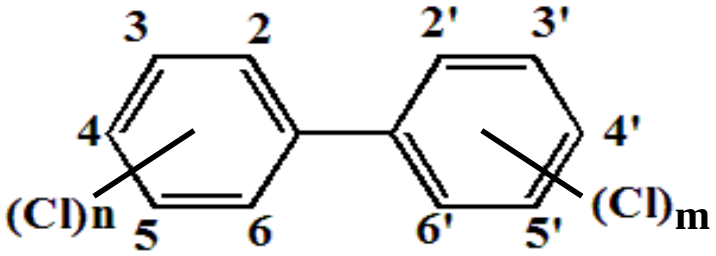
Removal of the toxic contaminants PCBs and PAHs by urban BMPs

STAC Workshop Contaminants of Concern in Ag/Urban Settings

Baltimore: May 22, 2019

Background



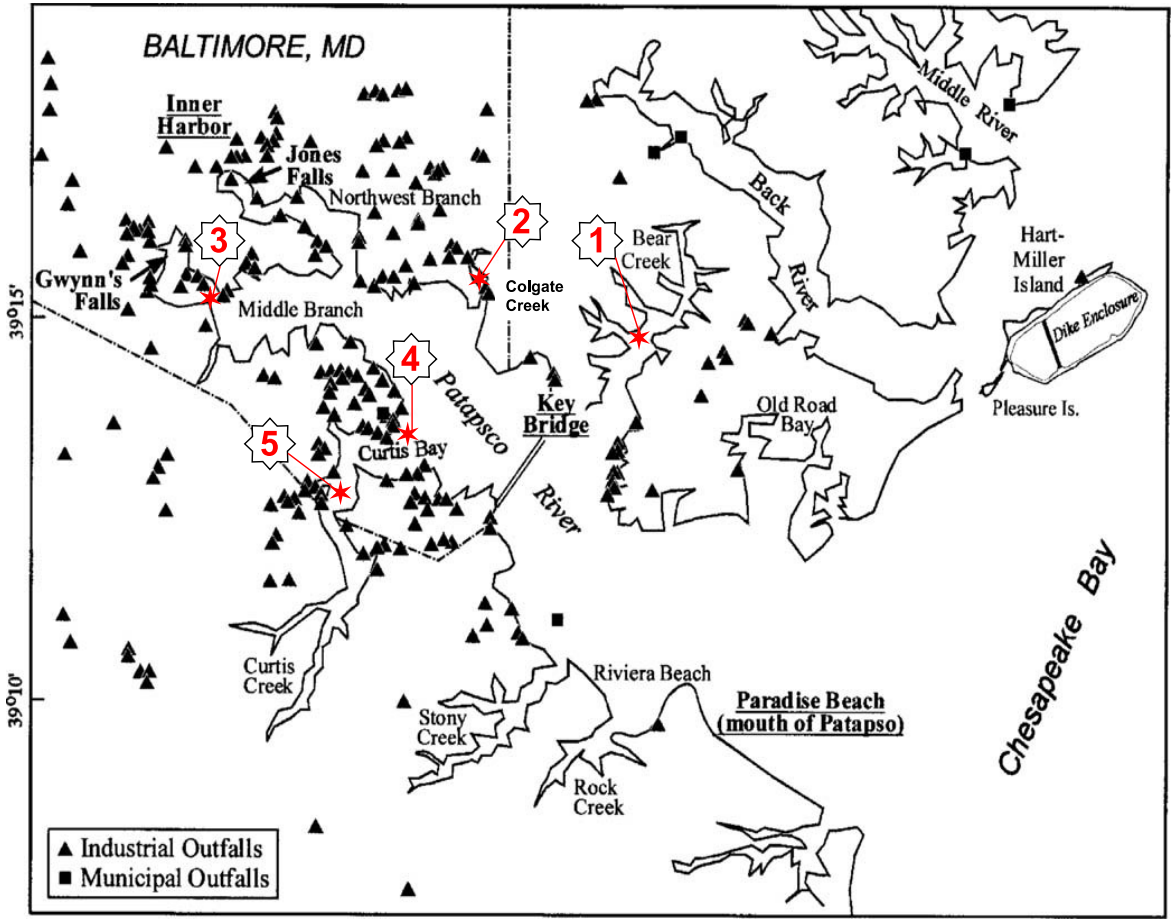
Polychlorinated Biphenyls (PCBs):

- No odor;
- Colorless-light yellow;
- log K_{ow} (4.50-8.26)-hydrophobic;
- number of chlorines ↑, K_{ow} ↑;
- Persistent Organic Pollutants (POPs)
- Coolants and lubricants in transformers, capacitors, and other electrical equipment.

Today:

- Presence of PCBs in sediment in Baltimore Harbor
- PCBs in stormwater particulate matter from highways and in wastewater effluent
- Biofilm based bioremediation of PCBs in sediment
- Introduction to new SERDP project: “Treatment Media for Control of Persistent Organic Pollutants and Metals in Stormwater”

PCBs in Baltimore Harbor: Example



Locations of sediment samples

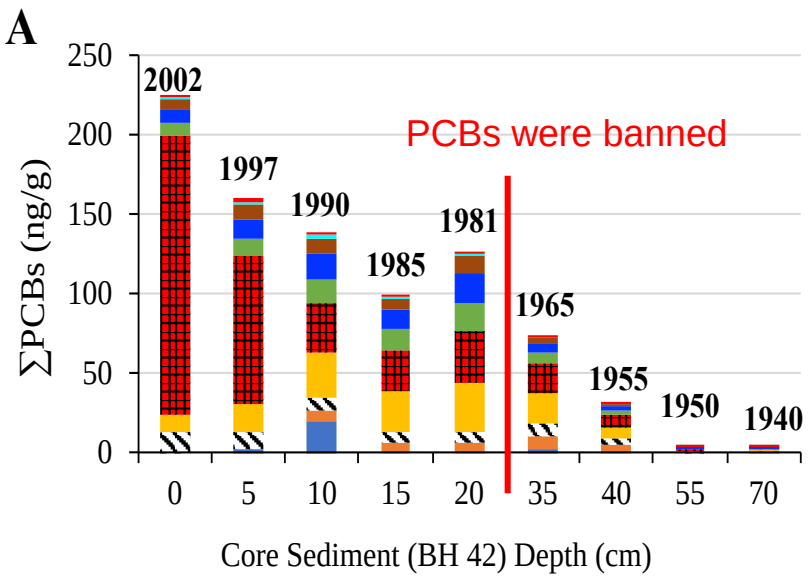
Surface grabs:
1) Highway (HWY) 157
2) Colgate Creek
3) Hannover Bridge,
5) Curtis Creek

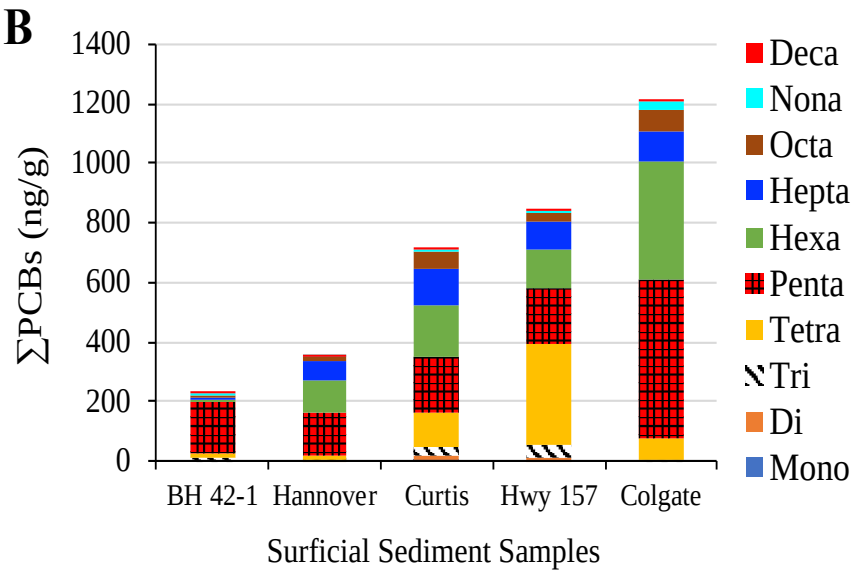
Core sample:
4) BH 42

Locations of municipal (squares) and industrial discharges (triangles) - modified from Ashley and Baker, 1999).

Kaya et al (2019), Sci. of the Total Env.

PCBs in Baltimore Harbor: Example



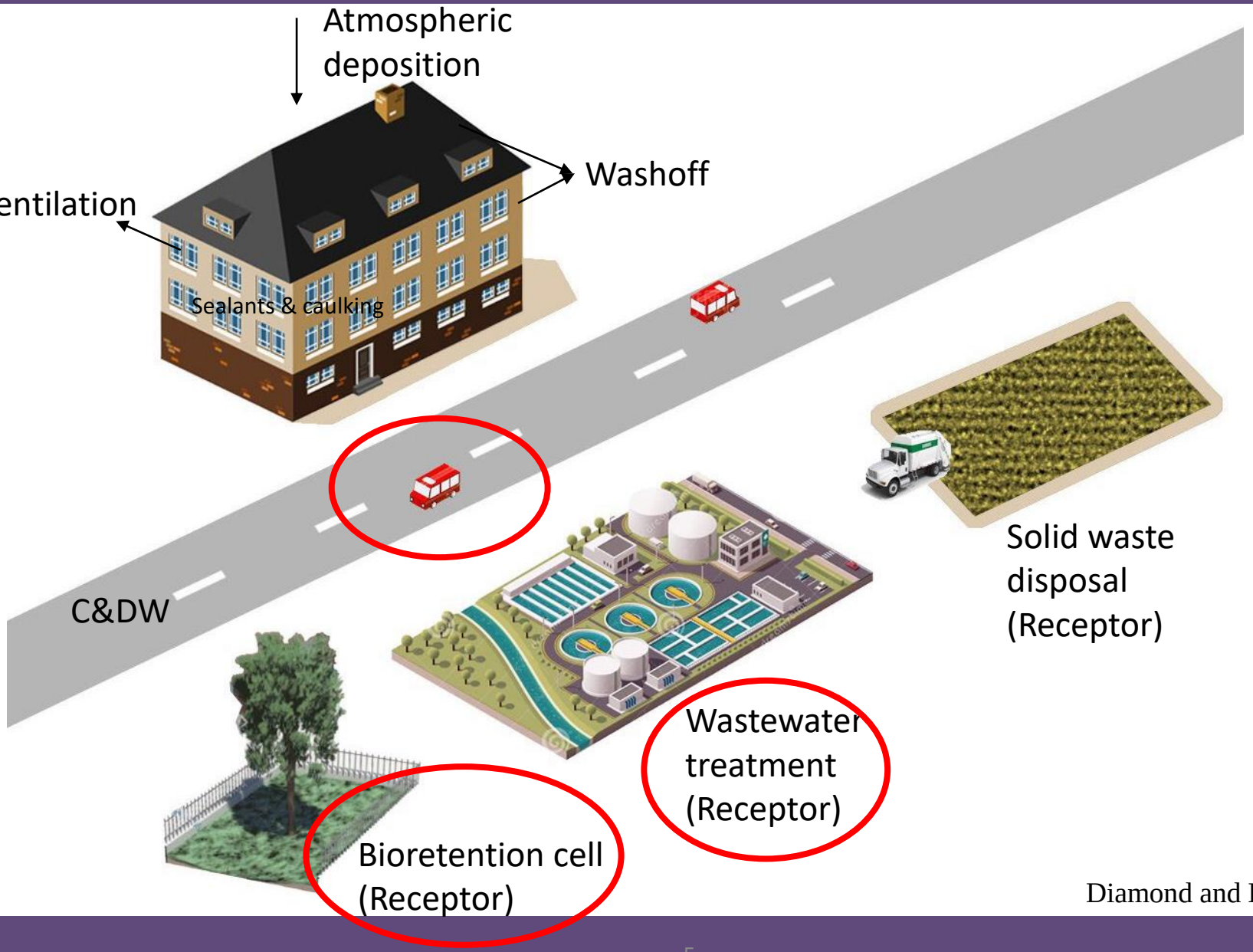


Summary:

- The presence of PCBs has increased over the past 80 years in Baltimore Harbor
- The national ban on production of PCBs in the 1970es had no effect
- Current sources are present in the urban environment (Here: BH)

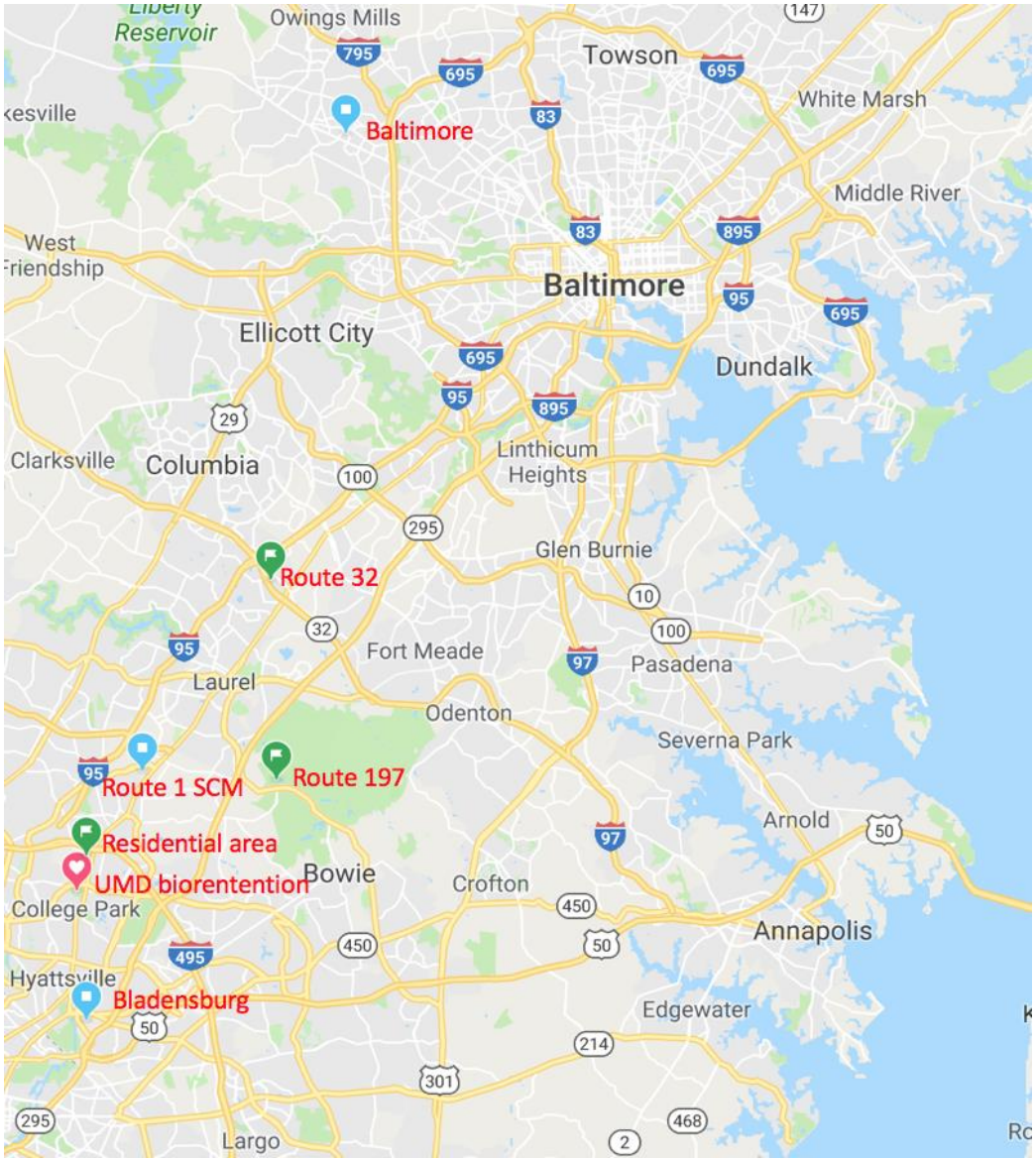
Kaya et al (2019), Sci. of the Total Env.

Sources and receptors of PCBs



Diamond and Hodge, 2007

Map of the sampling sites in MD

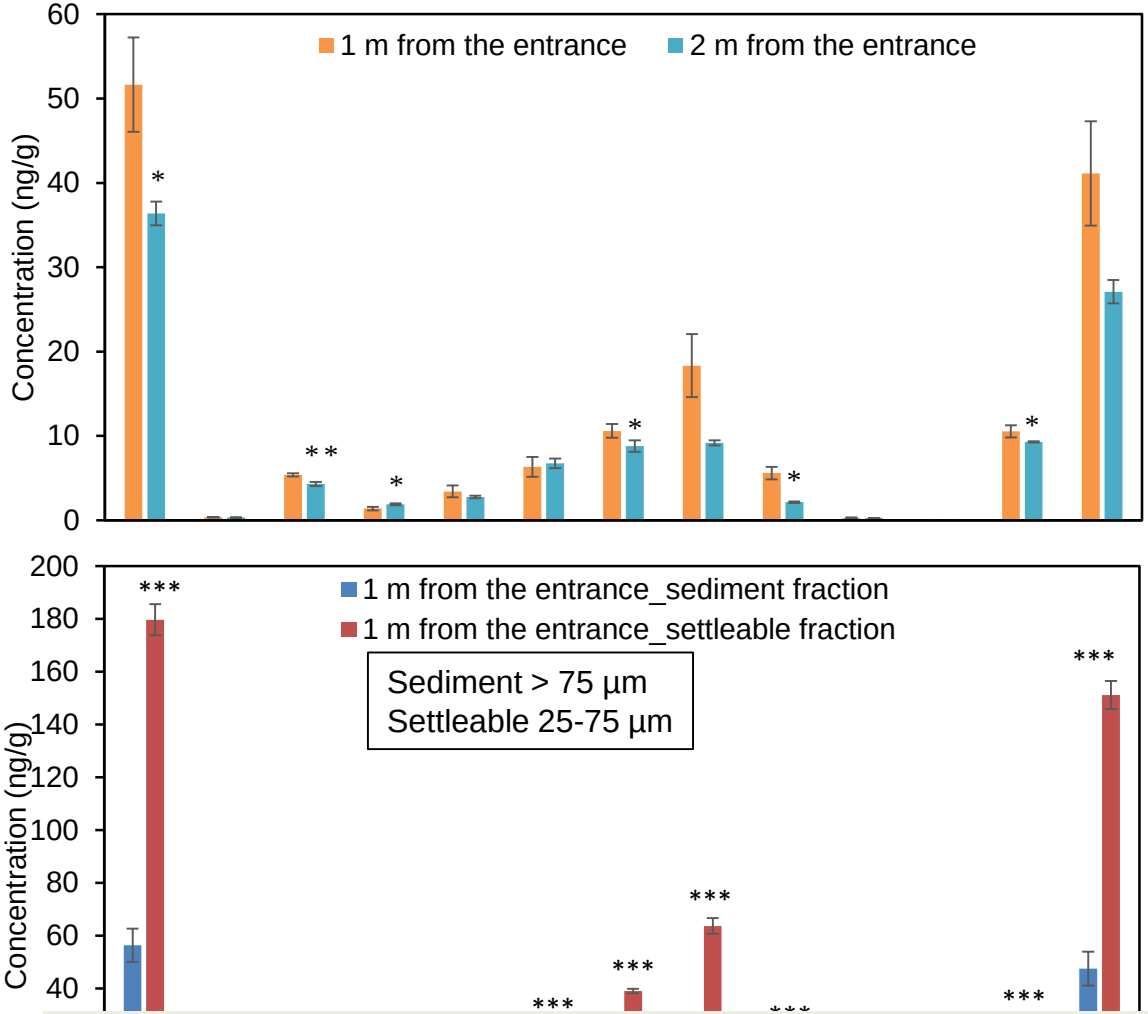


Examples of collected data will be shown.

Manuscript has been accepted to Water Research (under revision)

Cao et al (2019), Water Research

PCB concentrations at Bladensburg

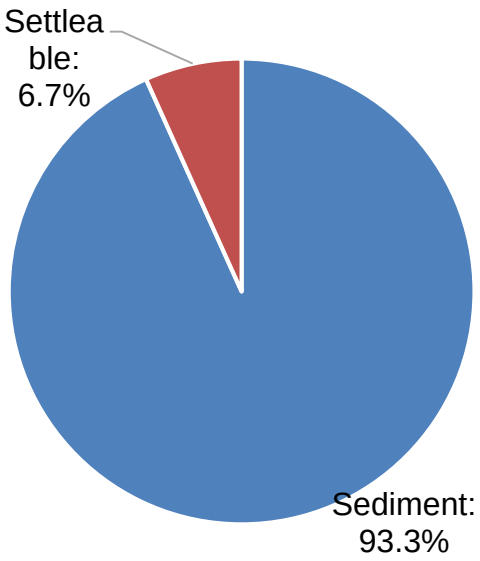


Summary:

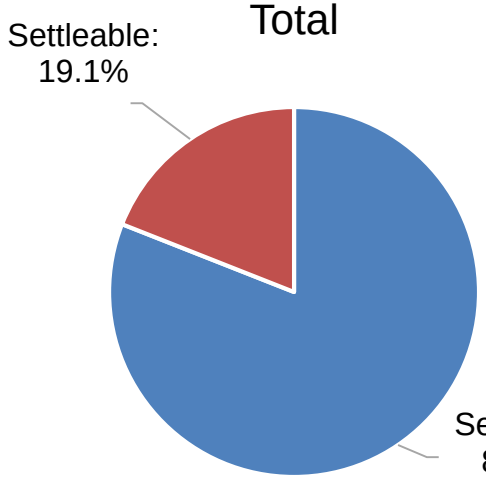
- Similar homologue pattern in the 2 samples
- PCBs with 5-7 chlorines were dominant congeners
- PCB concentration in settleable >> sediment fraction at 1 m from the entrance

Mass of PCBs in different fractions at Bladensburg

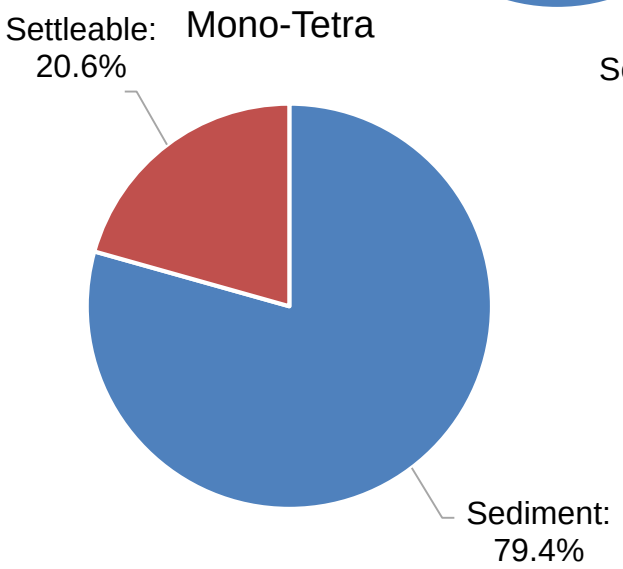
Sediment > 75 µm
Settleable 25-75 µm



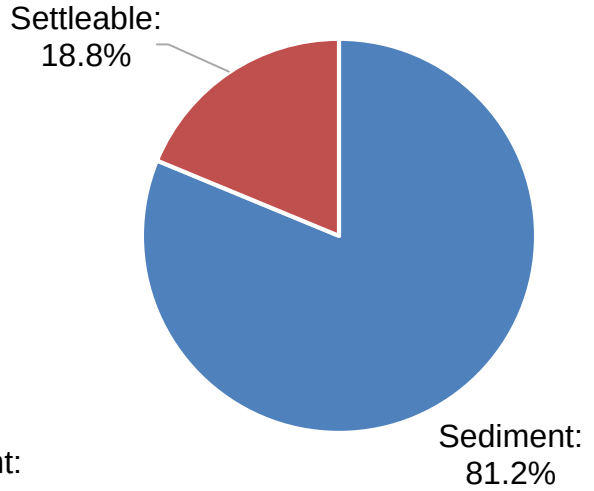
Total



Mono-Tetra



Penta-Deca

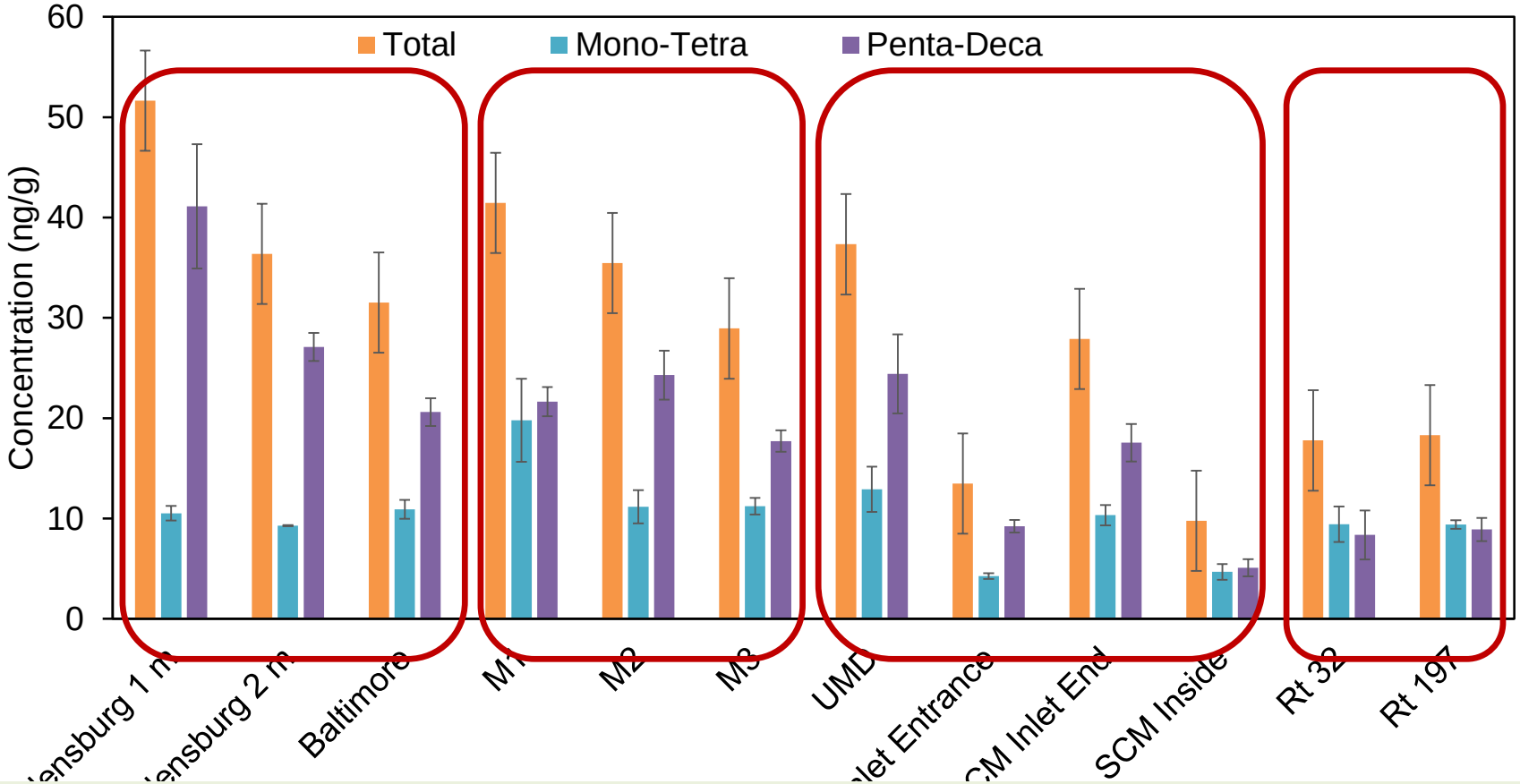


Summary:

- 80% of PCB mass was sorbed to larger sediment particles (> 75 µm)
- No majors differences between congeners

Cao et al (2019), Water Research

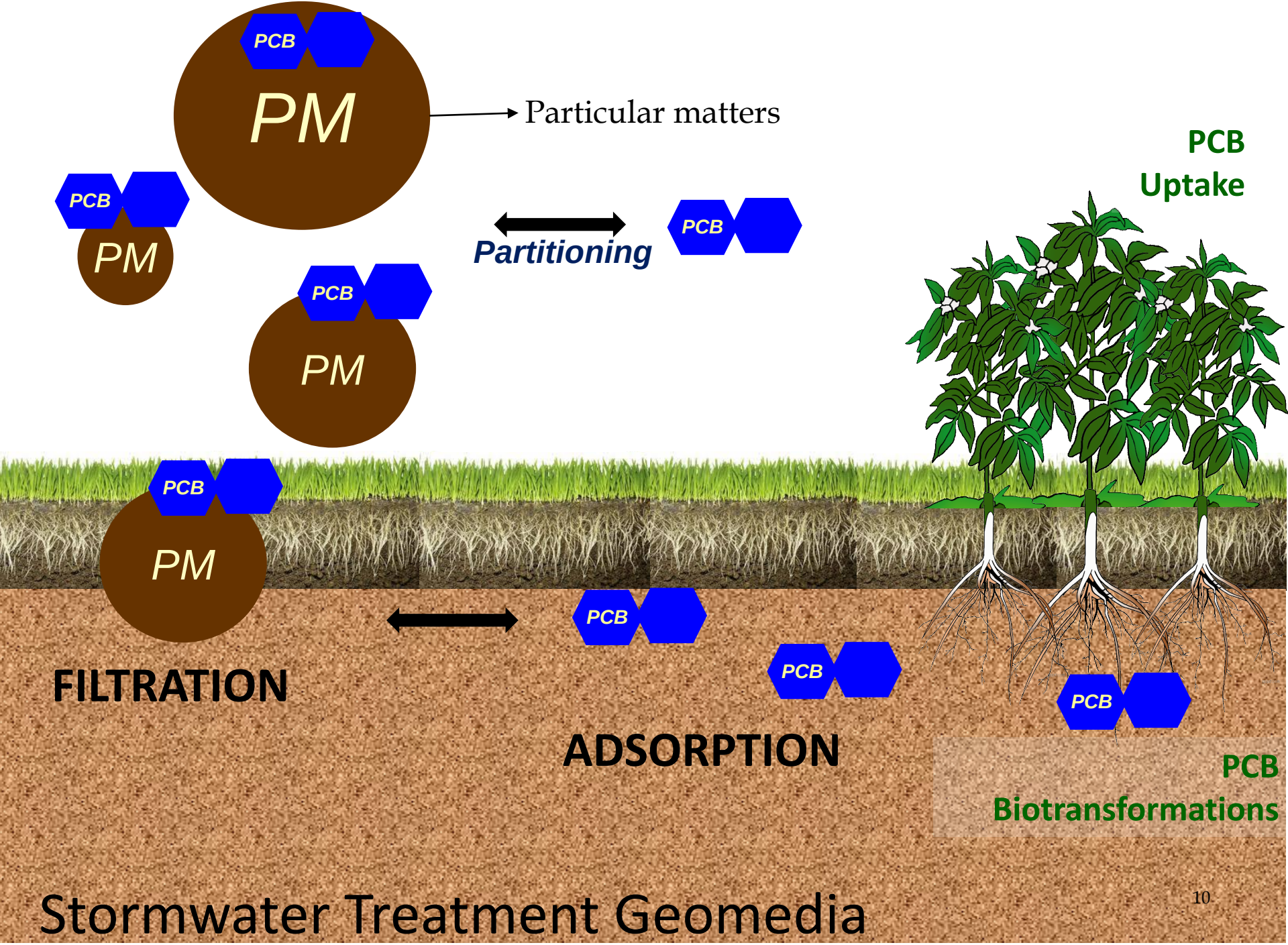
Comparison of the sites



Summary:

- Highest PCBs concentrations at Bladensburg - Surrounding old buildings and roadways could be PCB sources
- Lowest PCB concentration at Route 32 and 197 and different homolog patterns - Could be due to the absence of buildings around

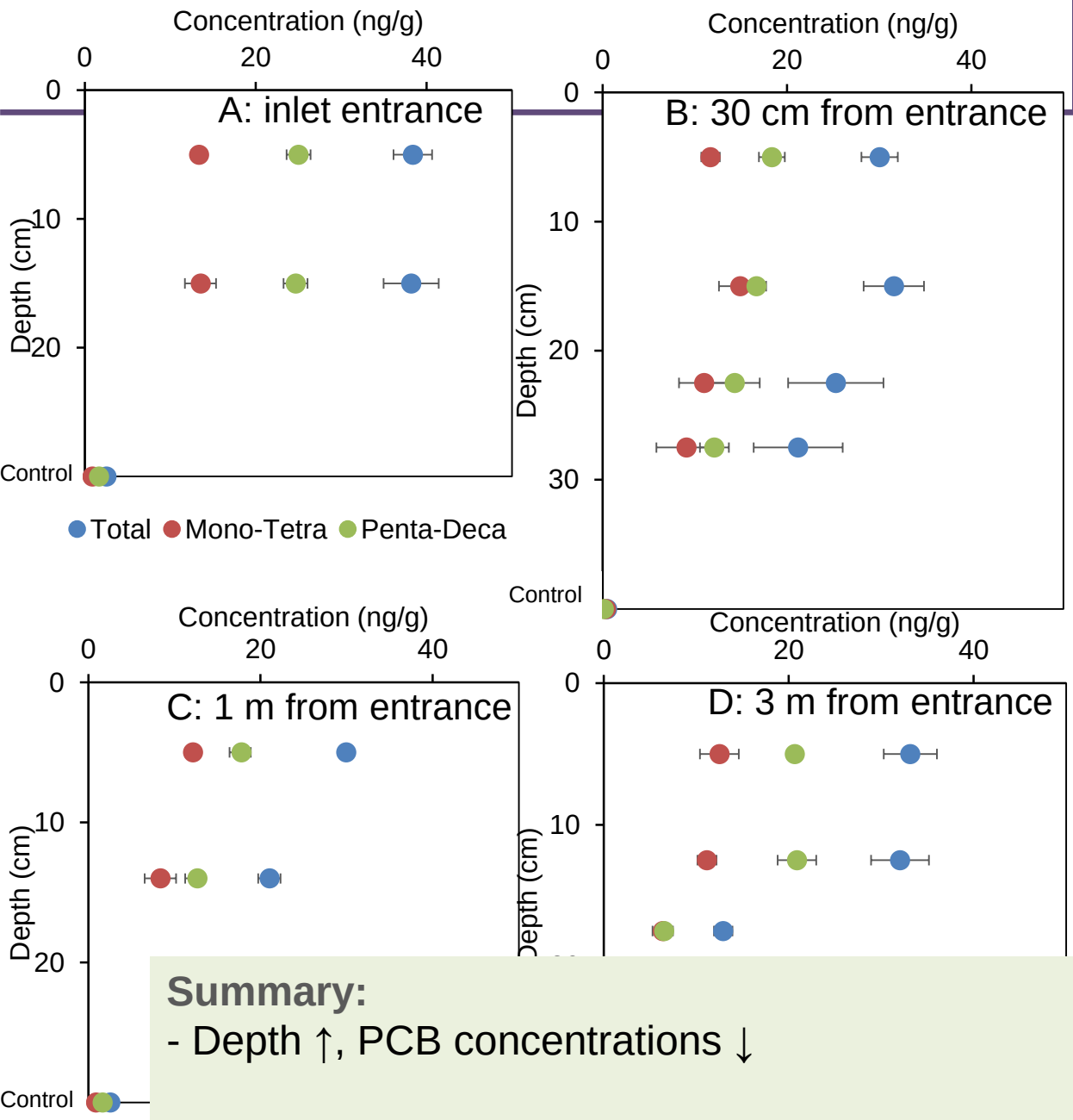
Cao et al (2019), Water Research



Stormwater Treatment Geomedia

UMD bioretention

PCB concentrations in UMD core samples



Summary:

- Depth ↑, PCB concentrations ↓

- Distance from the entrance ↑, PCB concentrations ↓

Cao et al (2019), Water Research

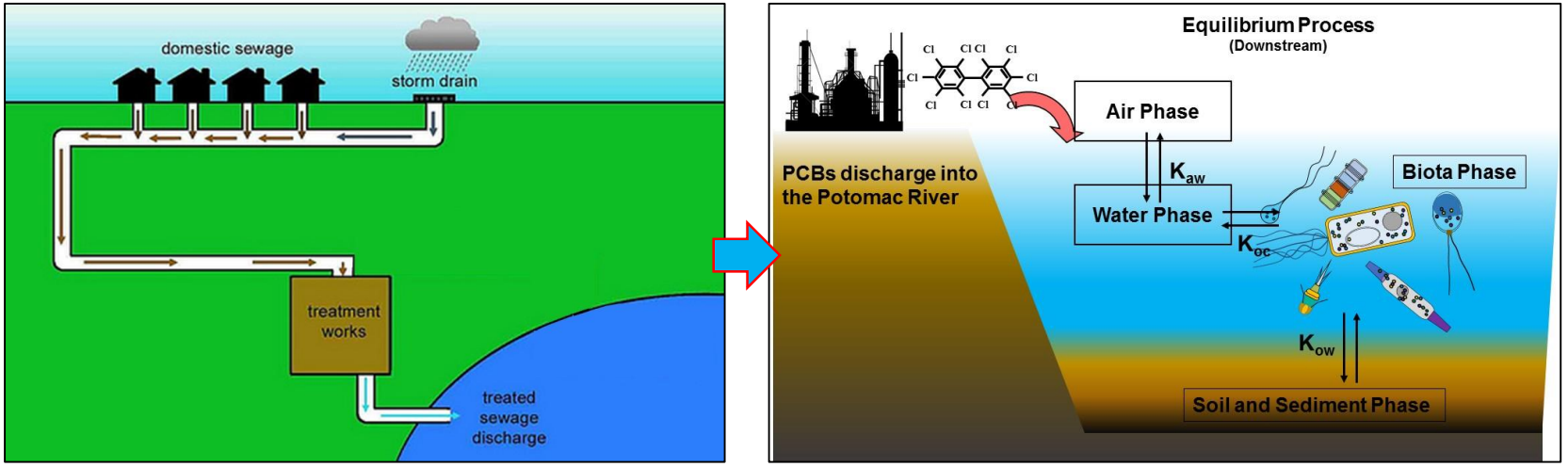
Biotransformation

- Many microorganisms have been reported to utilize and metabolize PCBs as carbon and/or energy sources under both aerobic and anaerobic conditions.
- Under aerobic conditions, lower-chlorinated congeners (≤4 chlorines per biphenyl) are good substrates and they act primarily as electron donors.
- Under anaerobic conditions, highly chlorinated congeners experience dehalorespiration and the number of attached chlorines is reduced.
- Biofilm creates a favorable environment for the growth of microorganisms and increases the possibility of degradation of PCBs.

Other current sources of PCBs

Potential PCB sources in wastewater:

1) Input from Legacy PCB contaminated sites (e.g. Washington Navy Yard)
2) Domestic/Industrial wastewater sources
3) Release of PCBs from waste storage and disposal sites

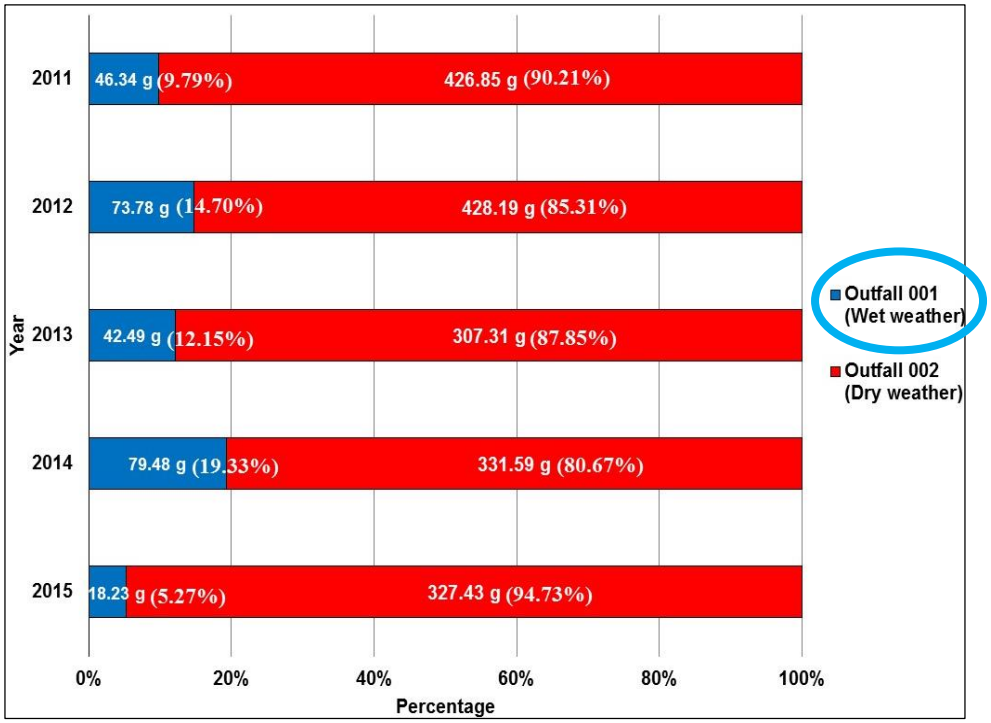


Question: Is the source of PCBs in wastewater mainly caused by the "real" wastewater or the stormwater overflows during rain?

Jing and Kjellerup, JES, 2018

Estimated Annual PCB Discharge

Based on 5 years of monitoring data



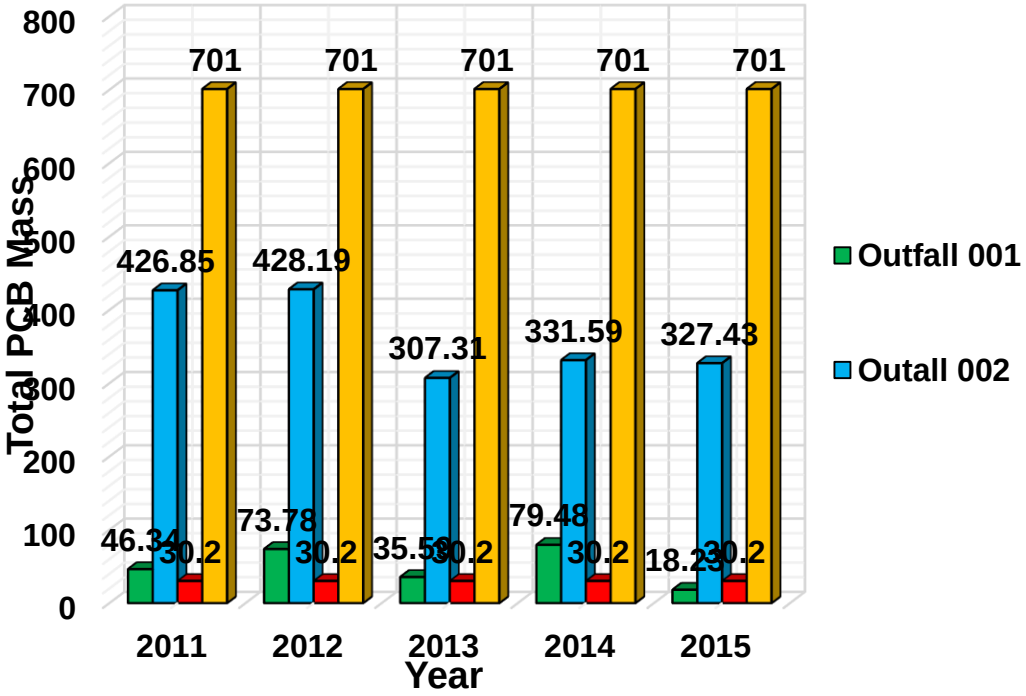
Stormwater contribution

Conclusion: The majority of the PCB mass comes from ”real” wastewater during all seasons.

Jing and Kjellerup, JES, 2018

Annual PCB discharge vs. TMDL

Based on 5 years of monitoring data



Stormwater contribution

Normal process contribution

Current TMDL

Estimate prior to current TMDL

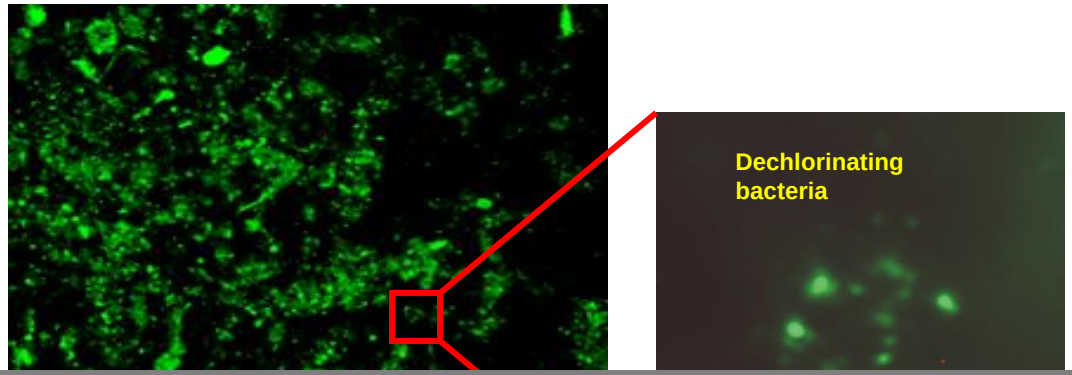
The *Total Maximum Daily Load* (TMDL) - exceeded

→ Actions should be taken

Jing and Kjellerup, JES, 2018

Bioremediation of sediment: Biofilm on GAC

SERDP Project ER-2135 (PI: Kjellerup)



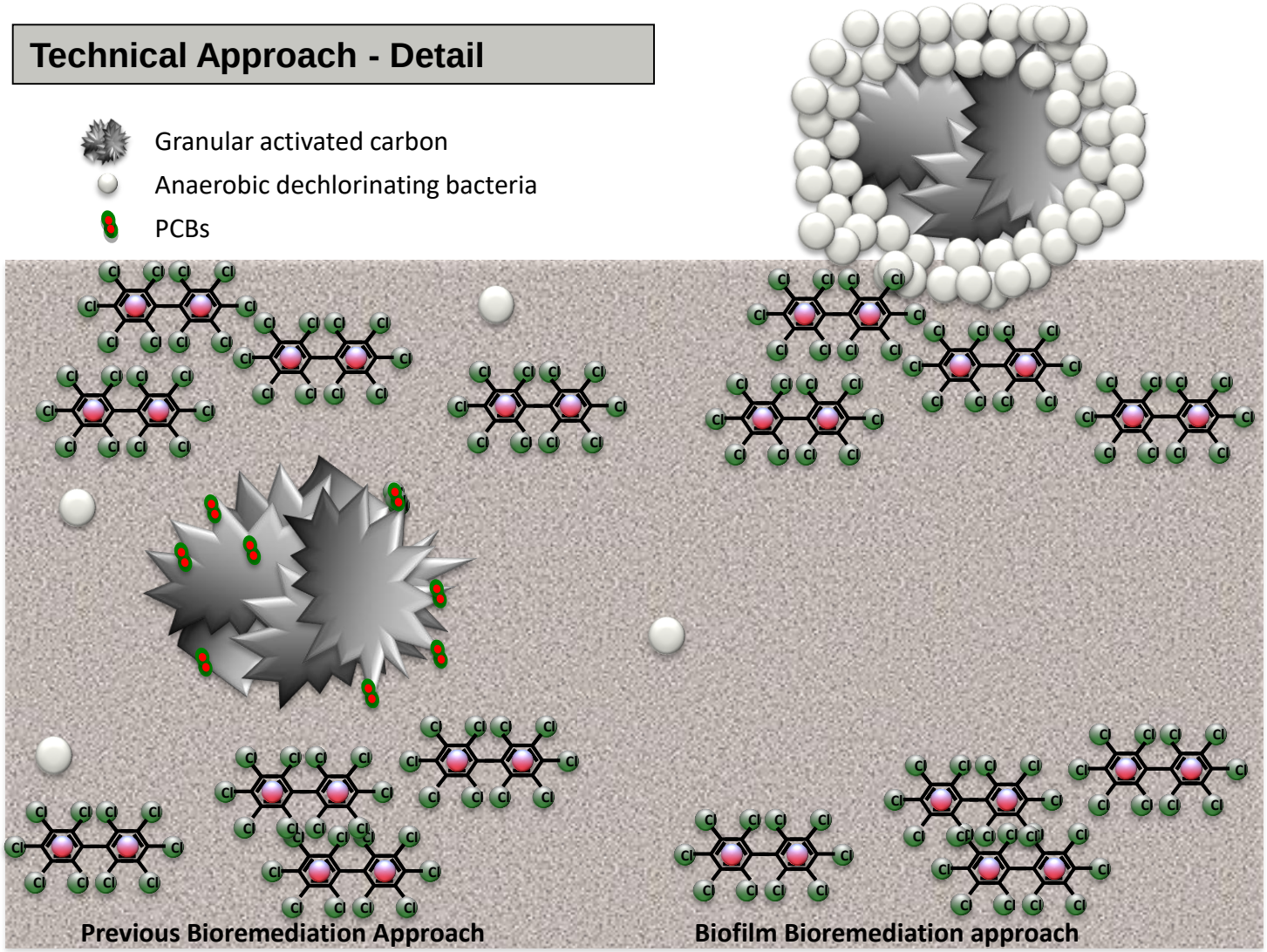
Dual approach:

1. Adsorption of PCBs on activated carbon
2. Biofilm instead of liquid inoculum for bioaugmentation?

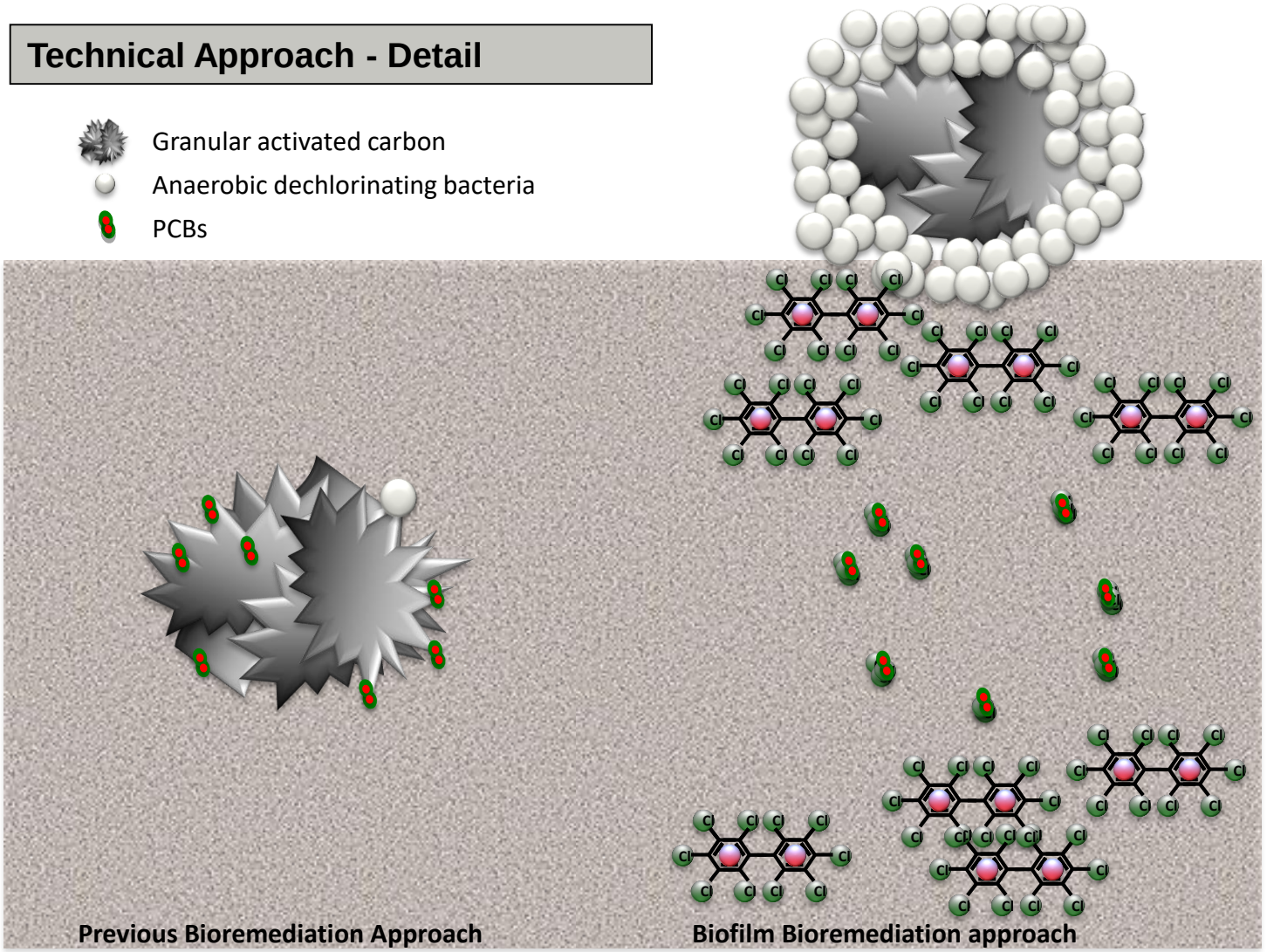
Objective:

Apply **biofilm** communities to PCB contaminated sediment as a **delivery system** to enhance dechlorination

Technical Approach - Detail



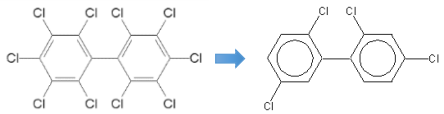
Technical Approach - Detail

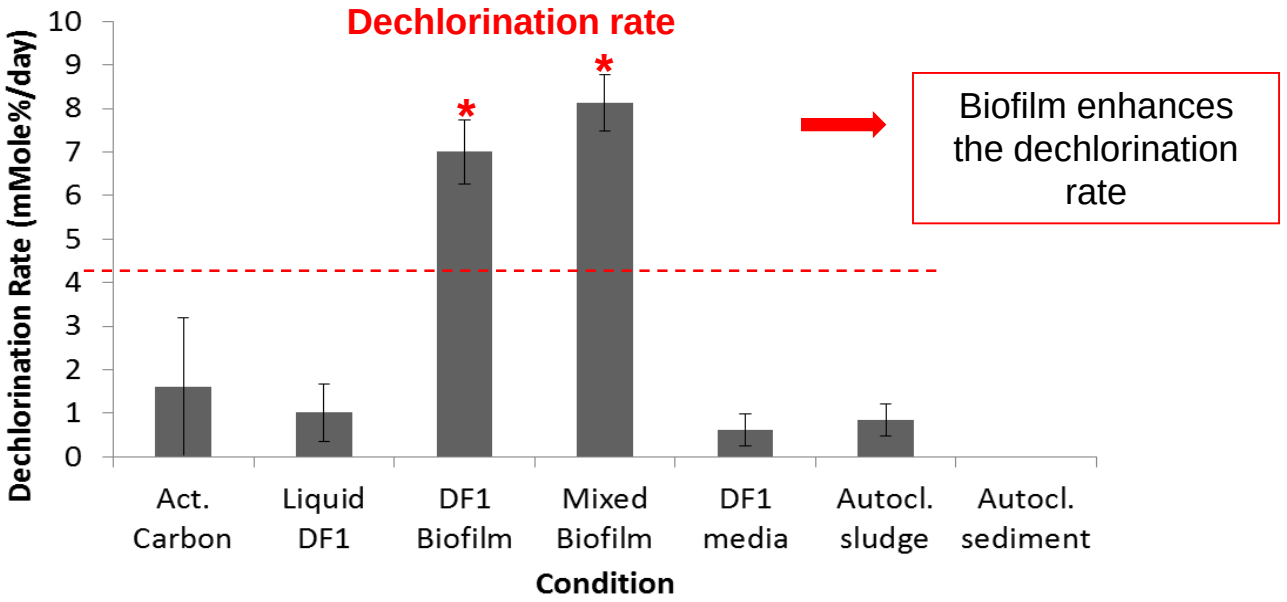


Effect on dechlorination?

Sediment mesocosms from Grasse River, NY

- **Two types of biofilm inoculum**

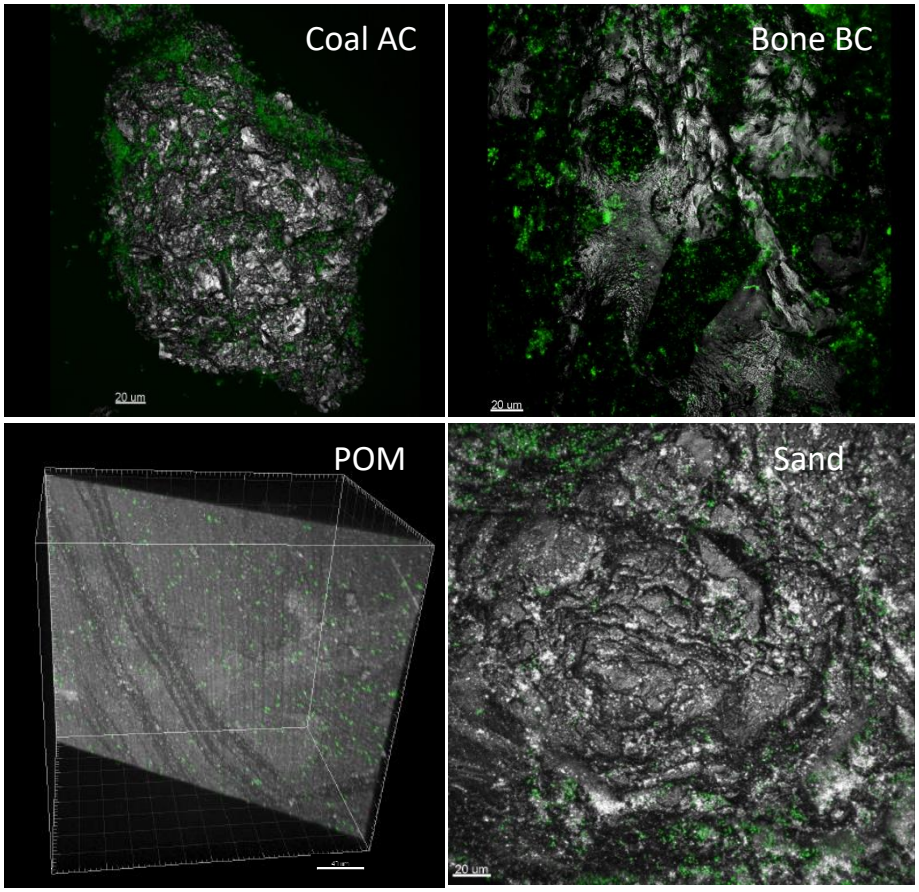




* Statistical significance <30% - EPA Standard

Edwards et al, 2019 (In prep)

Effect: Biofilm presence?



Best materials for biofilm formation:

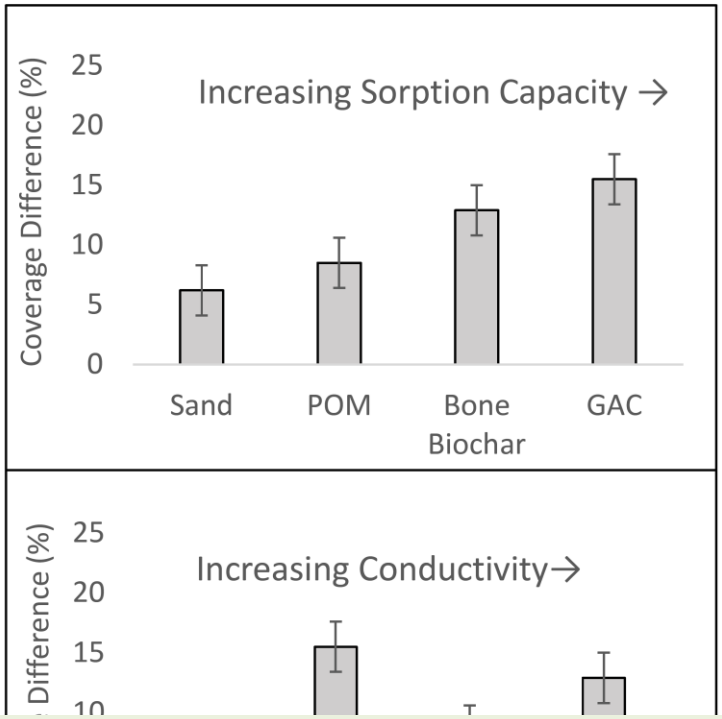
- **Biochar**
- **Activated carbon**

Are **sorption capacity** and **electrical conductivity** also important parameters in addition to biofilms?

-YES

S. Capozzi et al, Biofouling, 2019

Effect: Sorption capacity & conductivity?



Increased **biofilm coverage** with increasing **sorption capacity**

No increased **biofilm coverage** with increasing

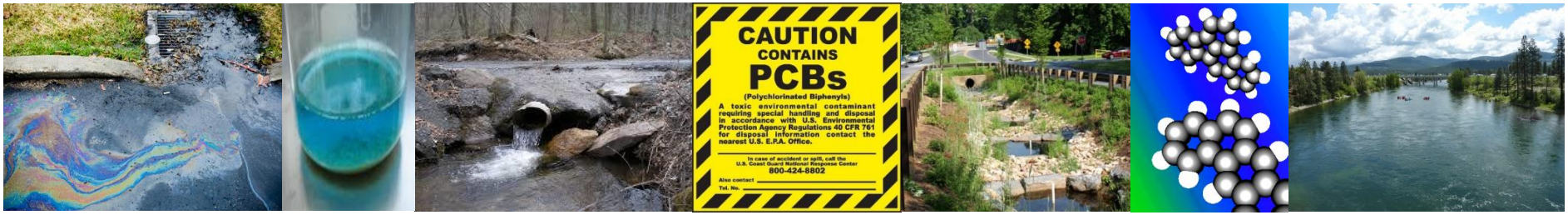
Summary:

- Biofilms increase PCB dechlorination
- Increased sorption capacity increases biofilm formation

→ Existing PCB contamination can be treated

HOW TO AVOID RECONTAMINATION??

Treatment Media for Control of Persistent Organic Pollutants and Metals in Stormwater (New Start: ER18-C3-1303)

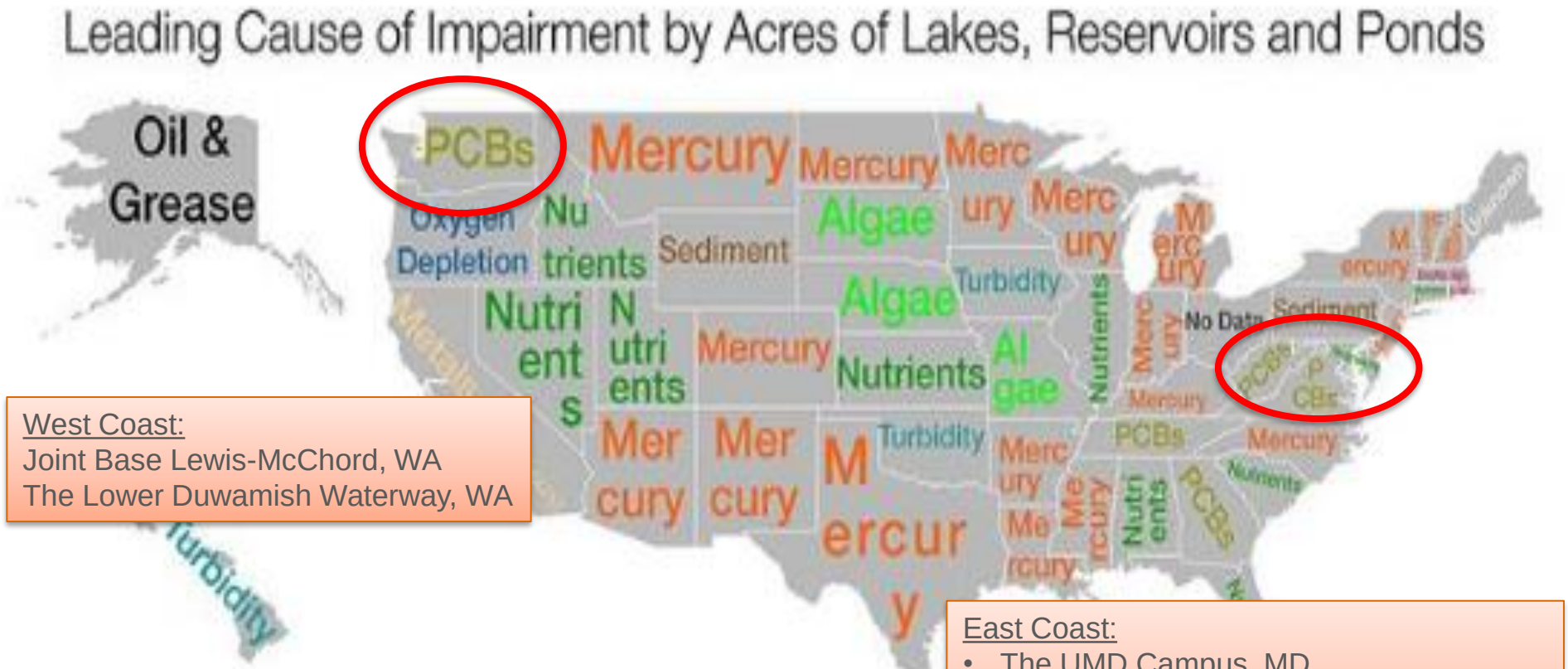


Principal Investigators: Dr. Birthe V. Kjellerup (PI) & Dr. Allen P. Davis (Co-I), University of Maryland at College Park, MD

Technical Objective

To develop new and innovative treatment media or mixes of media to provide optimum removal of Persistent Organic Pollutants and metals, with focus on PCBs, PAHs and copper, from stormwater runoff originating from DOD sites.

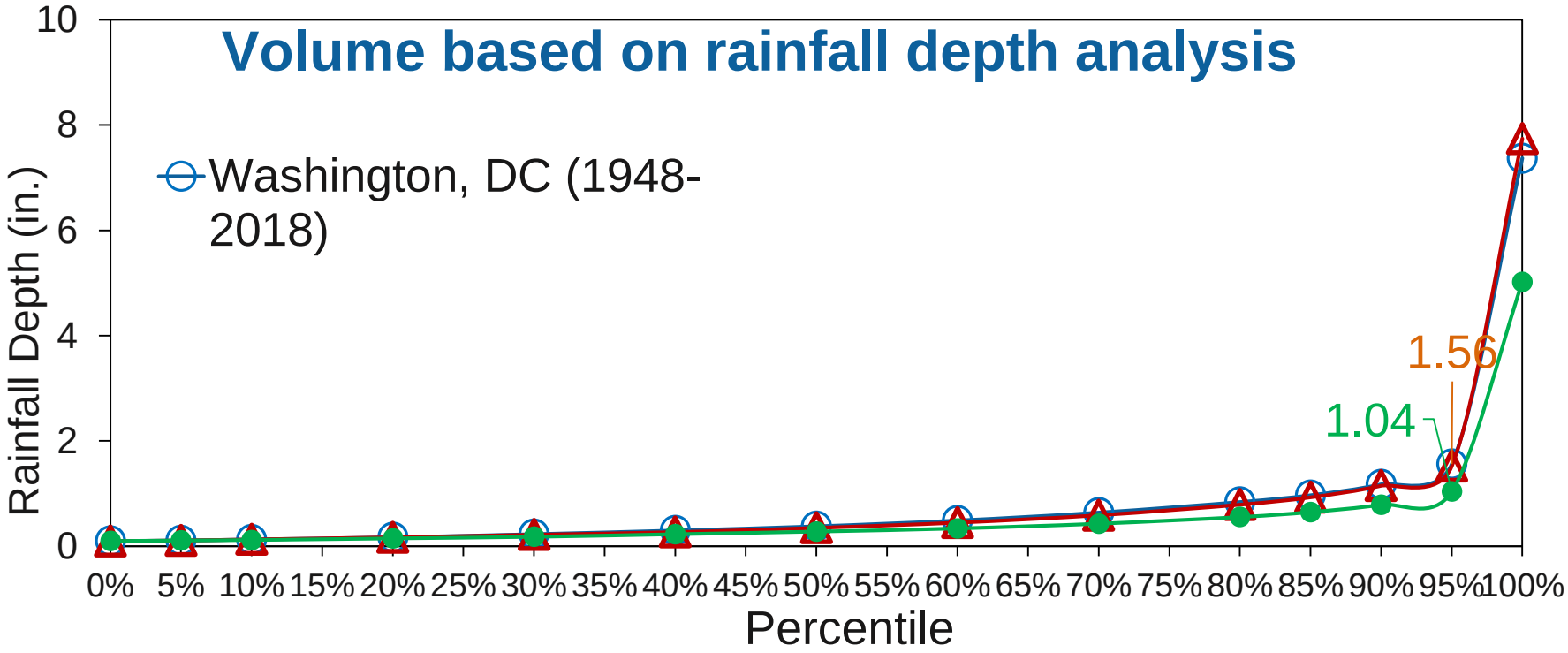
- Focus on removal of dissolved COC (particulate COC readily removed)
- Treatment train: 1) Removal of adsorbed PCBs/PAHs (via sorption), 2) microbial degradation of PCBs/PAHs, and 3) copper immobilization
- Monitoring using passive sampling
- Scale-up, implementation and commercialization aspects will be considered (**NO** Field studies)



West Coast:
Joint Base Lewis-McChord, WA
The Lower Duwamish Waterway, WA

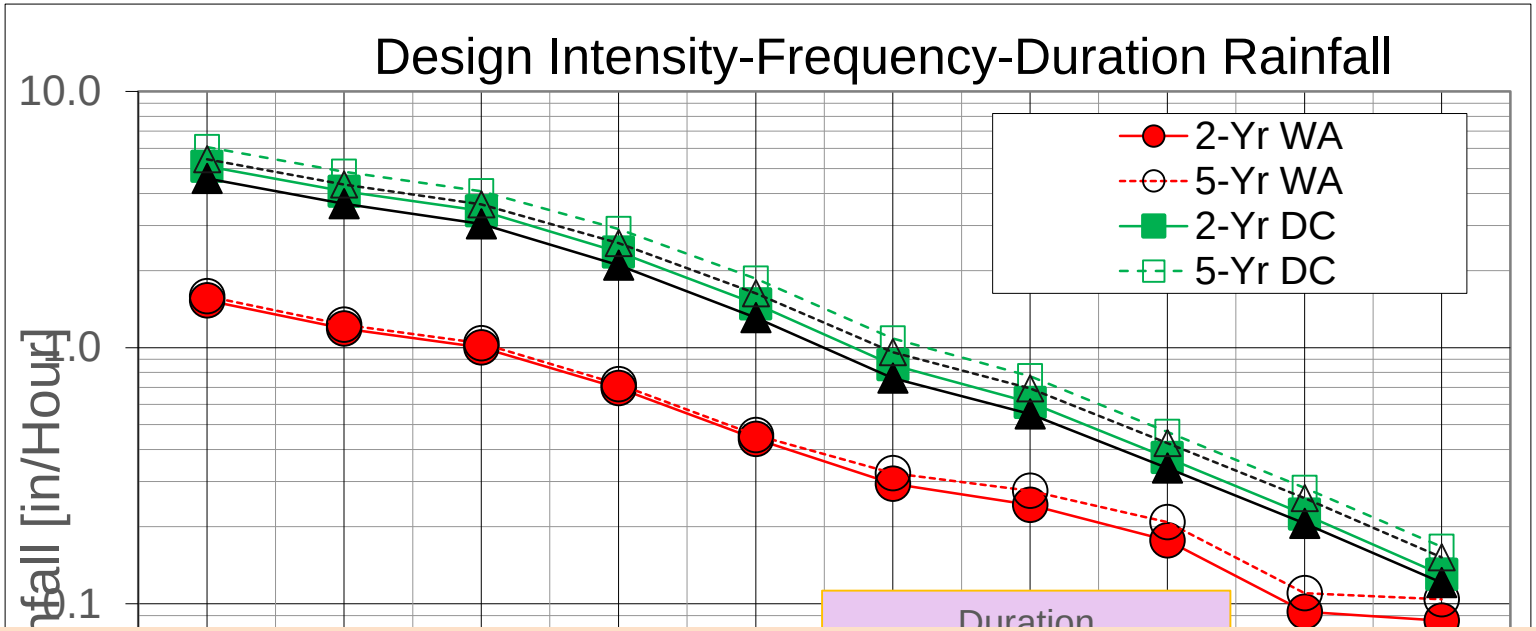
East Coast:
- The UMD Campus, MD
- Naval Support Activity Mechanicsburg, PA
- The Naval District Washington, DC

Collection of weather and hydrological data for involved sites (I)



Volume of stormwater in columns:
- 95% of all rain events < 1-1.6 inch
→ 95% will be captured, 5% will overflow

Collection of weather and hydrological data for involved sites (II)



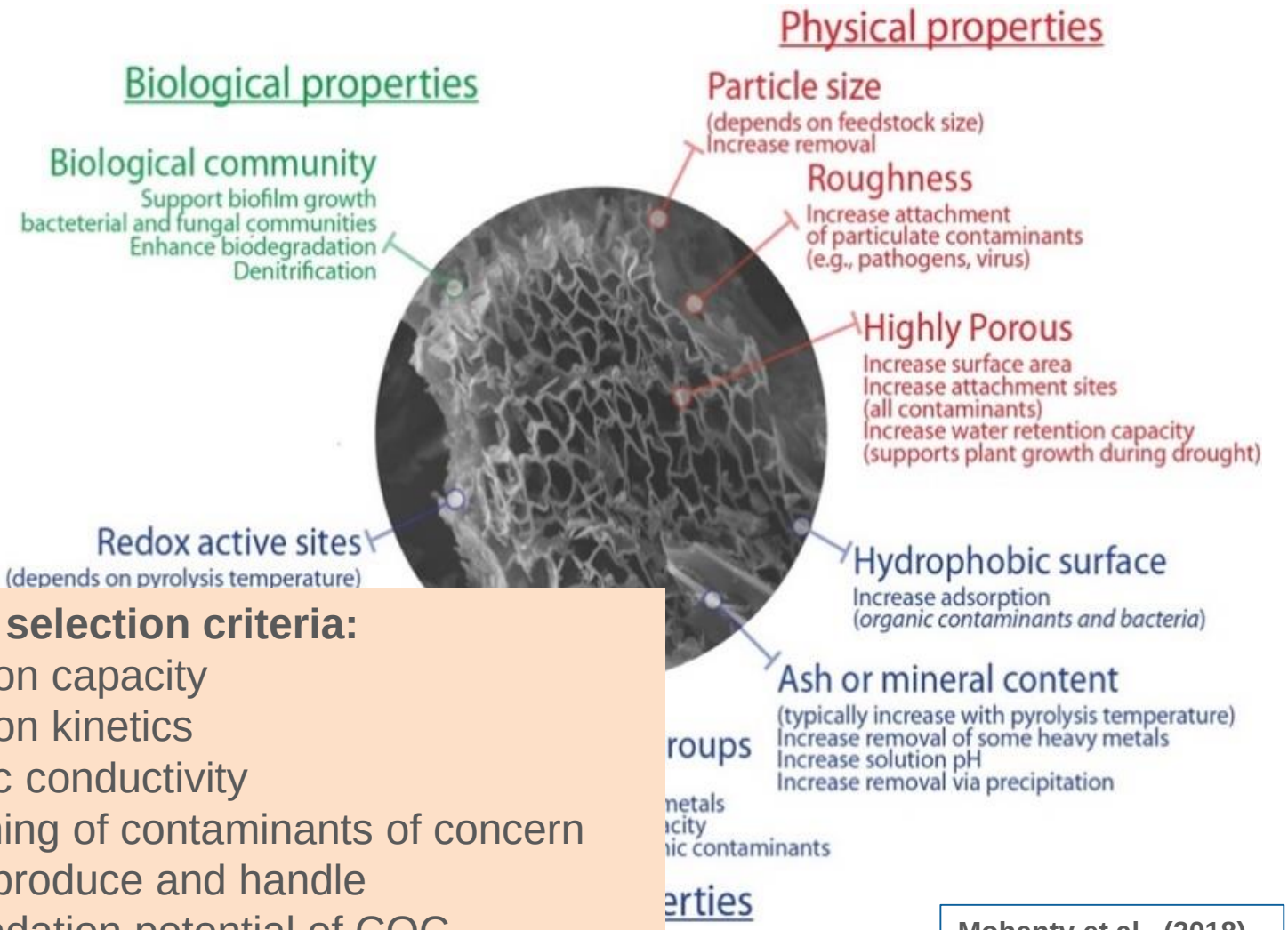
Flow rate of stormwater in columns:

- Biggest storms to be expected: 2, 5 years
- Duration: 1-6 h
- The largest storms will not be treated!

→ 0.1-1.5 inches per h

Prediction of weather and hydrological data due to climate change

Selection of Geomedia?
Selection of Geomedia



Pragmatic selection criteria:

1. Adsorption capacity
2. Adsorption kinetics
3. Hydraulic conductivity
4. No leaching of contaminants of concern
5. Easy to produce and handle
6. Biodegradation potential of COC

Mohanty et al., (2018)

Selection of Geomedia?

- Metals
  - Mineral-rich biochar
  - Oxidized-activated carbon
  - Chitosan amendment
  - Zero-valent iron

Granular Activated Carbon

Biochar

- Organics
  - Activated Carbon (coke-derived, rice husk)
  - Biochar
  - Wood ashes

Rice husk

Wood ashes

Chitosan

Summary

- PCBs are not only legacy contaminants
  → current sources exist (stormwater, wastewater)
  - Buildings contribute more PCBs than roads
- PCB 11 (3-3'-PCB) was detected in all samples
  → Marker of non-legacy PCB contamination
- PCB concentration and toxicity decreases
  - with depth in bioretention cell and distance
- Smaller stormwater particles sorb more PCBs
  - larger particles contribute more mass
- Sediment capture may be a viable treatment for stormwater PCBs.
- PCB-dechlorinating bacteria exist in soil biofilms
- Biofilms on GAC is effective for PCB degradation

Particle size↓ - sorption↑

→ Potential for on-site bioremediation and clean-up

Acknowledgements

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Questions?