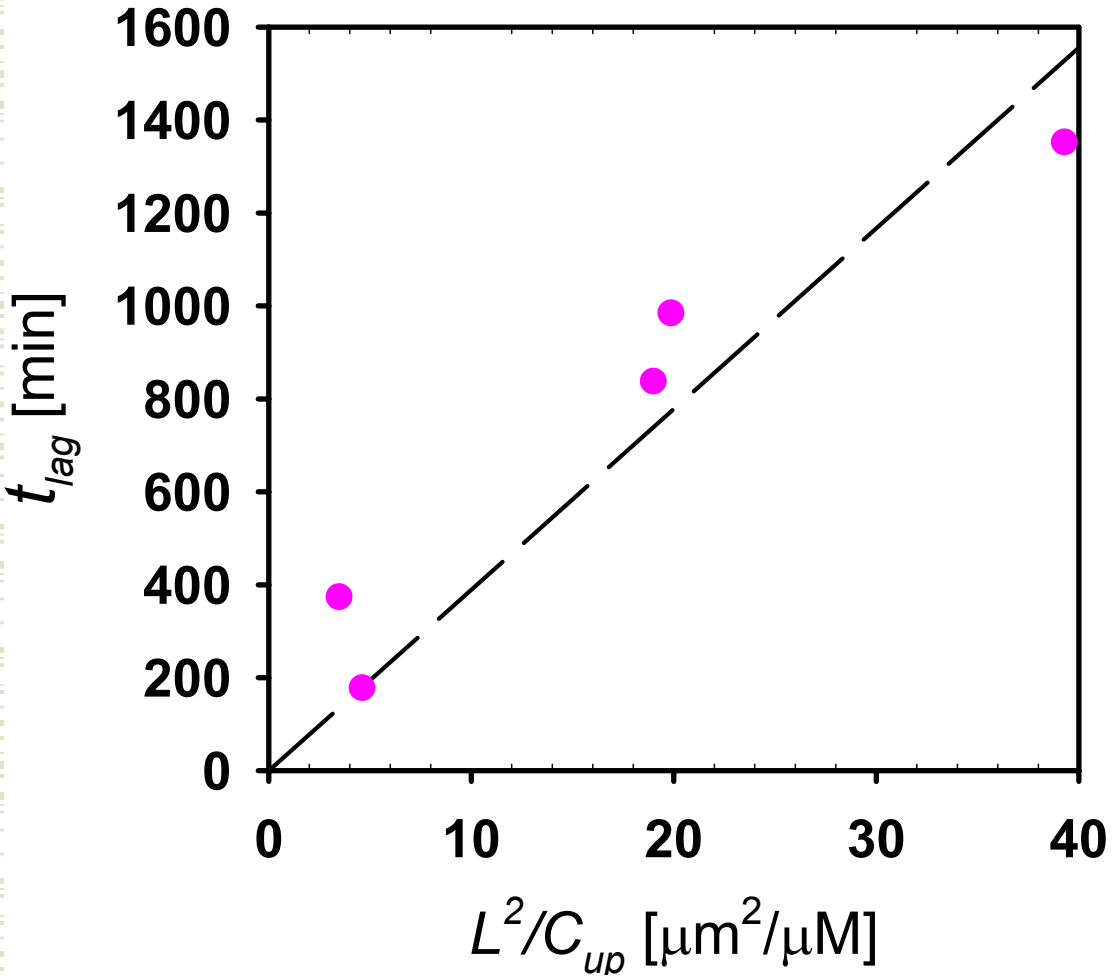
- **Irreversible, infinitely fast reaction**
- **n = 1 for both reactions i.e. Fe(0) → Fe^{2+}** { **CT → CF**; **Cu^{2+} → Cu**

predicted t_{lag}

Carbon tetrachloride : 4590 minutes

Cu^{2+} : 1619 minutes

Effective Iron Concentration



$$t_{lag} = \frac{C_{Fe}}{2nP}\,\frac{L^2}{C_{up}}$$

C_{Fe}

Synthesis : 1.0 M

From slope : 0.21 M

Only 20% of Fe(0) is used

Future Directions

- CST containing membranes
- Addition of flakes
- HDPE membranes
- Test performance with groundwater
- Numerical modeling

Interactions with DOE

- Groundwater samples from DOE sites
- Permeable membrane barrier group at INEEL