SMWG 2025 Fall Sponsor Forum

Optimizing Activated Carbon Use in Sediment Caps: Design, Application, and Lessons Learned

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ARCADIS

Discussion Topics

1 AC Cap/Amendment Design

2 AC Layer Placement

3 Summary & Lessons Learned

4 Q&A and Contact

GAC and PAC Fundamentals

GAC

- ASTM D2862-97: 90% larger than 0.180 mm
- Effective size: 0.55-0.75 mm (F400)
- 12x40 mesh (0.40-1.68 mm)
- Cost range: US$3,500 to 4,000 per ton

(Source: Calgon)

PAC

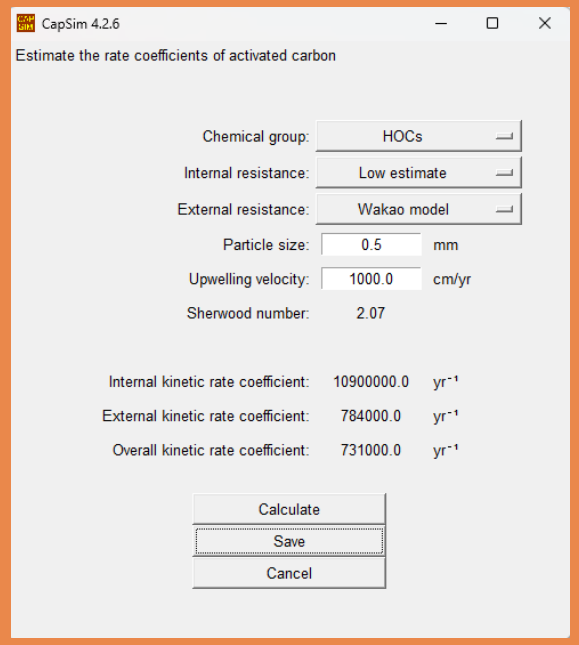
- ASTM D5158-98(2019): predominantly smaller than 80 mesh (0.177 mm)
- Typically, 90% smaller than 325 mesh (0.044 mm)
- It allows for faster contaminant uptake
- Requires a delivery technology to prevent loss
- Cost range: US$5,500 to 7,000 per AC ton, reflecting cost of proprietary delivery technologies

(Source: Calgon)

GAC's larger particle size facilitates its placement and may make it more cost-effective

PAC's smaller particle size makes it a more effective scavenger of dissolved chemicals

Key Performance Considerations

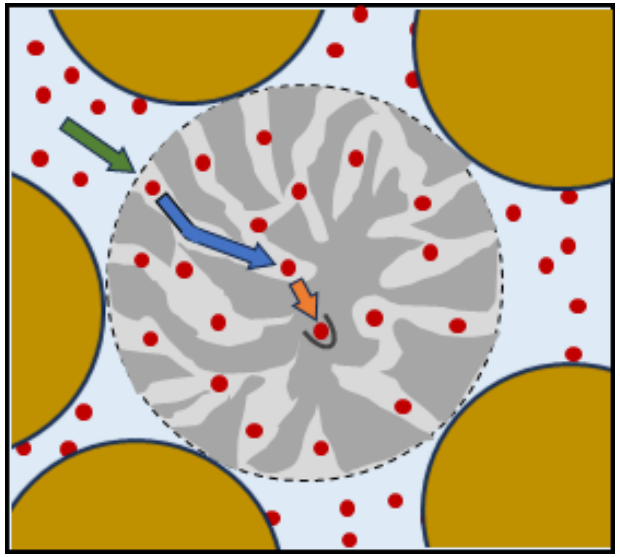


(Source: Shen et al. 2025)

- GAC and PAC are theoretically expected to achieve similar sorption capacities once equilibrium is reached
  - Comparable surface areas, as measured using BET sorption isotherms, and have pores on the nm scale
  - AC will remain in the cap for an extended duration, and continue to sorb COCs from upwelling porewater over time
- However, kinetics matters
  - PAC may outperform GAC when groundwater upwelling is high because this scenario limits contact time, and in thin AC-amended layers with low AC dose because this scenario limits contact probability
  - In these cases, equilibrium may not be established, making PAC's faster sorption kinetics advantageous

GAC and PAC Performance Modeling using CapSIM

AC Particles



Outside the AC Particle

Porewater-AC mass transfer

Key Factors

- Darcy velocity
- AC particle size
- AC load: Inter-particle/external resistances become more important as the spacing of particles is greater (e.g., low mass loading of GAC)

Column Kinetic Experiments

k_{ext}: Inter-particle/external sorption kinetic rate coefficient

λ_{ac}: First-order internal sorption kinetic rate coefficient (CapSIM default)

Inside the AC Particle

Intra-particle/internal transport

Adsorption on site

Key Factors

- Particle size
- Chemical partitioning

Batch Kinetic Experiments

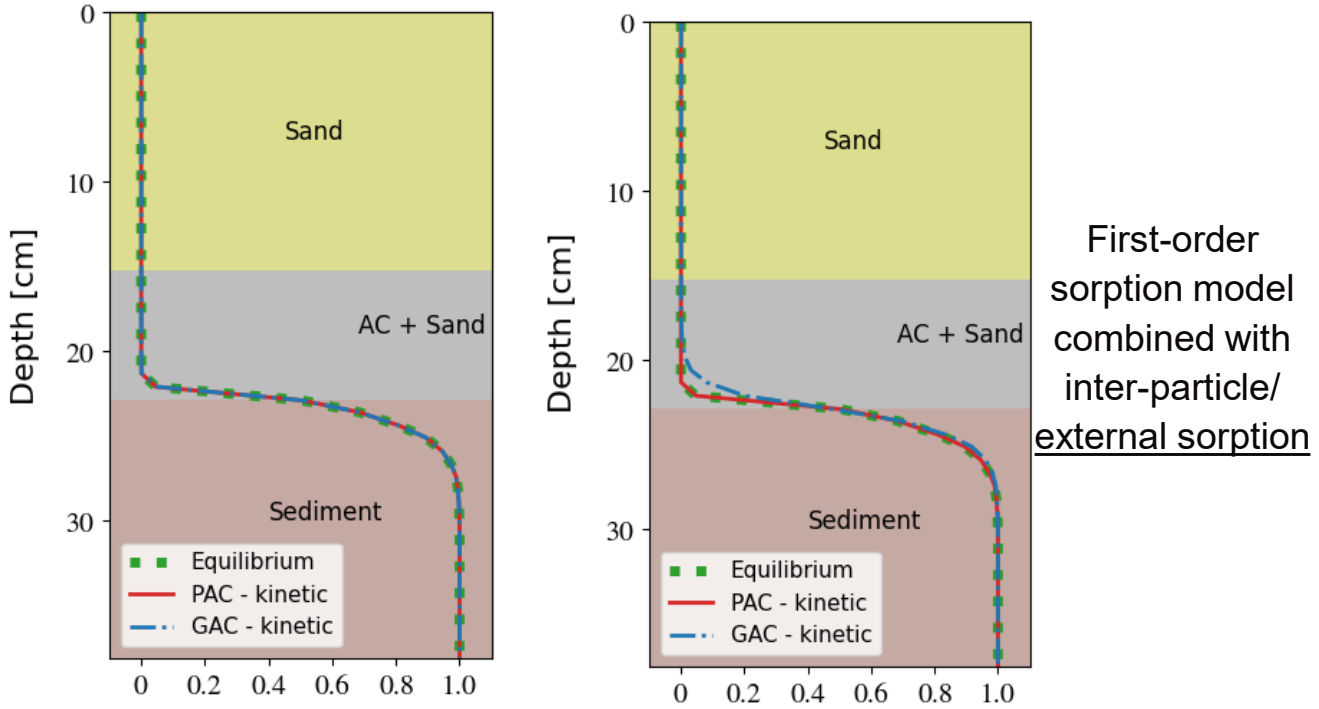
(Sources: Shen et al. 2018; Reible et al. 2024)

Examples of Capping Scenarios at 100 Years

3-inch 5% AC-Sand Reactive Cap Layer (DV = 1,000 cm/year)

- Model indicates no significant differences in long-term PAC and GAC performance, even at high upwelling velocity of 1,000 cm/year for a properly designed cap

First-order sorption model for AC (CapSIM default includes internal sorption)



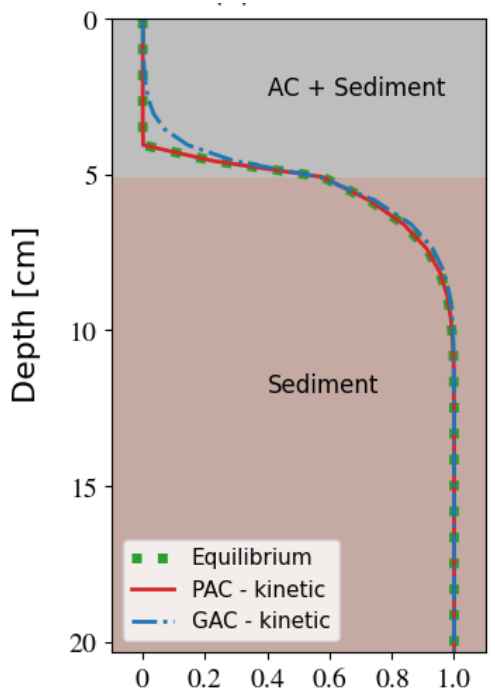
First-order sorption model combined with inter-particle/ external sorption

Dimensionless porewater concentration at 100 years (3-inch 5% AC-sand layer)

Example of In-Situ Amendment Scenarios at 100 Years

2-inch 10% AC-amendment Surface Sediment Layer (DV = 1,000 cm/year)

- CapSIM predicts negligible difference in long-term PAC and GAC performance for Darcy velocities up to 1,000 cm/yr for a properly designed remedy



Dimensionless porewater concentration at 100 years
(First-order sorption model combined with inter-particle/ external sorption)

AC Placement and Specification Considerations

Design Considerations	GAC	PAC Proprietary Technologies (10 – 50% by weight)
Delivery Technology	• Typically mixed with sand • Reactive mat	• Proprietary (pelletized PAC, PAC-coated particle, and sand-PAC mixture with binder)
Placement Method	• Mechanical (e.g., excavator bucket) • Hydraulic • Alternative methods (e.g., slinger, pneumatic) • Proprietary methods	• Same as sand/GAC, except for limited applicability of hydraulic and pneumatic methods
QC Tests to Verify Specifications are Met	• Visual observation • Analysis of sample to measure AC content (e.g., modified version of ASTM D2974-20e1, chemical oxidation method, Lloyd Khan, or loss on ignition)	• Vendor certificate • Analysis if in-situ verification is required using same methods of GAC
Dose Variance	• 0 to 30% additional GAC	• NA (certificates)
Overplacement Variance	• 3 to 6 inches	• 10 to 30% of amendment load

PAC Delivery Technologies

Pelletized PAC
(Source: Arcadis)

PAC-coated particles
(Source: Arcadis)

Sand-PAC mixture with binder
(Source: Arcadis)

AC Placement Methods

Proprietary placement method and PAC delivery technology
(Source: Arcadis)

Slinger placing a proprietary PAC delivery technology
(Source: Arcadis)

Summary of Key Points Covered

- PAC and GAC performance can be differentiated with the current version of CapSIM, accounting for internal and external sorption kinetics
- While PAC exhibits faster sorption kinetics, GAC shows comparable long-term performance to PAC at Darcy velocities ≤ 1,000 cm/yr
- Several delivery technologies and construction QA/QC enable controlled placement, proper mixing of AC with sand, and AC dose verification
- Multiple successful methods exist for both GAC and PAC placement, providing flexibility to address site-specific challenges
- Strategic material selection, robust modeling, clear specifications, and accurate placement can significantly improve remediation outcomes

Core and catch pan collected to verify amendment thickness after placement *(Source: Arcadis)*

Thank you for joining!

Questions? please reach out to:

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