Evaluation of Activated Carbon for Environmental Remediation Applications

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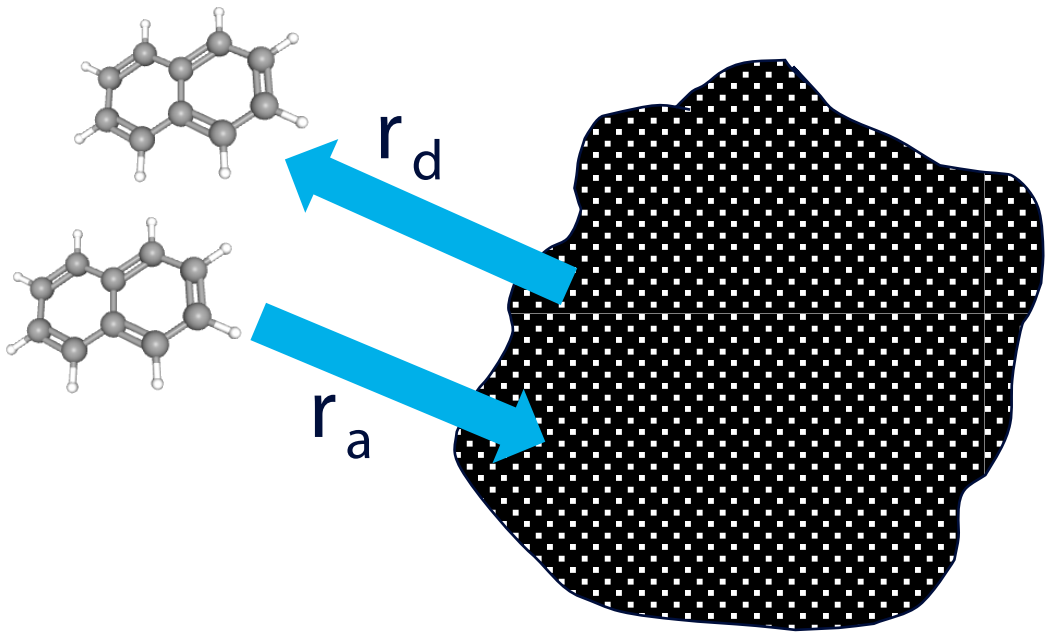
Outline

1. Adsorption equilibrium
2. Adsorption kinetics
3. Significance of kinetics on cap designs
4. Demonstration test: impact of carbon particle size on adsorption

Adsorption Equilibrium and Kinetics



Transient (unsteady state): $r_a \neq r_d$

Equilibrium (steady state): $r_a = r_d$

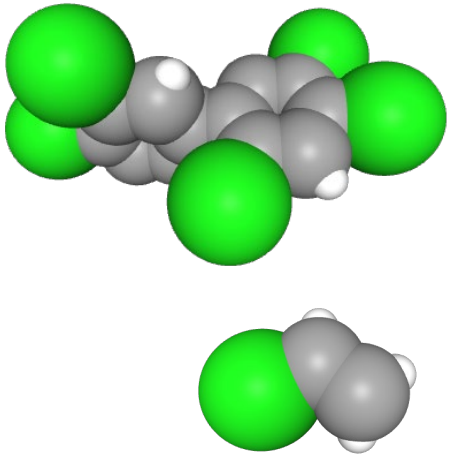
Equilibrium Loading Capacity → Carbon Consumption

Kinetics ⇢ Carbon Consumption

Factors Affecting Equilibrium Loading Capacity

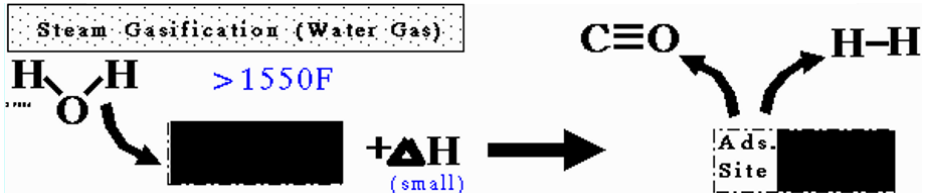
Adsorbate

- Concentration
- Solubility
- Molar Volume
- Polarizability
- (Background Organics)



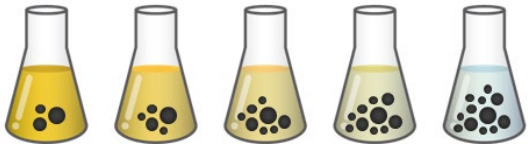
Adsorbent

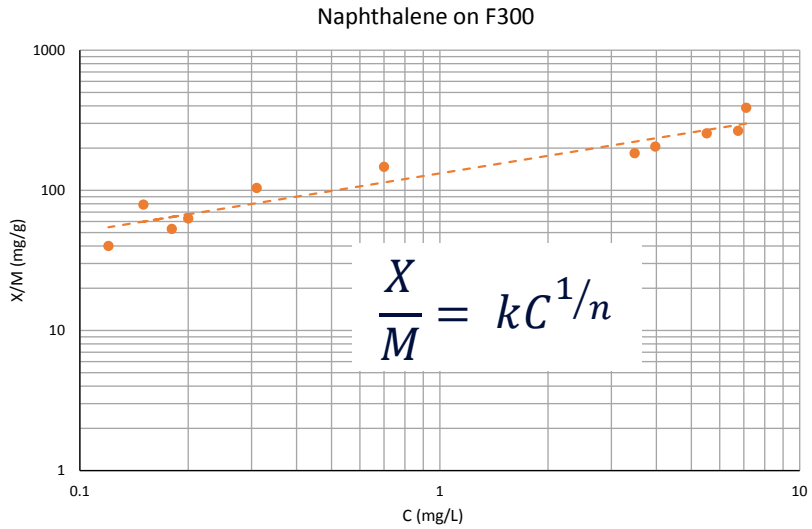
- Base Material
- Degree of Activation



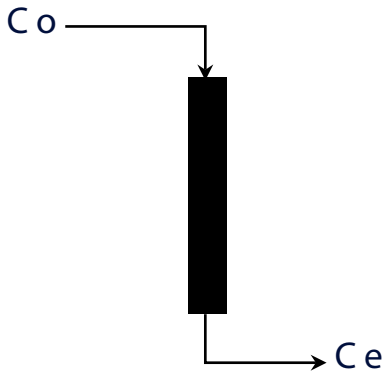
Evaluating Equilibrium Loading Capacity

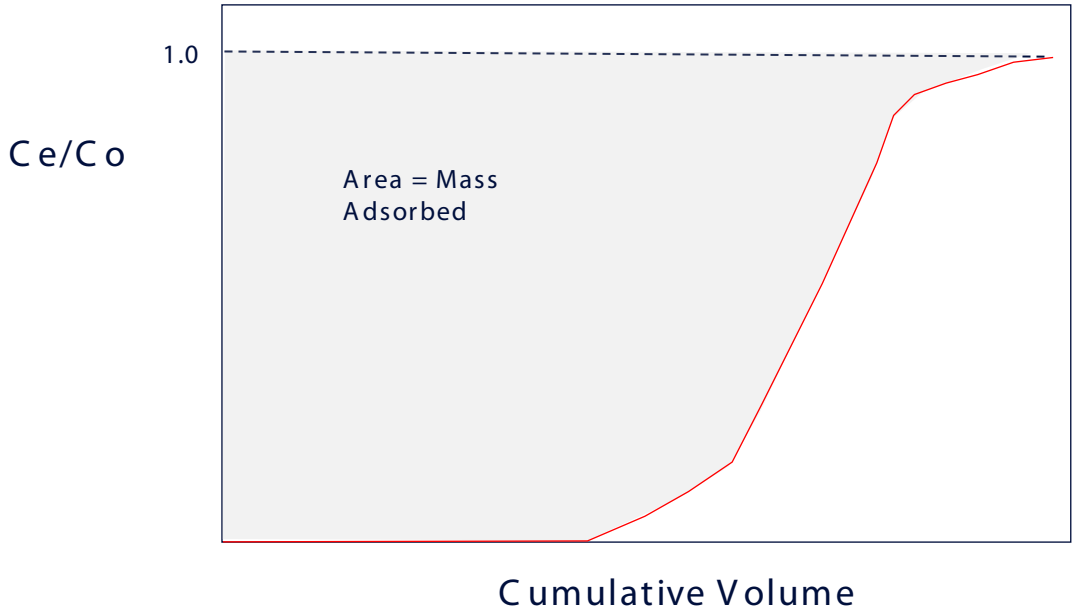
Isotherm (ASTM D 3860)



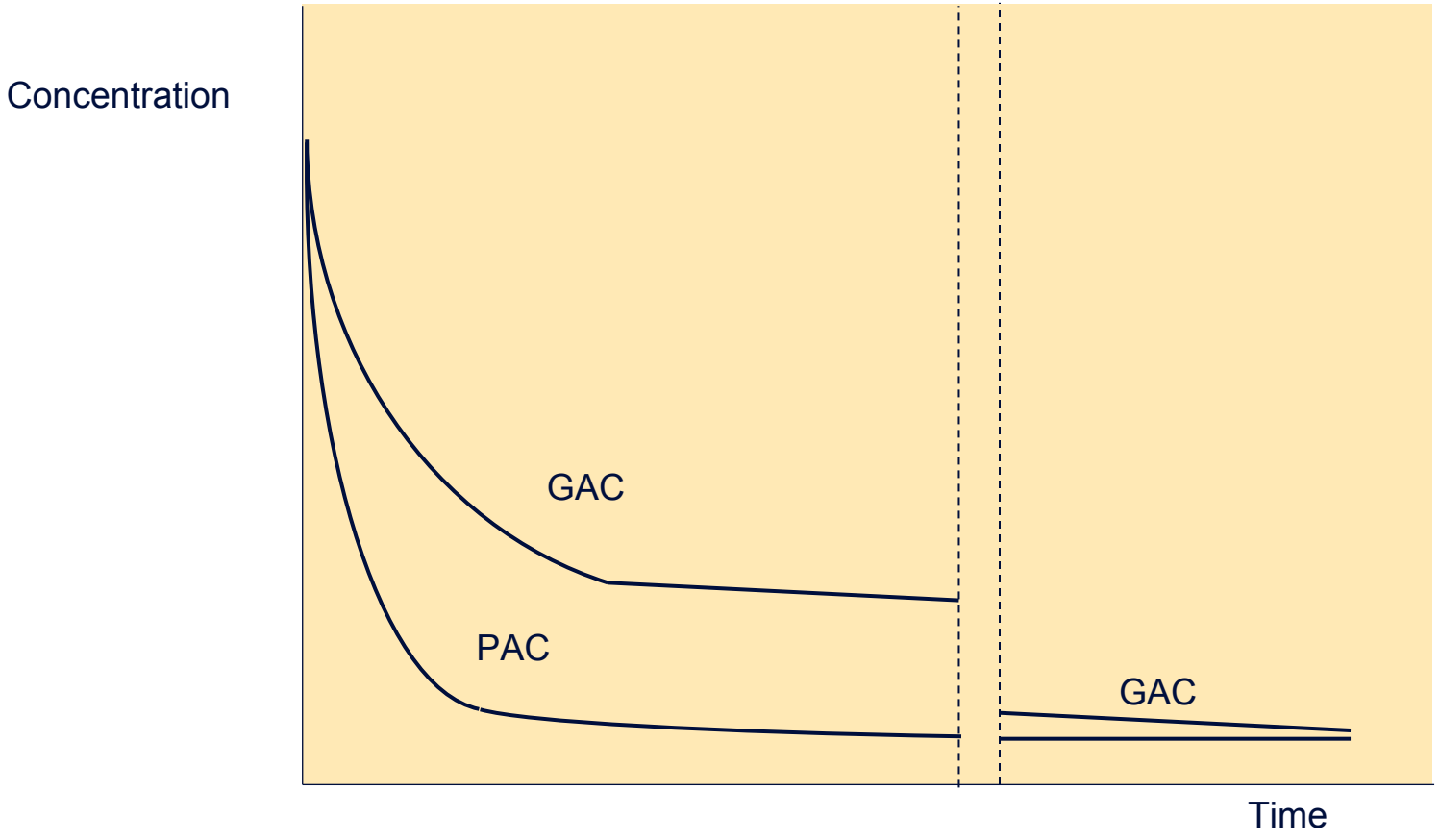


Column Test





Evaluating Equilibrium Loading: Common Pitfall

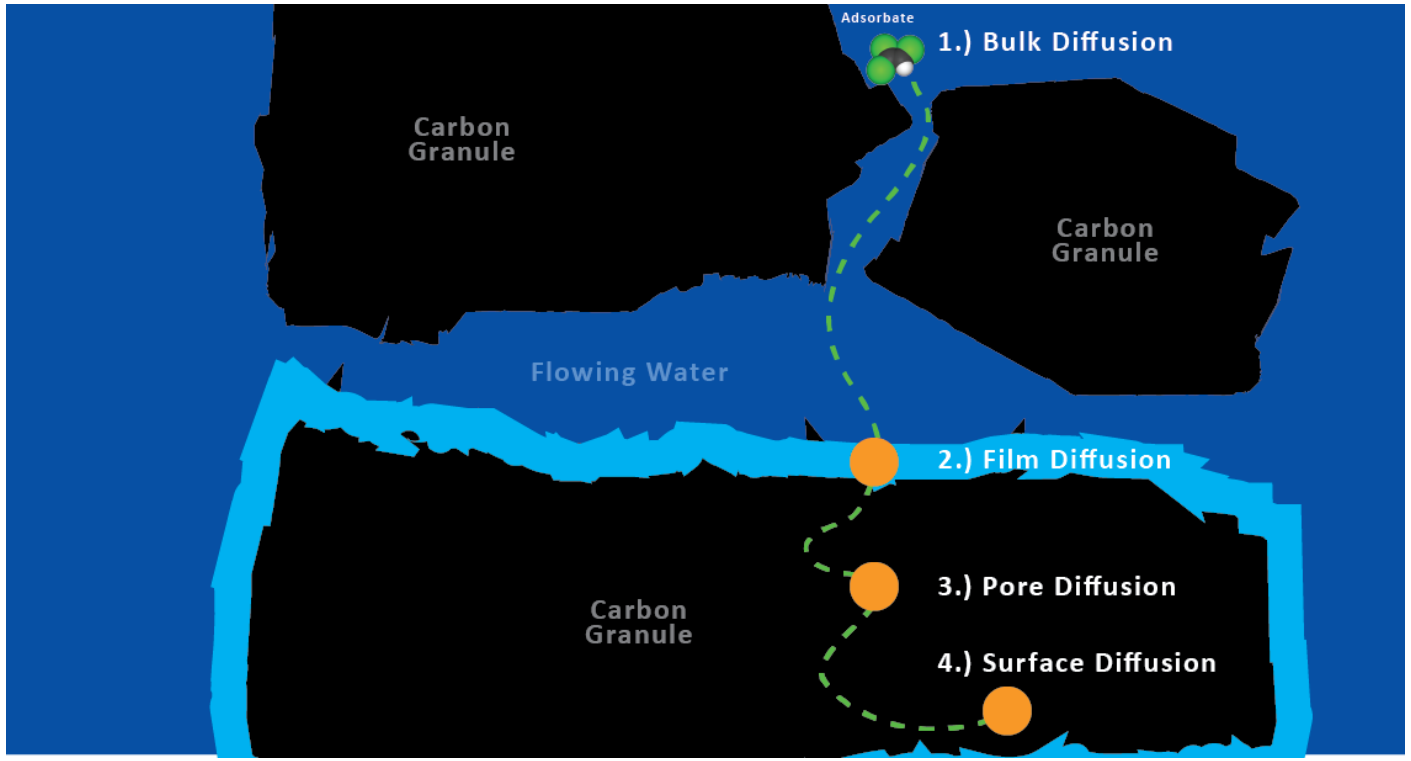


Peel et al. 1980; Randtke et al. 1983

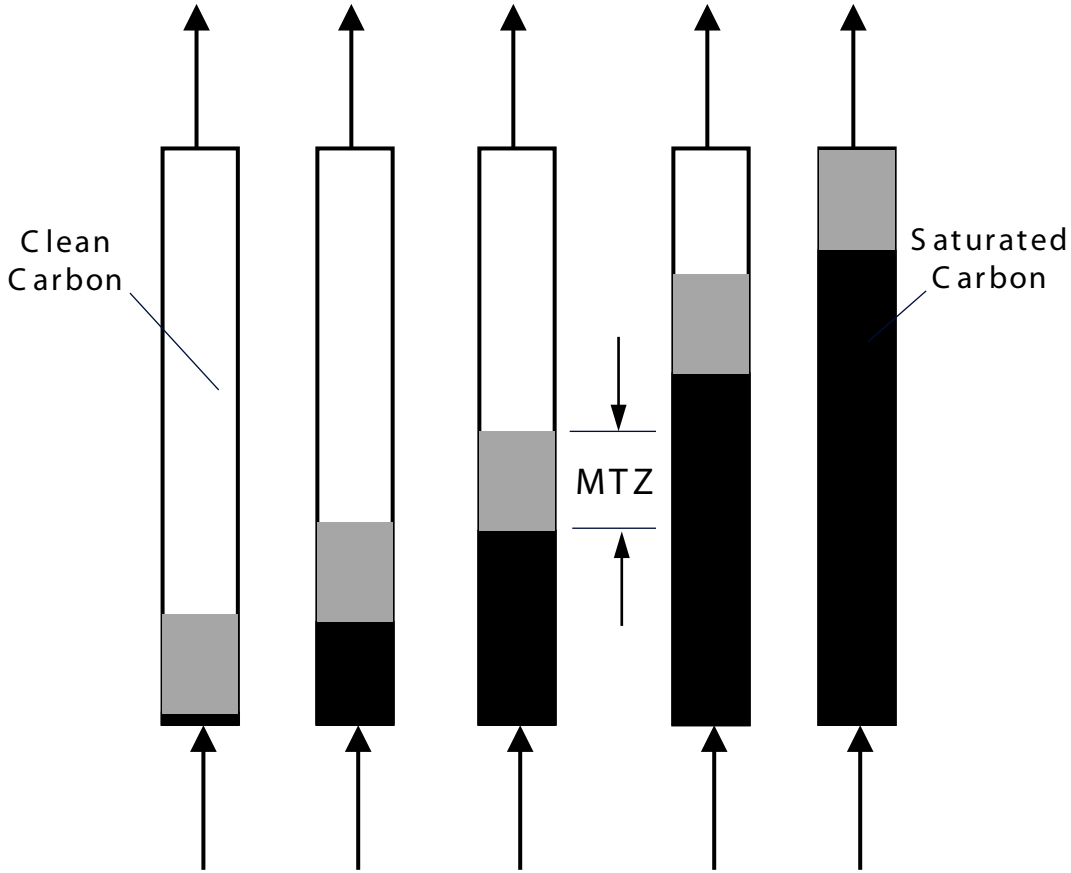
- Not waiting long enough to approach equilibrium
- Not pulverizing the carbon (e.g., 95% -325 mesh)

Kinetics

Diffusion Processes



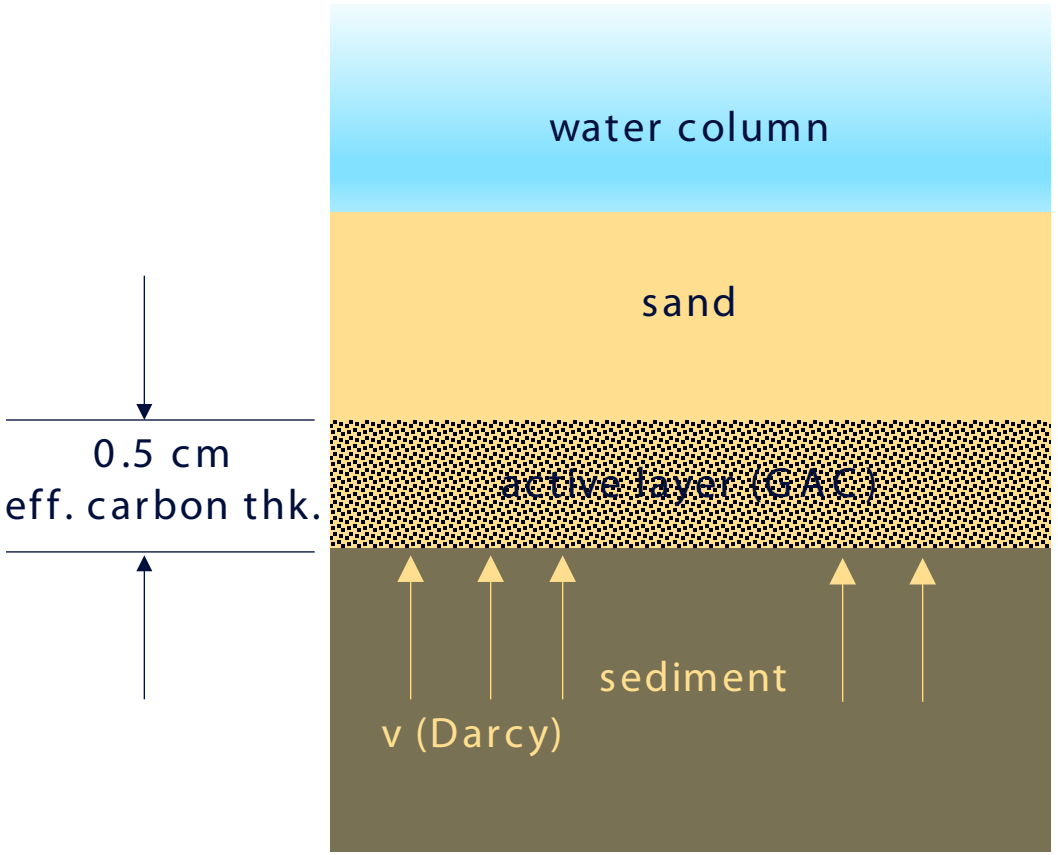
Mass Transfer Zone (MTZ)

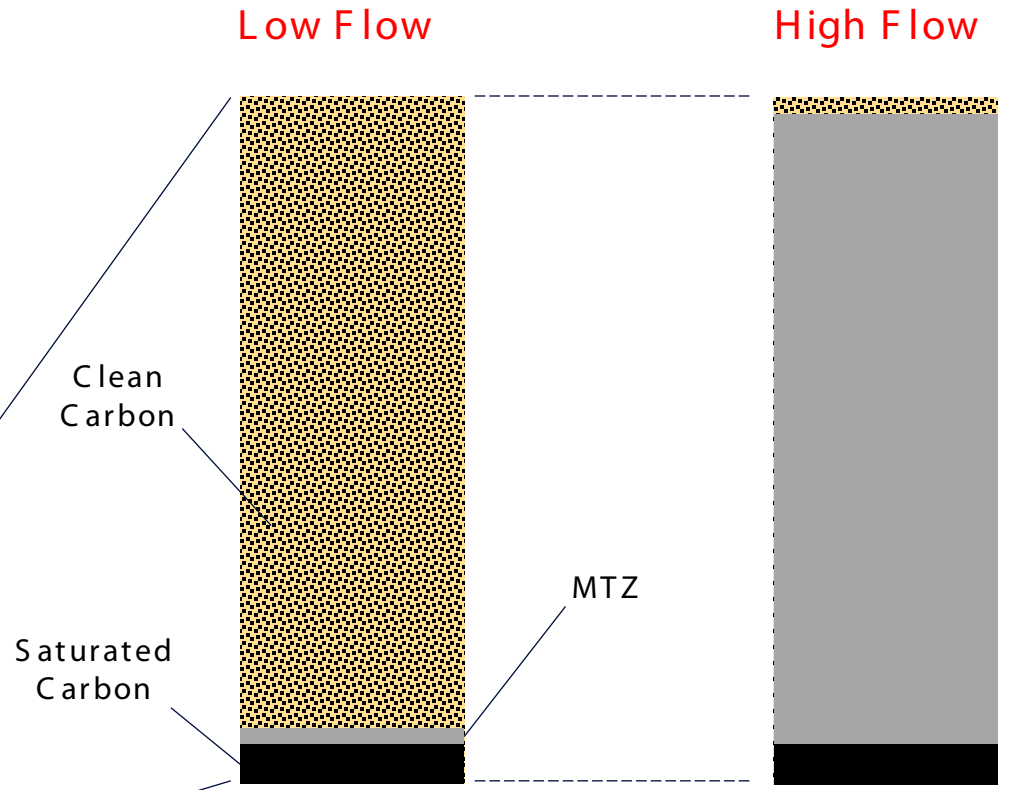


Characteristics That Increase the Rate of Adsorption

- ↓ Carbon Particle Size (most important)
- ↑ Contaminant Diffusivity (Ficks's Law: $J = -D\frac{dC}{dx}$)
- ↑ Water Temperature (↓ Viscosity)
- ↑ Transport Pore Volume (between 1,000 and 100,000 Å, when bulk diffusion through large pores is limiting)

Significance of Kinetics in Cap Designs

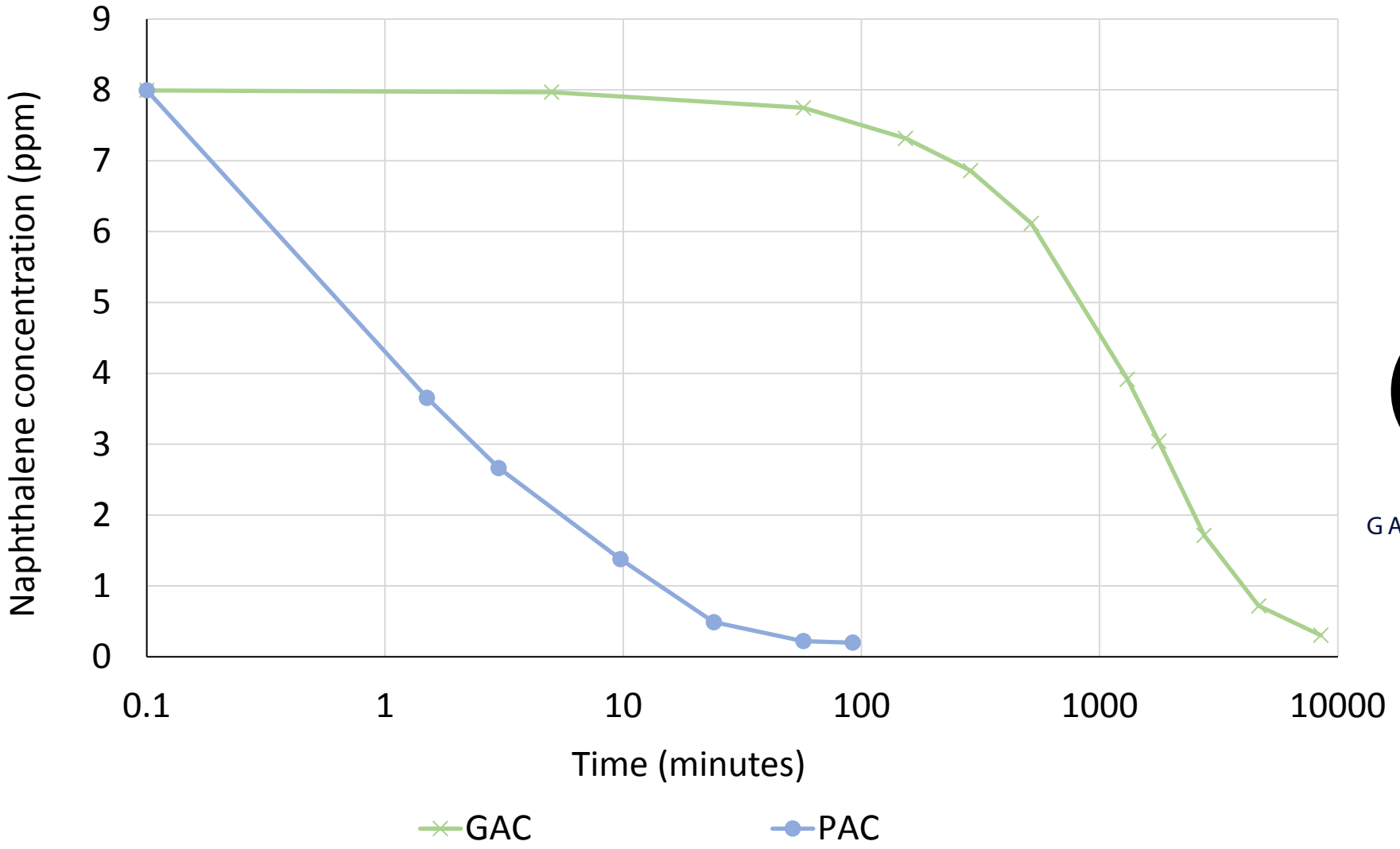




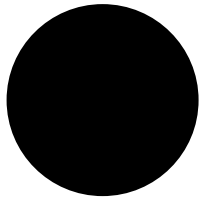
$v << \sim 1$ cm/day
$t_{contact} >> 12$ hrs
$t_{sorption} << t_{contact}$
diffusion dominated
MTZ easily contained
kinetics not important

$v >> \sim 1$ cm/day
$t_{contact} << 12$ hrs
$t_{sorption} \approx t_{contact}$
advection dominated
MTZ barely contained
kinetics important

Impact of Particle Size on Adsorption



Test Conditions:
Adsorbate = naphthalene
Solvent = distilled water
Co = 8 mg/L
Carbon dose = 50 mg/L
Sample volume = 1000 mL
Analysis: UV spectroscopy



GAC = F300 8x30

PAC = F300 sized to 95% -325 mesh

Summary

- Equilibrium loading capacity is fundamental to all activated carbon applications
- Take care when evaluating capacity: particle size and contact time will impact results
- Adsorption kinetics may be significant for some applications, but not for all

Thank you.