Granular Activated Carbon Evaluated Through CapSim Modeling and Column Study

John A. Collins and Moses Ajemigbitse, Ph.D. (AquaBlok Ltd.)

Keegan Roberts, Todd Burgesser (CDM Smith)

Important Questions for Implementation of AC in Contaminated Sediment Remediation

Sediment Management Work Group

11/13/2024

Presentation Outline

1. Activated Carbon Basics: Commercially Available Products
2. Key Issues in the Evaluation and Implementation of AC for Sediment
3. Impacts of Adsorption Performance - PAC vs GAC
4. Potential Impact of GAC Placement on Modeling & Remedy Performance
5. Summary and Take-aways

Activated Carbon Basics –
Commercially Available Activated Carbon Products

Granular (GAC)

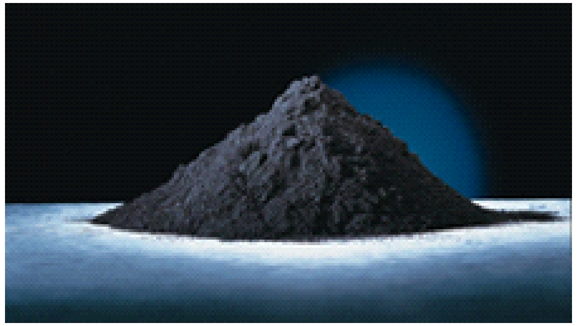
ASTM D2652-11:
>80 mesh

Typical Size:
20x80 mesh
(0.42-0.84 mm)

Powder (PAC)

ASTM D2652-11:
<325 mesh

Typical Size:
200-325 mesh
(0.074-0.044 mm)



Typical Pure Activated Carbon – Bulk Density: 20-35 lb/ft^3 (0.32-0.56 g/cm^3)

AquaGate+PAC

- Typical Size:
  3/8" Minus
- Bulk Density:
  75-80 lbs./ft^3
- PAC Content:
  0.66 lbs./ft^2 in 1" layer

Sedimite

- Typical Size:
  1/4" Minus
- Bulk Density:
  45 lbs./ft^3
- PAC Content:
  1.875 lbs./ft^2 in 1-inch layer

Mat-Based Delivery (RCM – Tektoseal)

- Typical Size:
  15'x100' Rolls
  Approx. ¼" Thick
- Bulk Density:
  45 lbs./ft^3
- GAC Content:
  0.6 lbs./ft^2

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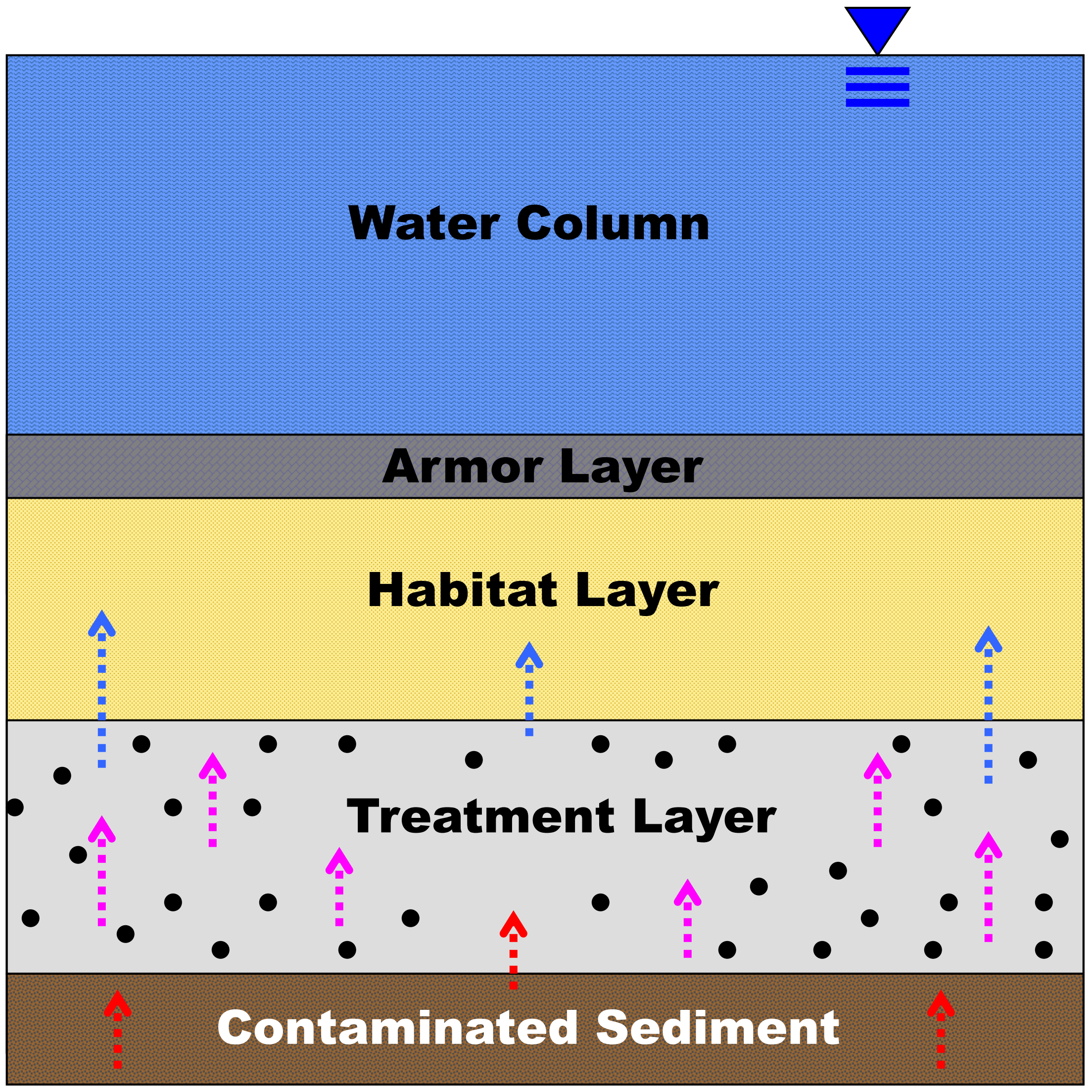
Background – Key Aspects of Design for Amendment Application
Treatment Utilizing A Permeable Amendment Layer

- *Uniform Distribution* of material within Treatment Layer increases *contact time.*
- Thickness and upwelling determines *Residence Time* for adsorption AND will impact *Capacity* or amount adsorbed.
- Increased Treatment Layer thickness and larger quantity of amendment is sometimes required to protect against breakthrough from higher concentration areas or an *Isolated Seep Zone.*
- Models are intended to predict *Time to Contaminant Breakthrough* based on design, treatment material performance and successful implementation of construction assumptions.



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Differences in GAC vs PAC Performance Have Been Well Documented

Anacostia River Treatability Study – Final (AECOM)

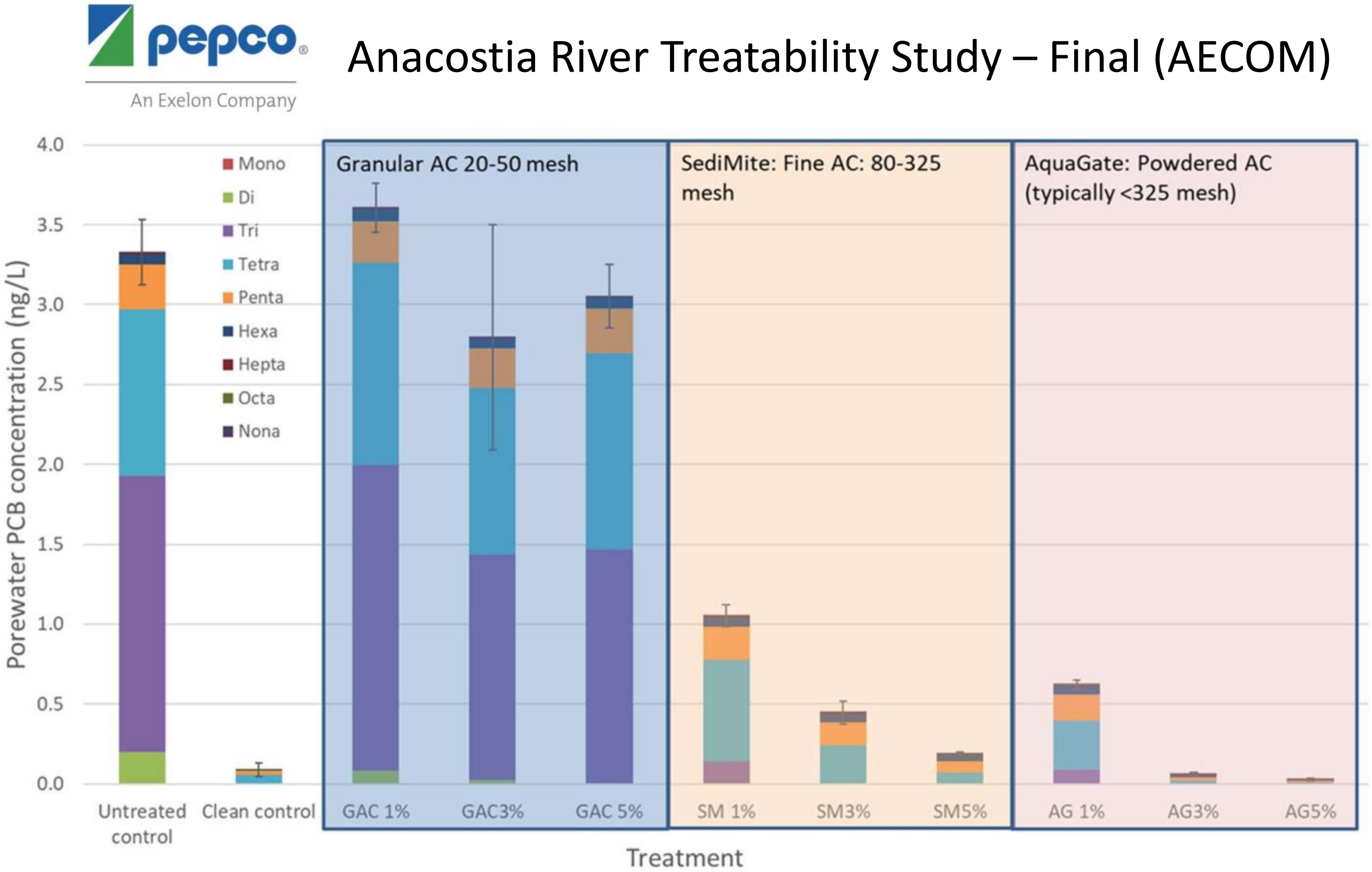

Figure 3-11: PCB Concentration in Sediment Porewater from Exposure Chambers

AECOM 2021. Benning Road Facility. Treatability Study Report, Final.

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Key Facts: AC Performance in Sediment Remediation

1. Particle size plays an important role on AC adsorption speed and AC capacity – *smaller is faster and allows for greater capacity & utilization of AC capacity*.
2. Distribution of AC within the sediment cap impacts residence time – *nonuniformity increases risk of remedy*.
3. Residence time of the contaminant within the capping layer *does not represent* contact time between AC and contaminant within the cap.
4. Actual contact time between mass of AC applied and the contaminant controls quantity of contaminant adsorbed.

Practical Implementation:
Differences in Modeling Assumptions vs. Real World Placement

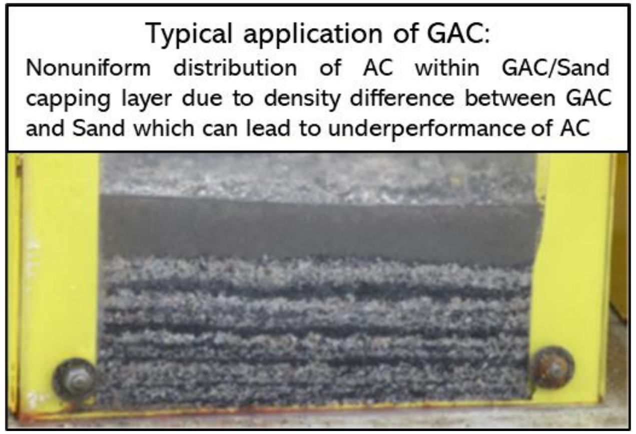
- Numerical models typically assumes “uniform” distribution of all AC within the capping layer.
- Current models do not inherently account for construction related risks – *vertical nonuniformity of AC within the capping layer.*
- Difficult to evaluate this effect due to lack of available long-term monitoring data for existing mixed GAC-Sand remedies.

Columns constructed in the lab
“Best Case Scenario”

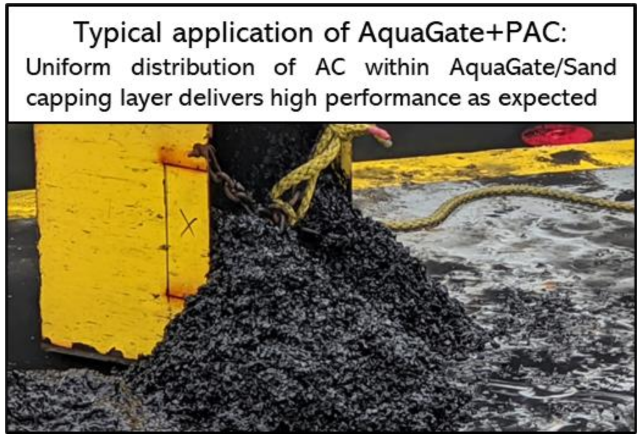
AquaGate® + PAC

Sand + GAC

Cap constructed in the field
“Real World Scenario”



Sand + GAC

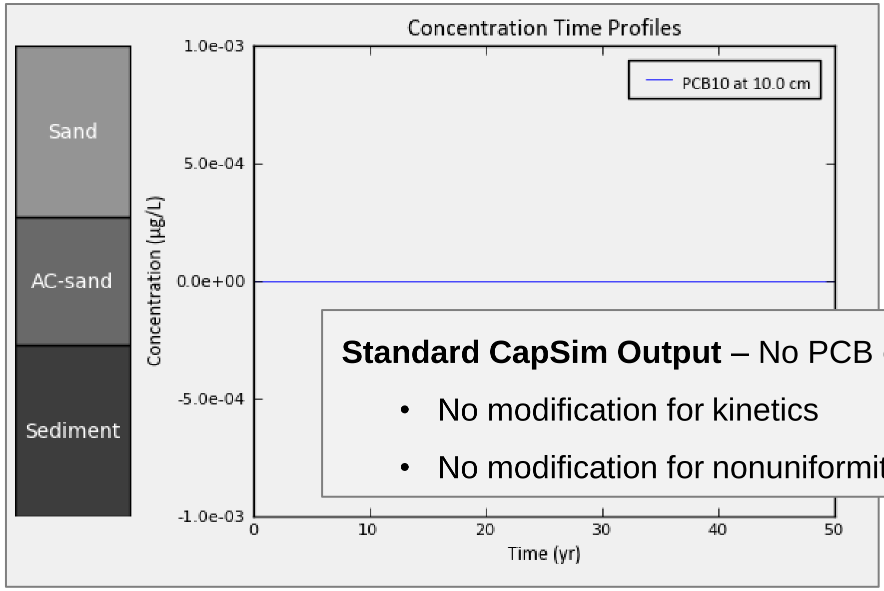


AquaGate® + PAC

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.

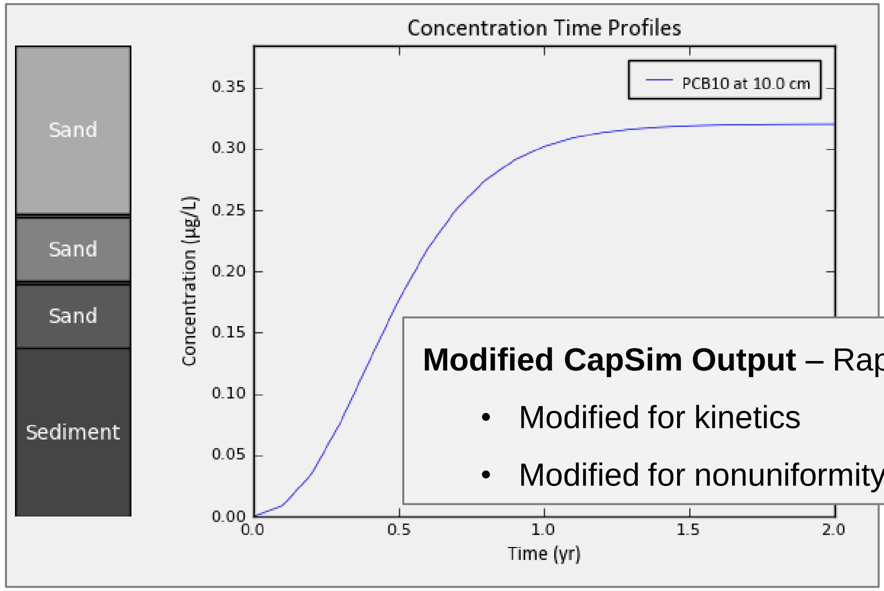
Impact of GAC Performance on Cap Life and Risk-of-Remedy

- Modified model to account for nonuniformity and kinetics to evaluate their effect.
- Modifications included
  - Creating discrete layers of GAC over sand.
  - Adjusting the linear partition coefficient based on actual GAC contact time.
- Incorporating nonuniformity and adsorption capacity based on residence time indicates an increased risk of cap failure.
- <u>Modeled Conditions:</u>
  - 1.5% GAC mixed with Sand.
  - 5 cm/d groundwater upwelling velocity.
  - Initial conc. of PCB-10 at 320 ng/L.



Standard CapSim Output – No PCB conc. for 50 years

- No modification for kinetics
- No modification for nonuniformity



Modified CapSim Output – Rapid rise in PCB conc.

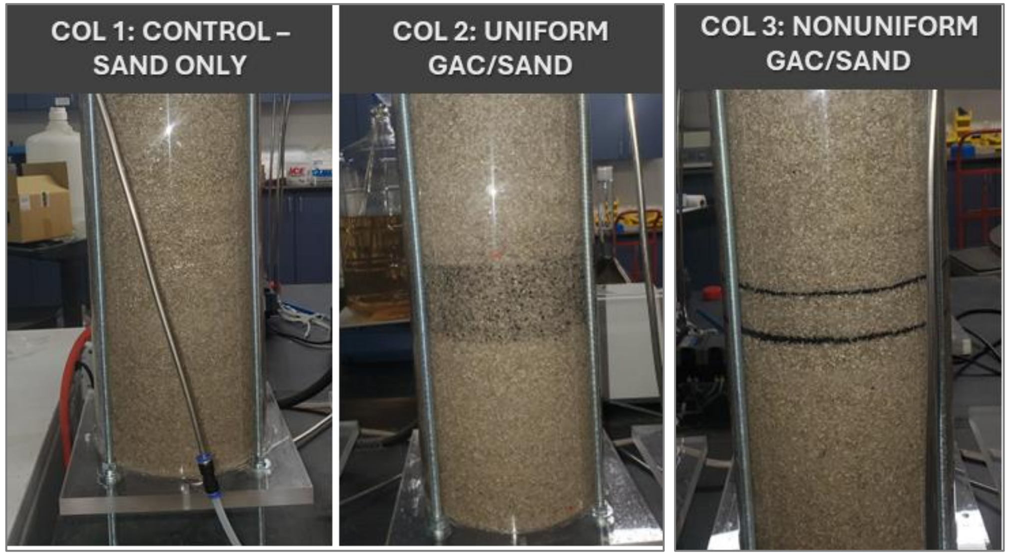
- Modified for kinetics
- Modified for nonuniformity

Column Study to Evaluate GAC Kinetics and Nonuniform Placement

- Large disparity between the model outputs prompted the need for empirical validation.
- Designed a column study in collaboration with CDM Smith to evaluate and compare the actual performance of a mixed GAC-Sand capping layer to the predicted outcomes of the model.

Key Study Question

Are the current modeling approaches providing accurate and representative outcomes for GAC-Sand caps in sediment environments with high levels of groundwater upwelling?"



Lab Column Construction

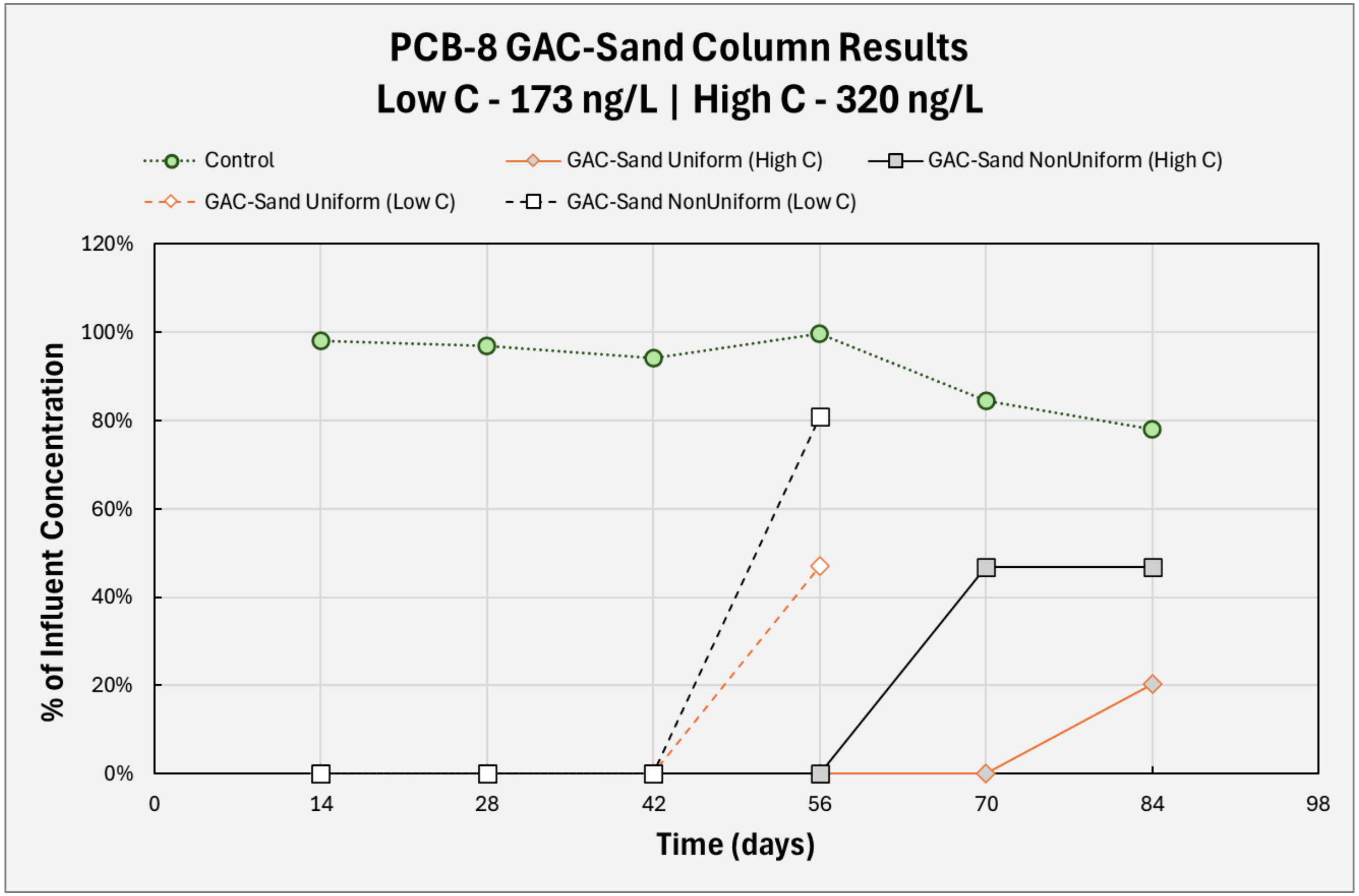
The cap layer was composed of 3-in of sand mixed with 1.5% activated carbon by weight (~50g).

Simulated groundwater velocity of ~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.

Column Study Results: Nonuniform GAC Distribution in Capping Layer Accelerates Time to Breakthrough

- Results showed contaminant breakthrough that followed the following trends:
  - The nonuniform column experienced breakthrough before the uniform column.
  - Breakthrough was more significant at the lower influent concentration.
- Results from the column study were as expected.



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

Column Study Results: Which Model Better Predicted Column Results?

- Two alternative approaches to CapSim modeling to predict the column study results:
  - Standard CapSim Model – model as-is.
  - Modified CapSim Model – modifications for kinetics and nonuniformity.
- Breakthrough in the columns was better predicted by the modified model.

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

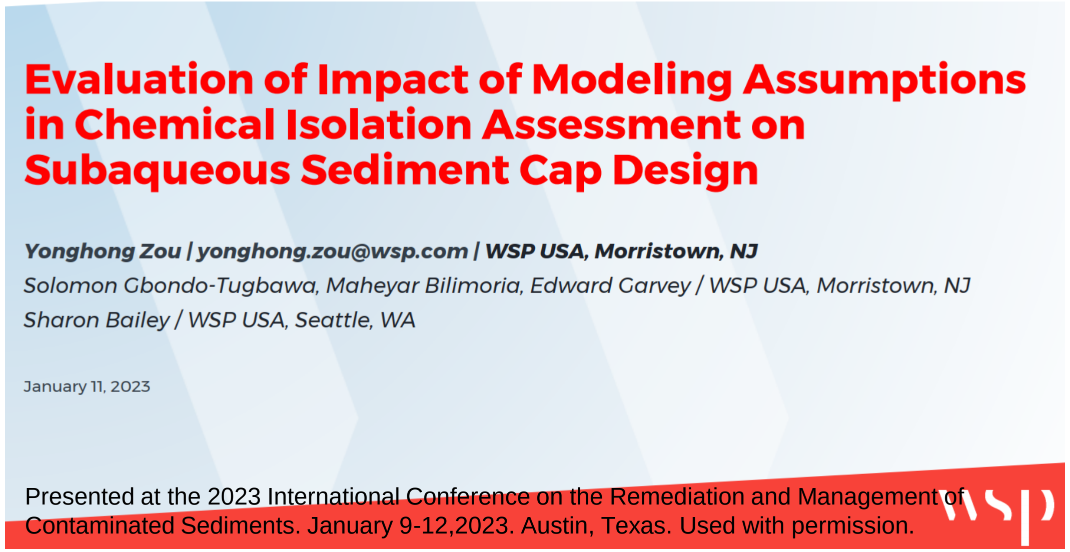
Porewater Concentrations from GAC-Sand Cap - Empirical Results vs CapSim Predictions in Dynamic High Upwelling Environment					
Column Configuration	**PCB-8 Concentration**	**Column Breakthrough Rate**	**Column Breakthrough Time**	**Standard CapSim Prediction (PCB-10)**	**Modified CapSim Prediction (PCB-10)**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

AC for Sediment Remediation – Ensuring Continued Success

- How do we increase our understanding of remedy outcomes?
- How can we improve modeling to provide reliable predictions of performance?
- Ensure that we are placing confidence in the right design parameters.

More successful applications of AC → Greater confidence in expected success → Risk becomes more strongly impacted by critical variables → Greater chance for any failure to be *catastrophic*

- Of several parameters evaluated by WSP, only two impacted remedy design to a point of "*catastrophic failure*", owing to a reduction in AC performance by:
  - Kinetics – Reduction of AC capacity from 10^6 to 10^5 L/kg.
  - Nonuniformity – Reduction in residence time due to increased groundwater upwelling velocity.



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Summary & Key Takeaways

1. Testing data has demonstrated that PAC will out-perform GAC – but particularly in a dynamic advection-driven environment (e.g., where GAC adsorption speed is slower than the advective transport).

2. Modeling and implementation of mixed GAC-Sand caps can have issues which can significantly increase Risk-of-Remedy.

3. Long term monitoring of installed caps is needed to validate performance expectations and assumptions.

Thank You!

John A. Collins

COO

jcollins@aquablok.com

Moses Ajemigbitse, PhD

VP Engineering Research

majemigbitse@aquablok.com

AquaBlok

175 Woodland Ave.

Swanton, OH 43558

(419) 825-1325

www.aquablok.com

Partners:

CDM Smith

listen. think. deliver.

Keegan Roberts, PhD, PE (CO, LA, MI, WI)

Associate

Todd Burgesser, CHMM

Denver Treatability Laboratory Manager

Wardah Azhar, PhD, PE

Formerly CDM Smith, now Parsons.

Important Questions for Implementation of AC in Contaminated Sediment Remediation

1. Have the effects of amendment particle size on the performance and implementation of AC-based remedies for sediment cleanup been adequately evaluated?

2. Is modeling of AC-based sediment remedies impacted by existing assumptions?

   - Real Impact of Residence Time and Kinetics on Remedy Performance
   - Differences in Modeling Assumptions vs. Real World Placement Scenario

3. Based on data obtained, are we comfortable with some of the typical design assumptions – How is Risk-of-Remedy Impacted?