New Data and Studies Supporting the Application of Activated Carbon for Contaminated Sediment Remediation

What Have We Learned?

October 21, 2025

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SMWG
Sediment Management Work Group

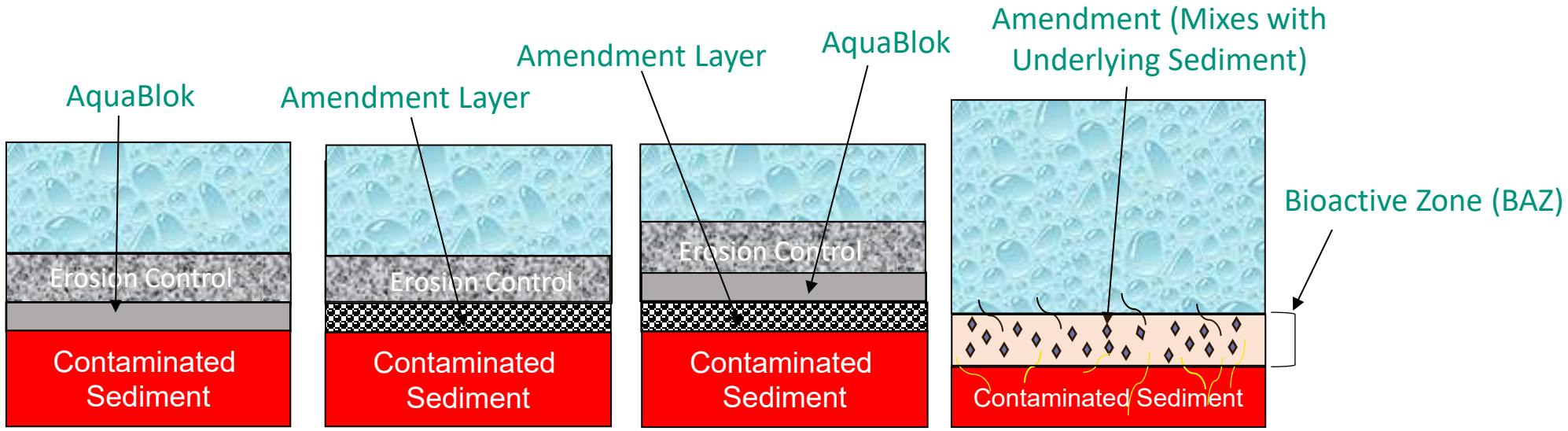
AquaBlok®

Presentation Outline

1. ***Cap Designs & Key Issues in Evaluation and Implementation***
2. Questions Answered – Findings of Lab Studies and Modeling
3. Summary and Take-aways

Cap Designs To Adress Contaminated Sediments

(Sand Cap Not Included)



Chemical Isolation

- Sequestration (Low Perm)
- Physical Separation
- Erosion Resistant
- Seismic Stability

Permeable "Reactive" Cap

- 'Conventional' GAC/Sand or AquaGate+PAC
- Intercepts Pore Water Contaminants

Horizontal Funnel & Gate "Reactive" Cap

- 'Conventional' GAC/Sand or AquaGate+PAC
- Limits Potential for 'Breakthrough' From Isolated Seep Zones

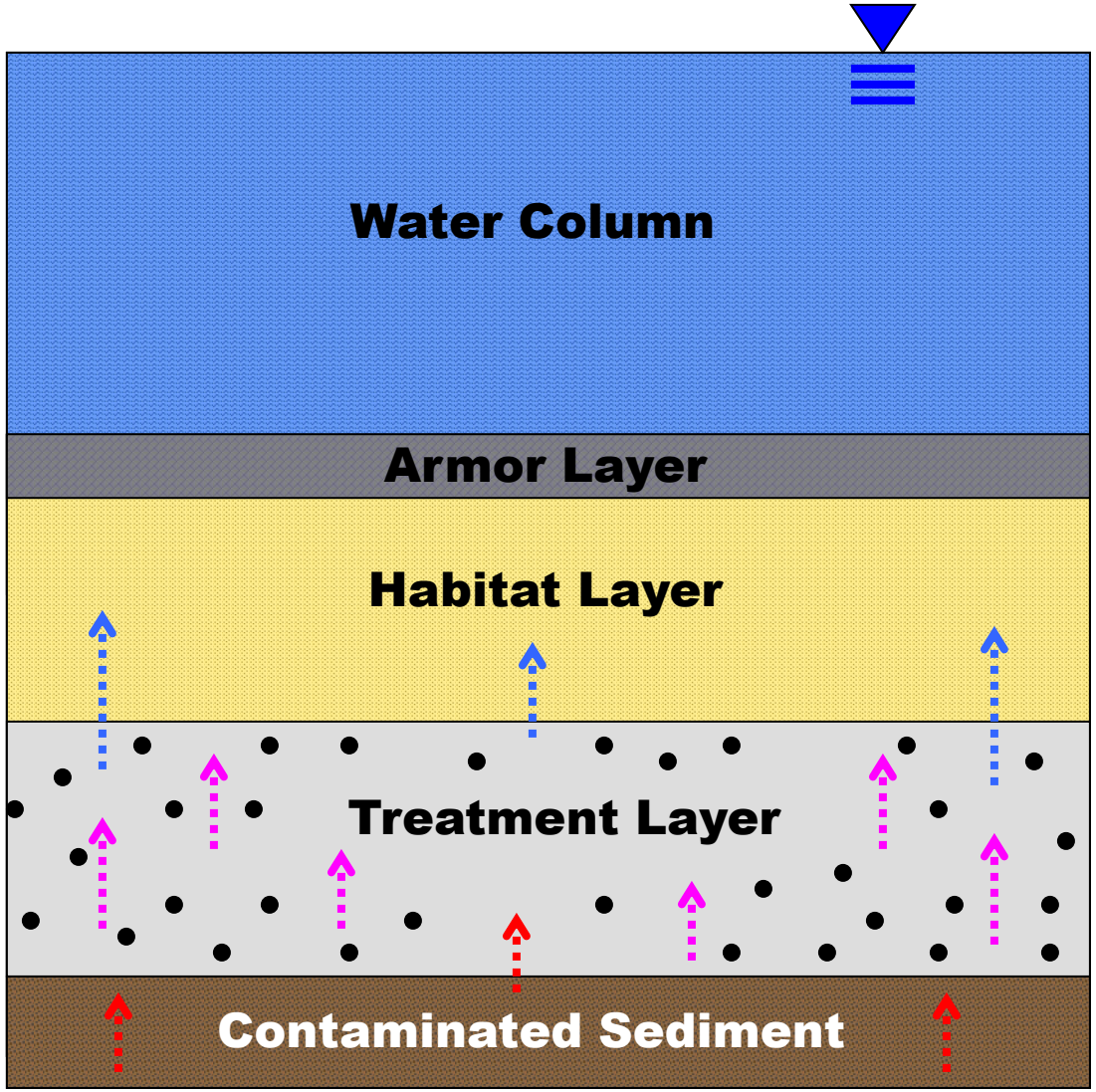
In-Situ Treatment

- Performed Only Using PAC Delivery Methods
- Intercepts Pore Water Contaminants

Key Issues in Design for Amendment Application

*"**Reactive Capping**" - Treatment Utilizing a Permeable Amendment Layer*

- *Uniform Distribution* of Treatment Material within Layer is Critical to Ensure Contact and C*ontact Time*
- Layer Thickness and Upwelling Rate determines *Residence Time* for Adsorption AND will impact *Capacity* or amount adsorbed
- *Isolated Seep Zones* may require increased thickness and larger quantity of amendment to protect against breakthrough from higher concentration areas
- Models are intended to predict *Time to Contaminant Breakthrough* based on design, treatment material performance and the key assumption of successful implementation



Key Issues in Design for Amendment Application

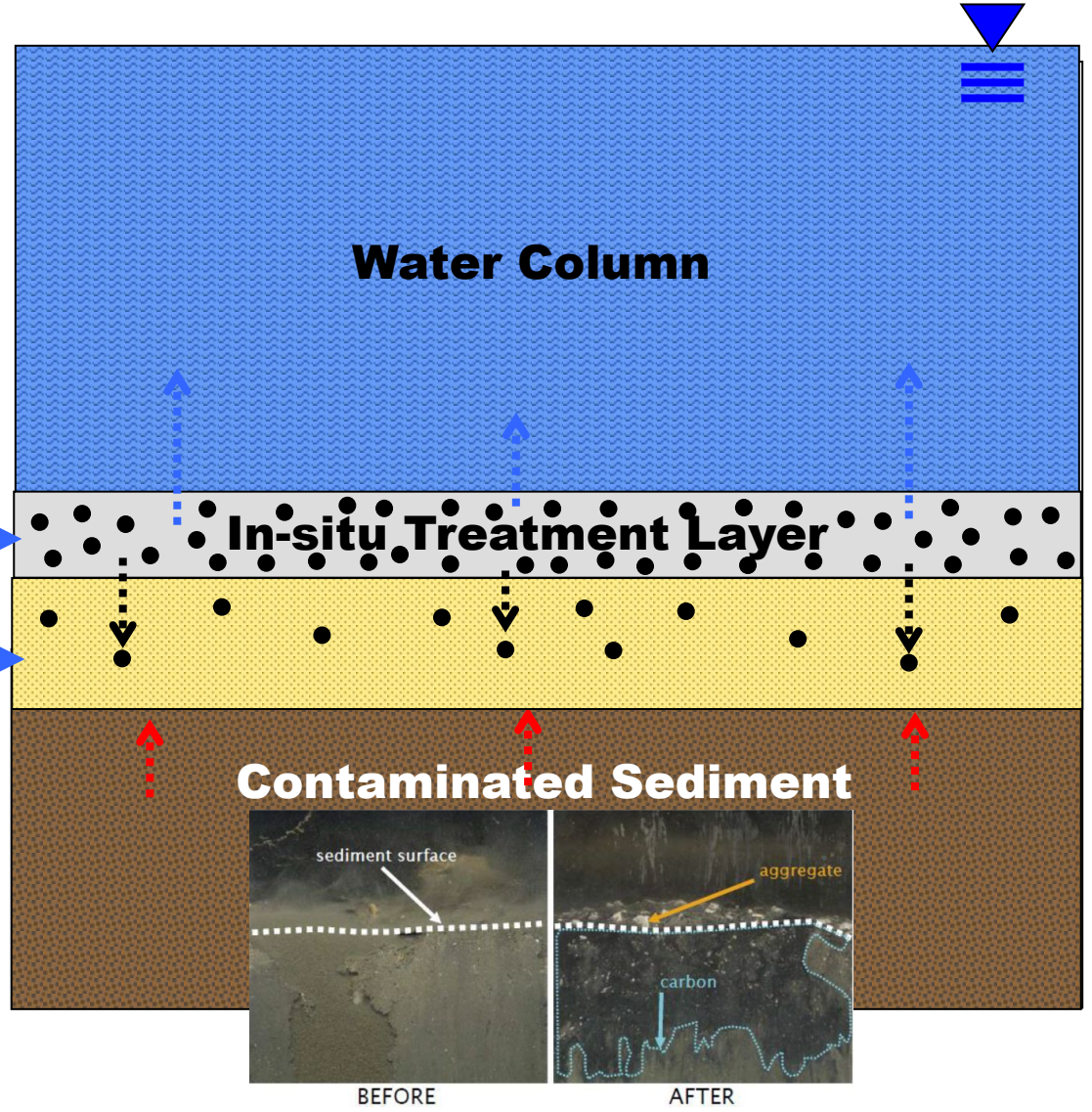
*"**In-Situ Treatment**" – Natural Mixing of PAC into Native Sediments*

Goal: Reduce Pore Water Concentration of Target Contaminant in the Biologically Active Zone (BAZ)

Thin Layer is Applied Directly to Sediment Surface – Not a 'Cap'

Treatment Material Mixes into Sediment BAZ through Natural Bioturbation

Concentrations of Contamination in the BAZ Pore Water are Reduced



All Design & Construction Aspects of Active Capping Apply to In-Situ Treatment

Control and Construction Verification of PAC Content & Layer Thickness is Critical

Reductions in Bioavailable Concentrations Can be documented through Passive Sampling

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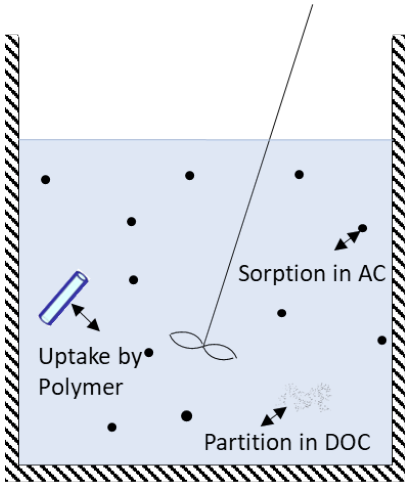
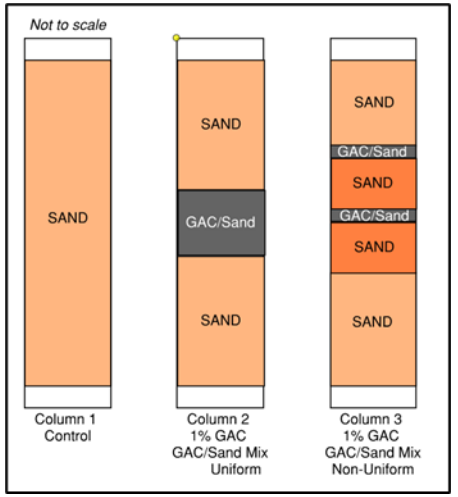
Lab Studies Answer Key Questions Relating to the Implementation of AC for Sediment Remediation

What have study results indicated regarding the *effects of amendment particle size*?



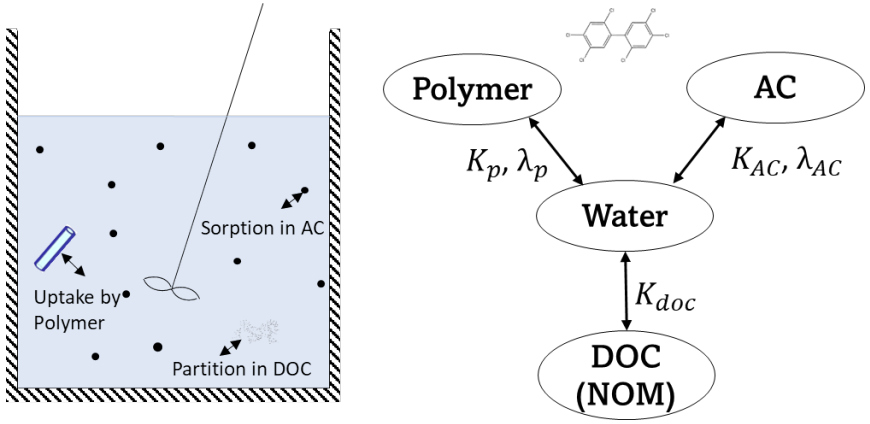
How *do implementation challenges potentially affect modeling and typical design assumptions*?



What have study results indicated regarding the effects of amendment particle size?

First True Extended Adsorption Study for PAC & GAC

- 50 Week evaluation of PAC & GAC for PCBs (joint effort of AquaBlok, ADA Carbon & Texas Tech).
- Data provide the *rate of adsorption* (kinetics) and the *capacity* of equal masses of PAC and GAC.
- Results provide inputs for a representative CapSim model to demonstrate effect of particle size / kinetics on expected remedy performance.
- Allows comparison of model assumptions to full-scale implementation.



Mass balance

$$V_w C_w + \rho_{doc} K_{doc} C_w + V_p C_p + V_w \rho_{ac} q_{ac} = M$$

Kinetic uptake by polymer

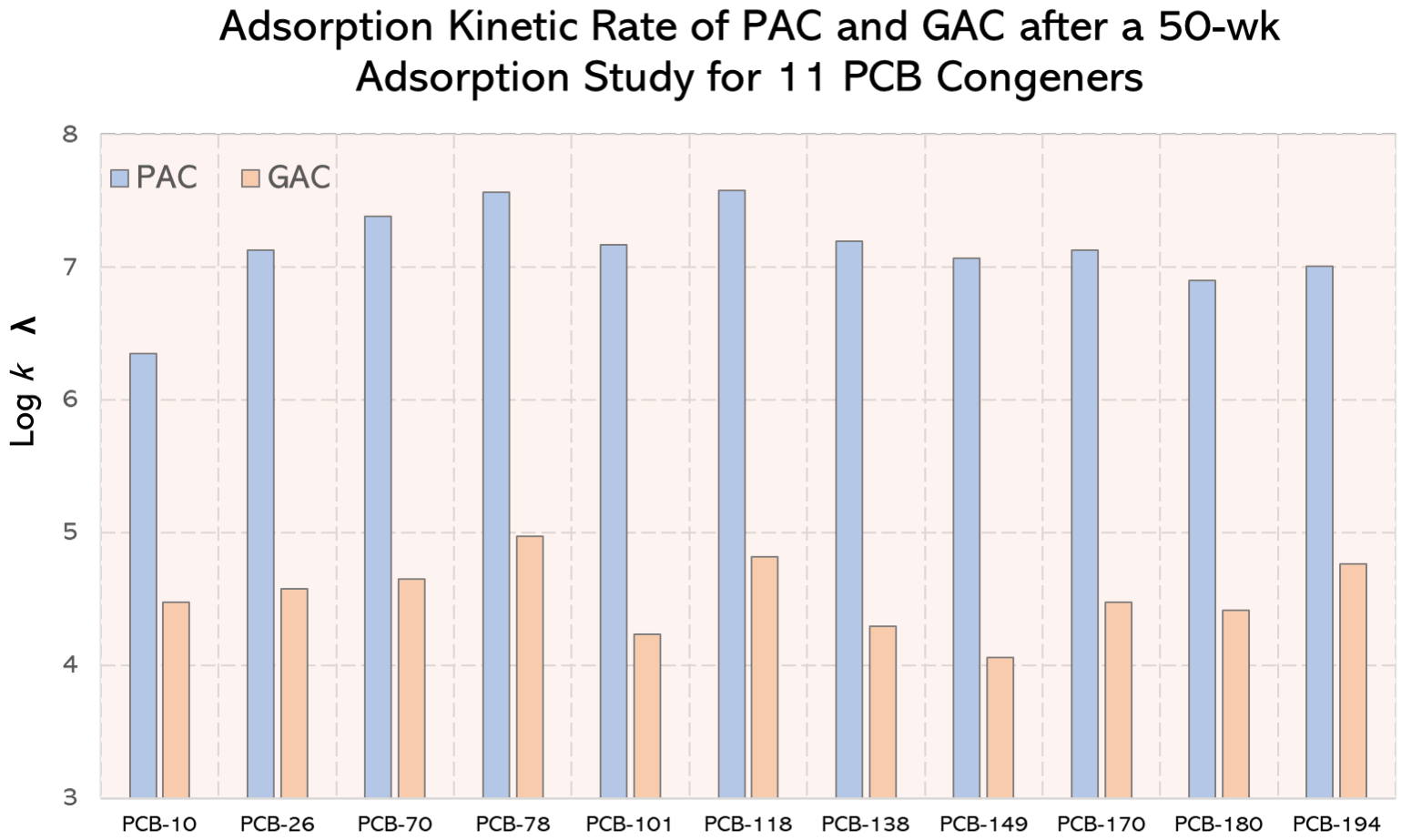
$$\frac{dC_p}{dt} = \lambda_p (C_w K_p - C_p)$$

Courtesy Reible et al 2023. Presented at the 2023 International Conference on the Remediation and Management of Contaminated Sediments. January 9-12,2023. Austin, Texas. Used with permission.

What is the impact of particle size on the *speed of adsorption*?

Key Question Answered: *PAC Adsorbs Contaminants Much Faster*

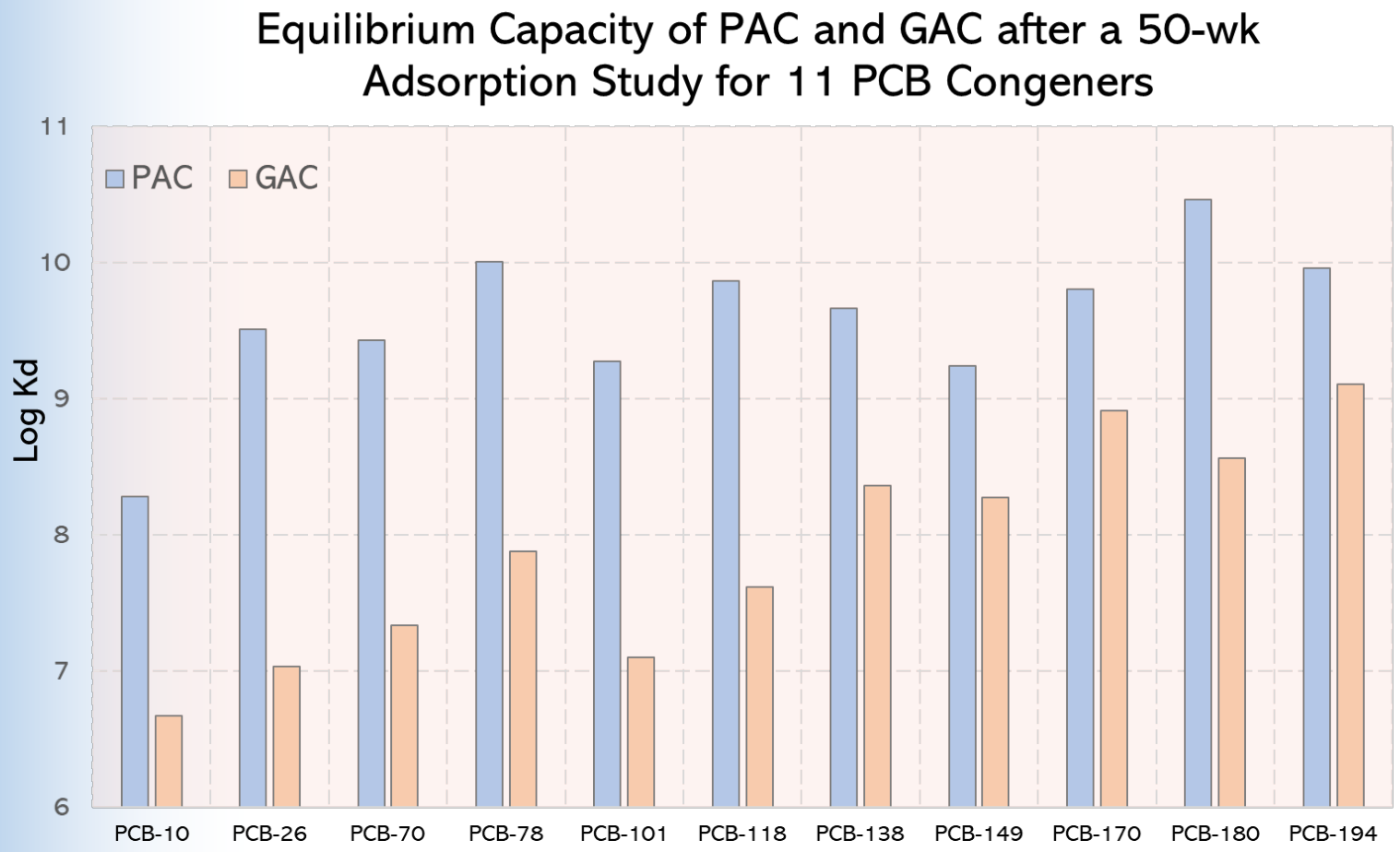
- ***PAC adsorption rate was 1300 times faster than GAC***, taken as an average of the 11 PCB congeners.
- Data makes it clear that ***pulverizing / grinding GAC for treatability testing purposes provides incorrect results for GAC***
- Raises the question – ***Will GAC adsorb contaminants fast enough to be effective in high upwelling environments?***



Shen et al. 2023, Water Research 236 (2023) 119978

What is the impact of particle size on the *amount* of adsorption?

Key Question Answered: *PAC Adsorbs Significantly More Than GAC*



Shen et al. 2023, Water Research 236 (2023) 119978

- ***PAC adsorption capacity was 210 times higher than GAC***, taken as an average of the 11 PCB congeners
- Comparing the maximum adsorption capacity of PAC and GAC over a one-year period showed that, because ***PAC will adsorb more contamination than GAC, less material would be required***.

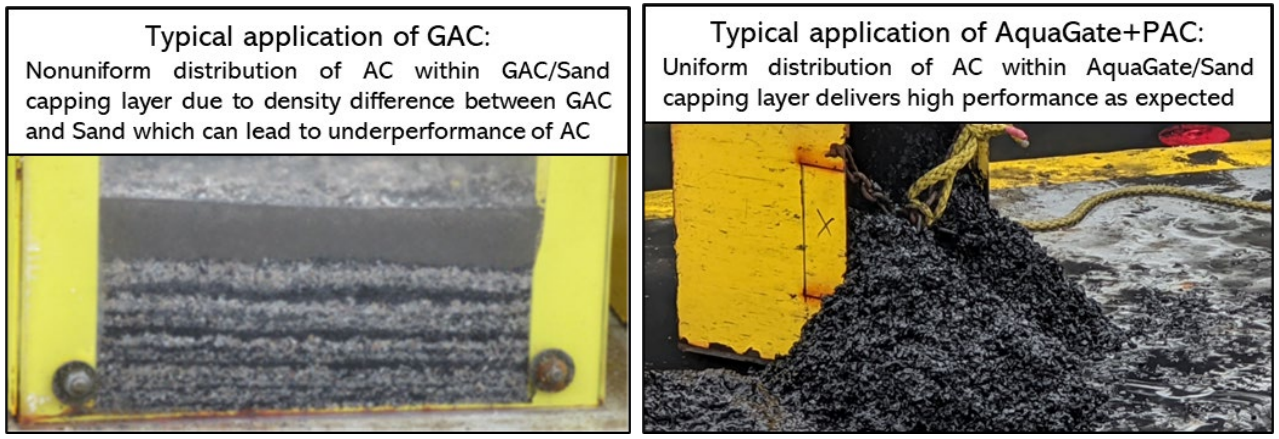
How do implementation challenges potentially affect modeling and typical design assumptions?

- Models assumes theoretically “uniform” distribution of all AC within the capping layer
- How much risk introduced during implementation? Does modeling output take into consideration the potential lack of ***vertical uniformity of AC within a capping layer?***
- The assumption of “uniform distribution” is not supported by data from many “Real World” field examples.

“Best Case Scenario”
Columns constructed in the lab

AquaGate+PAC | Sand + GAC

“Real World Scenario”
Cap constructed in the field



Sand + GAC | AquaGate+PAC

Photos courtesy of Integral presentation given at the 2023 International Conference on the Remediation and Management of Contaminated Sediments. January 9-12,2023. Austin, Texas. Used with permission.

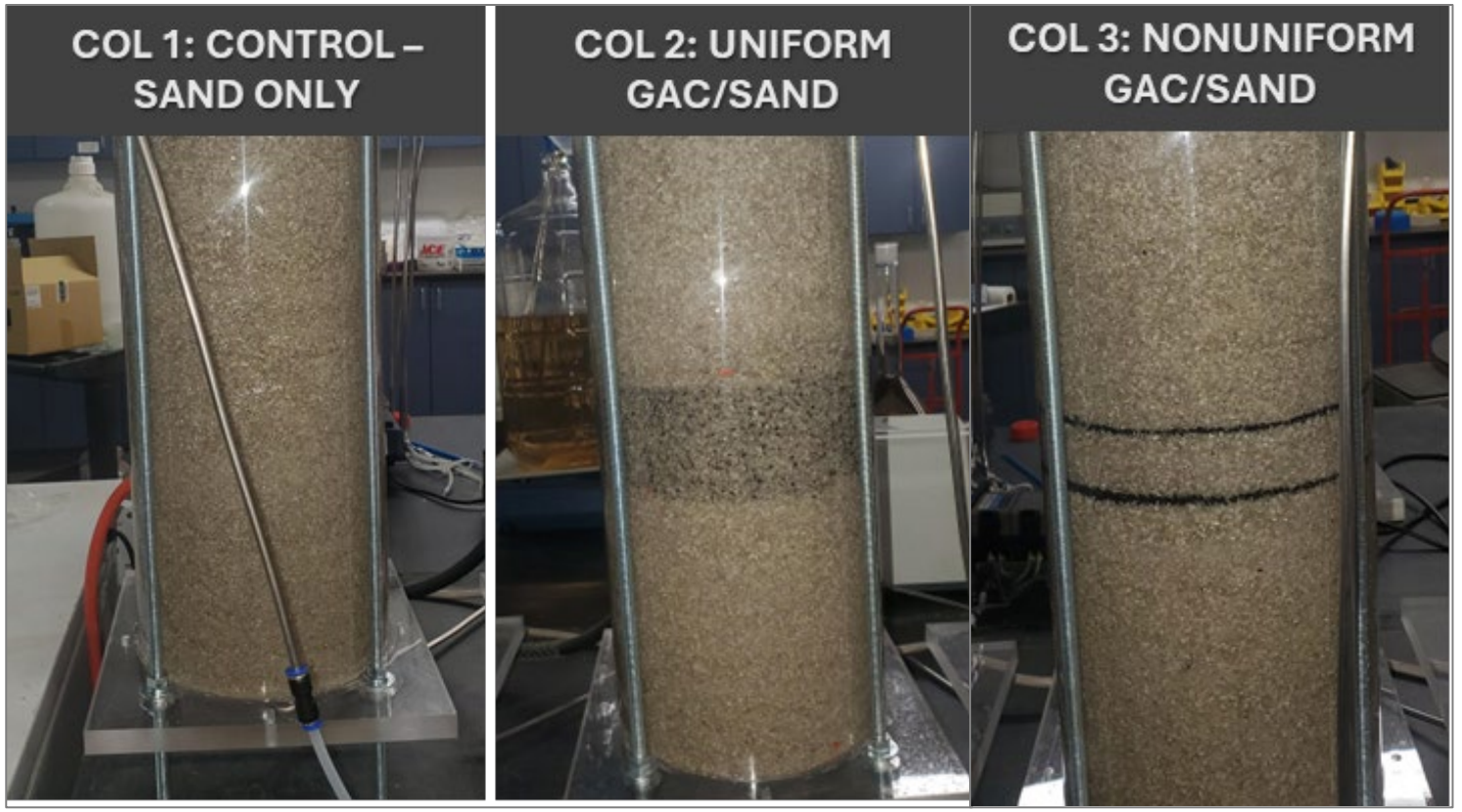
Column Study Performed to Evaluate GAC Performance for Both Placement Impacts & Modeling Assumptions

Lab Column Construction

Cap layer: 3-in of sand mixed with 1.5% activated carbon by weight (~50g).

Simulated groundwater velocity: ~5cm/d.

- **Col 1**: Control (Sand)
- **Col 2**: Uniformly mixed GAC-Sand layer
- **Col 3**: Nonuniformly mixed GAC-Sand layer placed in two lifts with a discrete layer of GAC settling on the sand during each lift



2025 Battelle Sediments Conference - Presentation by CDMSmith:
"Kinetic Differences between Granular Activated Carbon Distribution Evaluated and Demonstrated through CapSim Modeling and Column Study"

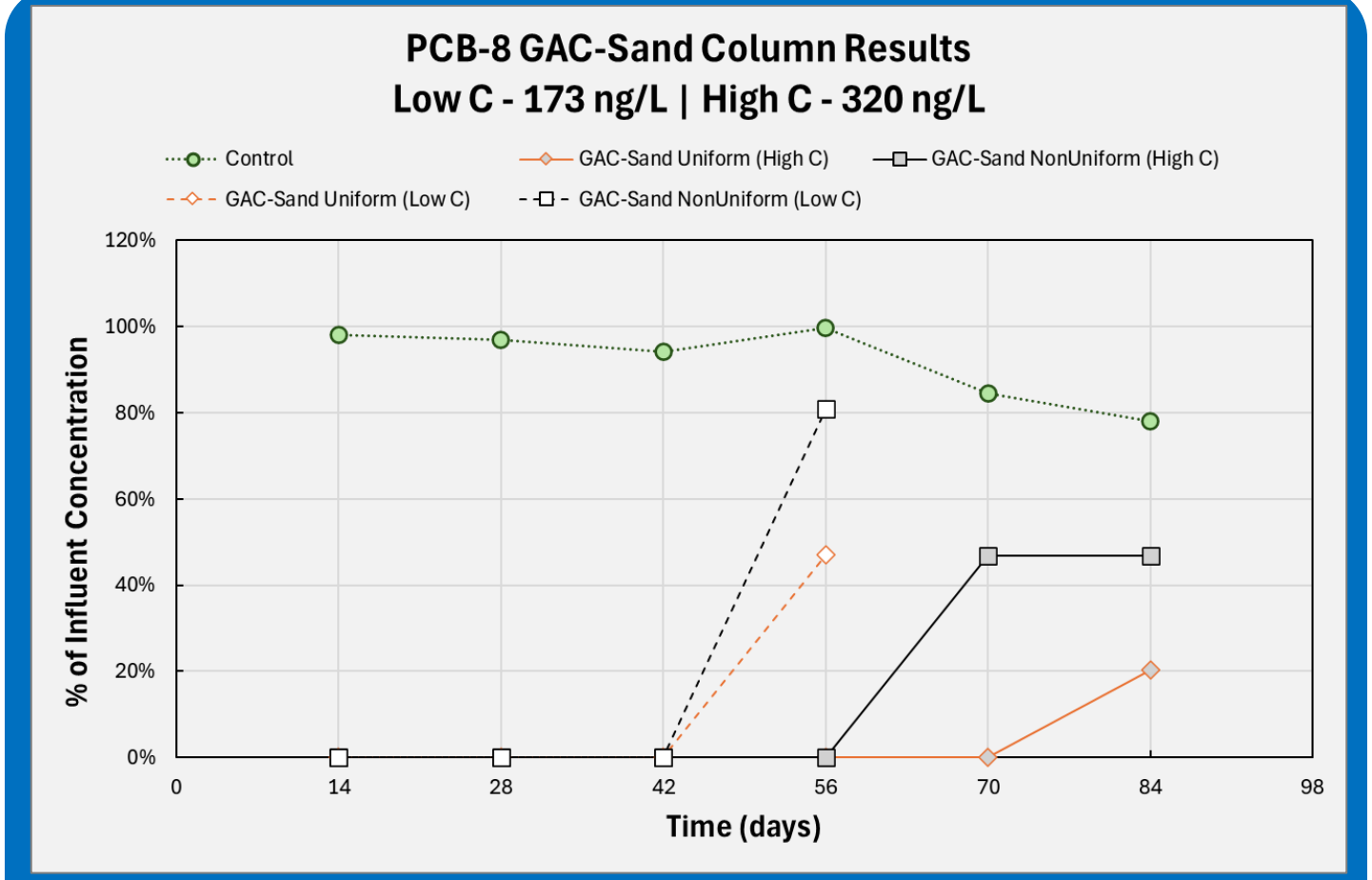
Results of Impact of Non-Uniform GAC Distribution in a Cap?

Key Question Answered:

1. Contamination breaks through more rapidly when GAC is not Uniformly distributed within the capping layer.

2. Breakthrough takes place far more rapidly in both columns than the model predicted.

Note: Lower concentration breaks through before higher concentration pore water.



Breakthrough – Defined as detection of measurable and significant (5 – 10% of influent) contaminant concentration above the capping layer, at least 10x above the method detection limit.

Are current industry modeling approaches for GAC-Sand remedies overestimating performance?

Porewater Concentrations from GAC-Sand Cap - Empirical Results vs CapSim Predictions in Dynamic High Upwelling Environment					
Column Configuration	**PCB-8 Concentration**	**Standard CapSim Prediction (PCB-10)**	**Alternative CapSim Prediction (PCB-10)**	**Column Breakthrough Rate**	**Column Breakthrough Time**
Uniform Distribution	173 ng/L	>50 yrs	~100 days	47%	56 days
Non-Uniform Distribution		>50 yrs	~100 days	81%	56 days
Uniform Distribution	320 ng/L	>50 yrs	~100 days	20%	84 days
Non-Uniform Distribution		>50 yrs	~100 days	47%	70 days

- Two alternative approaches to CapSim modeling were evaluated to attempt to predict the column study results:
  - *"Standard" CapSim Model* – uniform GAC distribution, default kinetics assumptions.
  - *Alternative CapSim Model* – implement effect of kinetics and nonuniformity.
- The modified model provided a better prediction of breakthrough in the columns.
- "Standard" CapSim Model overestimates performance of cap.

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Application of Powder Activated Carbon for Contaminated Sediments

Experience & Track Record Matters!

AquaGATE+ PAC

Projects Completed or Scheduled:

United States:

- Aberdeen, MD Proving Grounds – Pilot
- Bremerton, WA Navy Shipyard – Pilot
- Norfolk, VA (Little Creek) – Full Scale
- Pearl Harbor, HI (Sub-Base) – Pilot
- Passaic River (RM10.9) – Full Scale
- Hunters Point, CA (Navy) – Pilot
- Columbia River, OR – Pilot
- Willamette River, OR – Full Scale
- Middle River, Baltimore – Full Scale
- San Francisco Bay (Potrero) – Full Scale
- Pearl Harbor, HI (Navy) – Full Scale
- Detroit River, MI – Full Scale
- Port Lands, Toronto, CA – Full Scale
- Marine Base, Kaneohe, HI - Pilot
- Thomson Reservoir – Full Scale

❖ Guam, Navy – Pilot
❖ HECO Power Plant, HI – Full Scale

International:

- Sandefjord Harbor, Norway – Pilot
- Bergen Harbor, Norway – Pilot
- Leirvik Sveis Shipyard, Norway – Full Scale
- Naudoddan, Farsund, Norway – Full Scale

Note: Total Production of all AquaGate Products Exceeds 100,000 tons

Summary and Take-Aways

1. Long-term testing data has demonstrated that ***GAC performance is less likely be protective in a dynamic advection-driven environments*** (e.g., where GAC adsorption speed is slower than the advective transport).

2. Challenges associated with implementation of GAC/Sand Caps Can Impact Performance – Compared to Modeling Assumptions. ***Nonuniform GAC Distribution in Capping Layer may Significantly Accelerate Breakthrough***

3. Data indicates that PAC-based approaches ***can require far less amendment quantity and still provide superior performance over GAC*** – improving cost-effectiveness.

Thank You!

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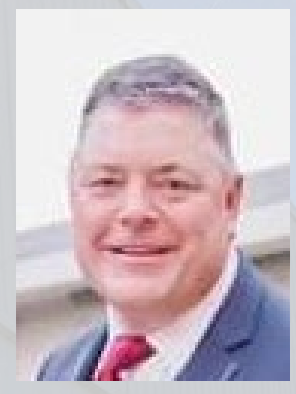

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