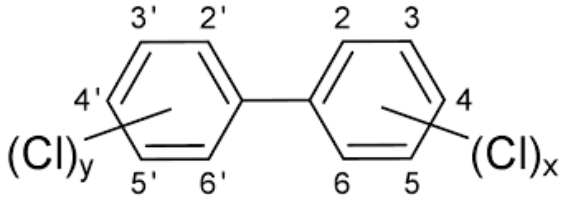
Presence and Treatment of Persistent Organic Pollutants and Metals in Stormwater

Birthe V. Kjellerup, Ph.D.
Dep. of Civil & Environmental Engineering
University of Maryland, College Park

PCBs: An environmental Legacy?

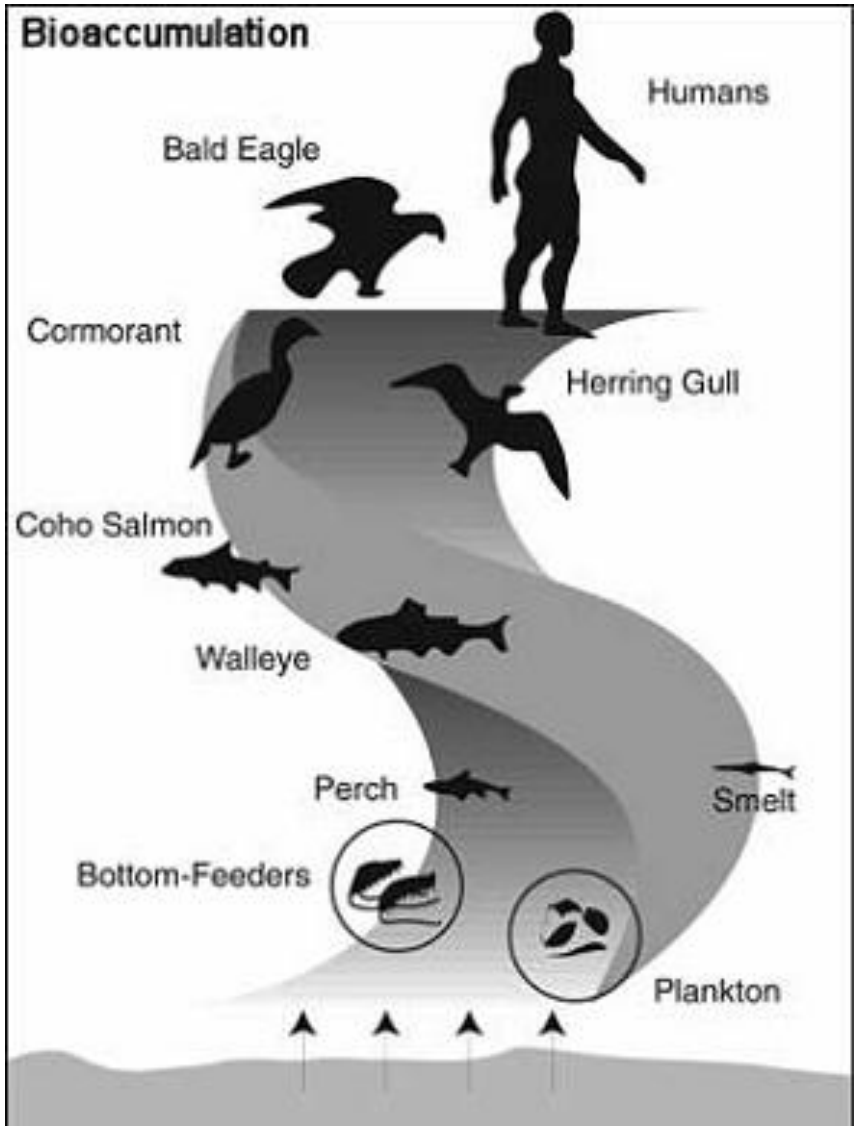


1865

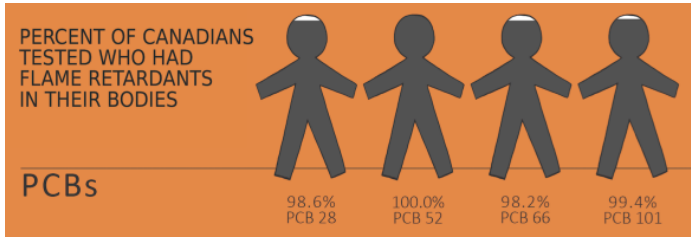
1970s

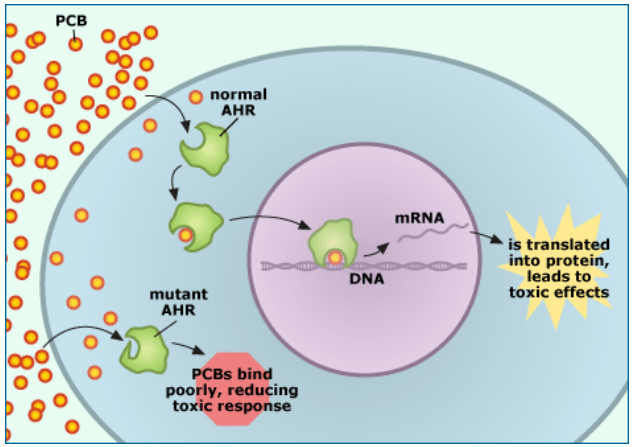
Estimate:
0.6-1.2 billion kg worldwide

Why are PCBs of concern?

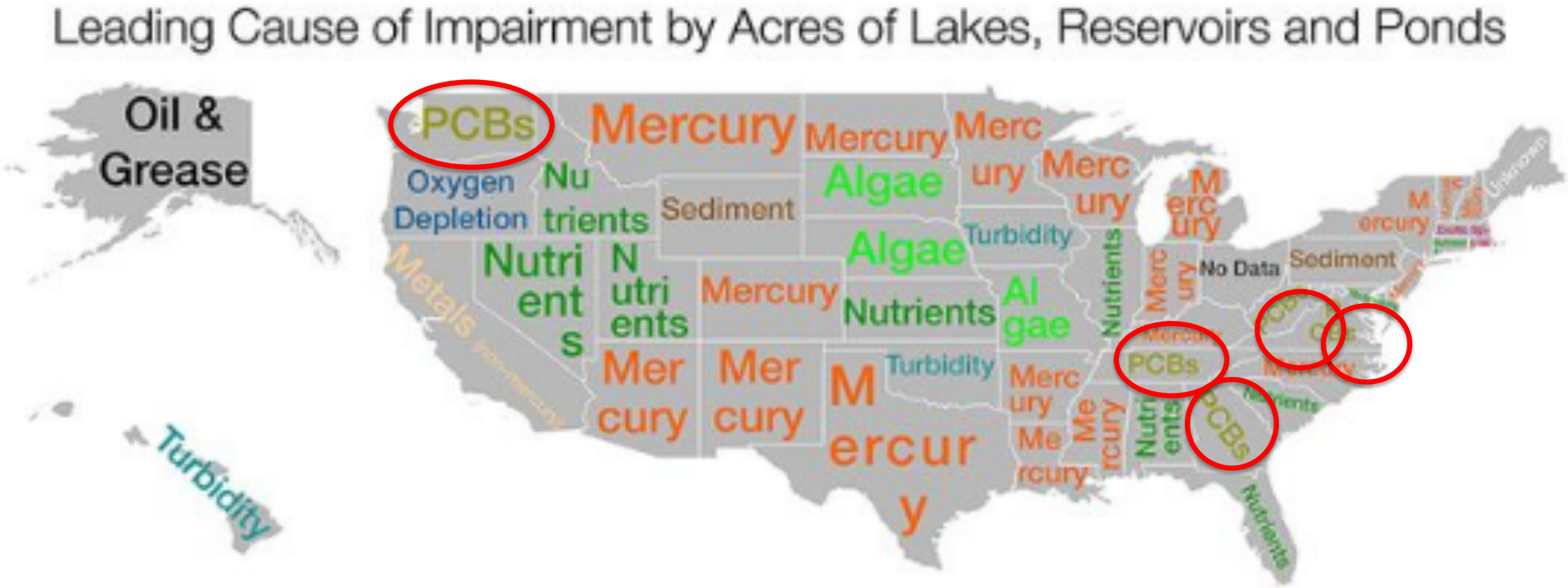


- Bioaccumulates and biomagnifies in the food chain
- Sediments/soils **= global sinks**
- Toxicological effects: Cancer, problems with endocrine and reproductive organs as well as immunological issues
- Humans: Source - ingestion (sea food, meat, poultry etc.)





Causes of water impairment in the US



PCBs in sediment – Baltimore Harbor

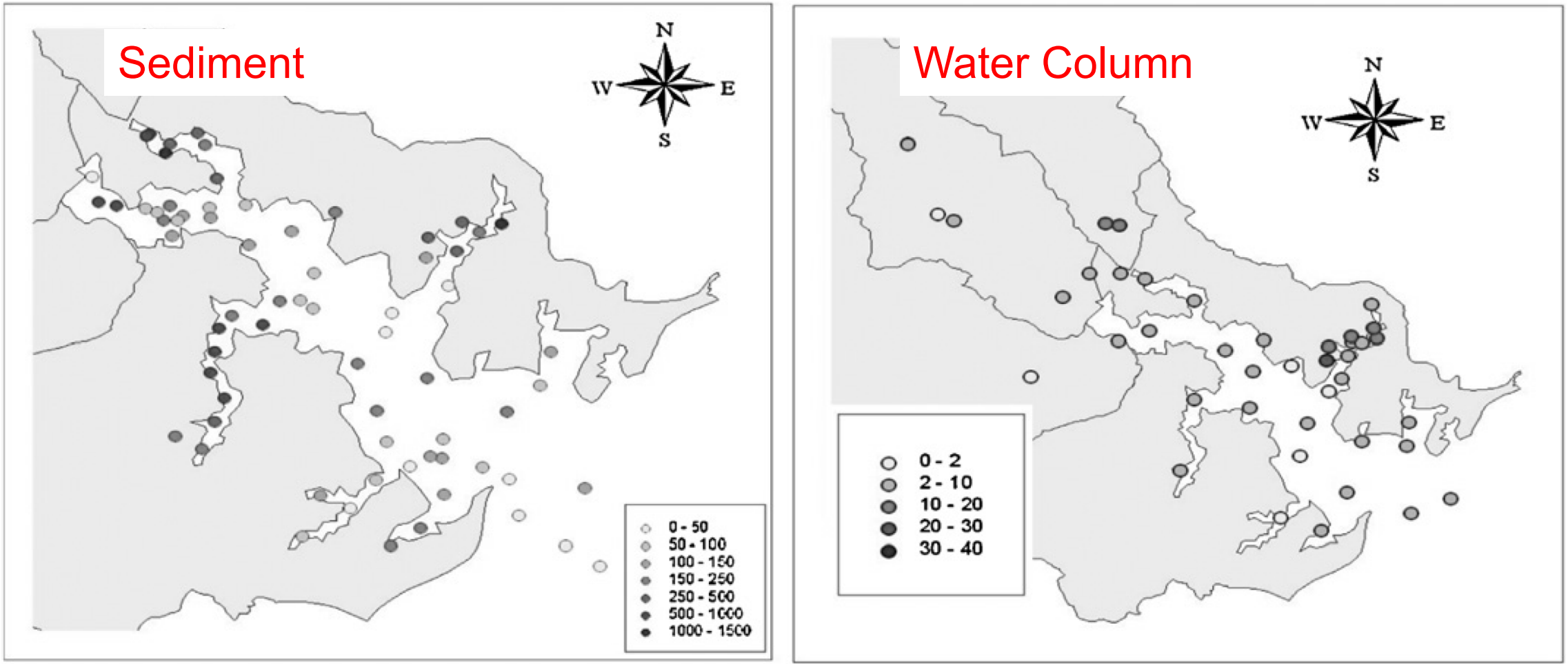
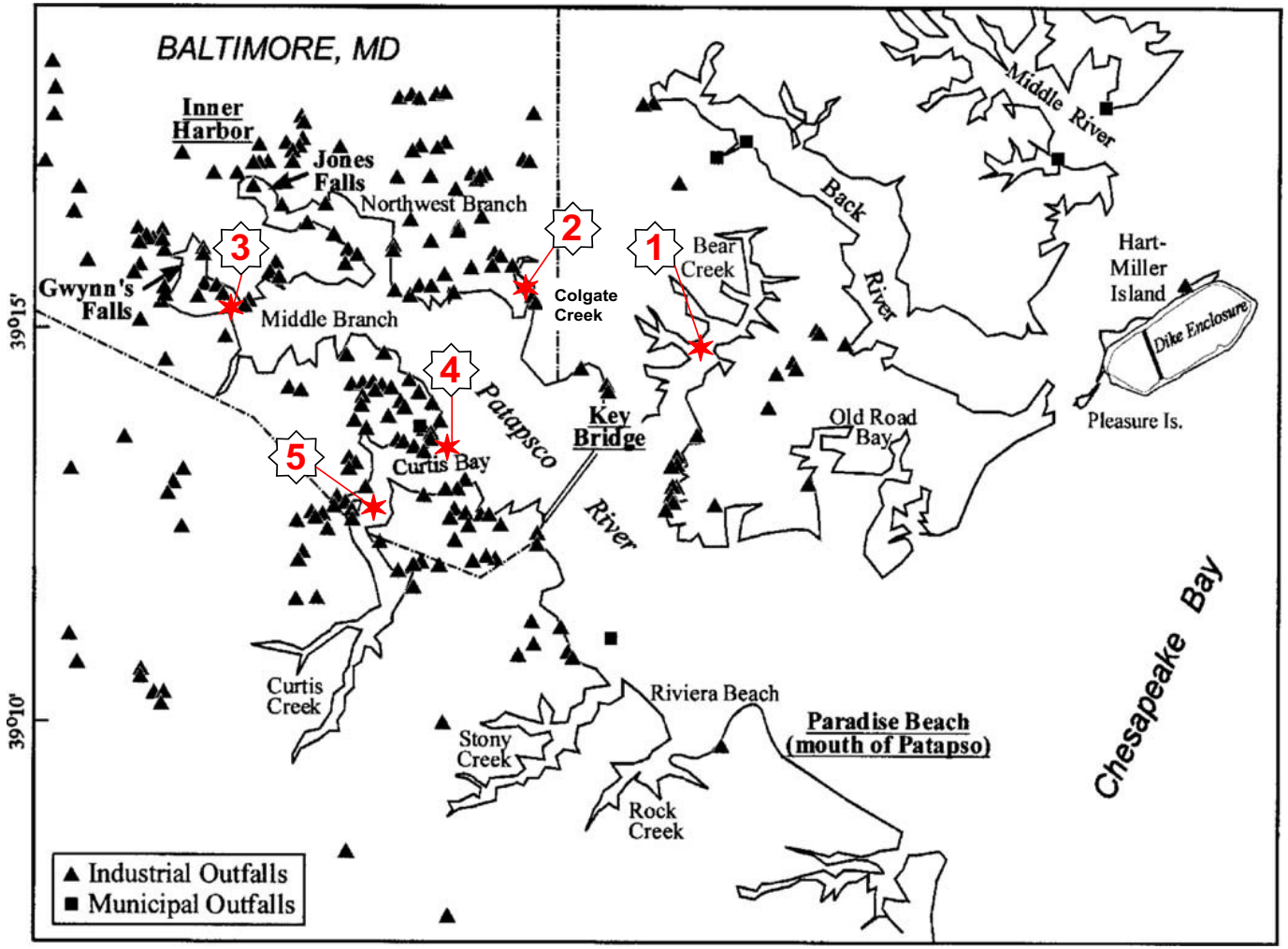


Fig. 3. Total PCB concentrations in bottom sediment (ng/g, left) and water column (ng/L, right). Results at each station are obtained by averaging all the available data.

Shen et al. Ecological Modelling 242 (2012) 54– 68

PCBs in Baltimore Harbor: Example



Locations of sediment samples

Surface grabs:

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

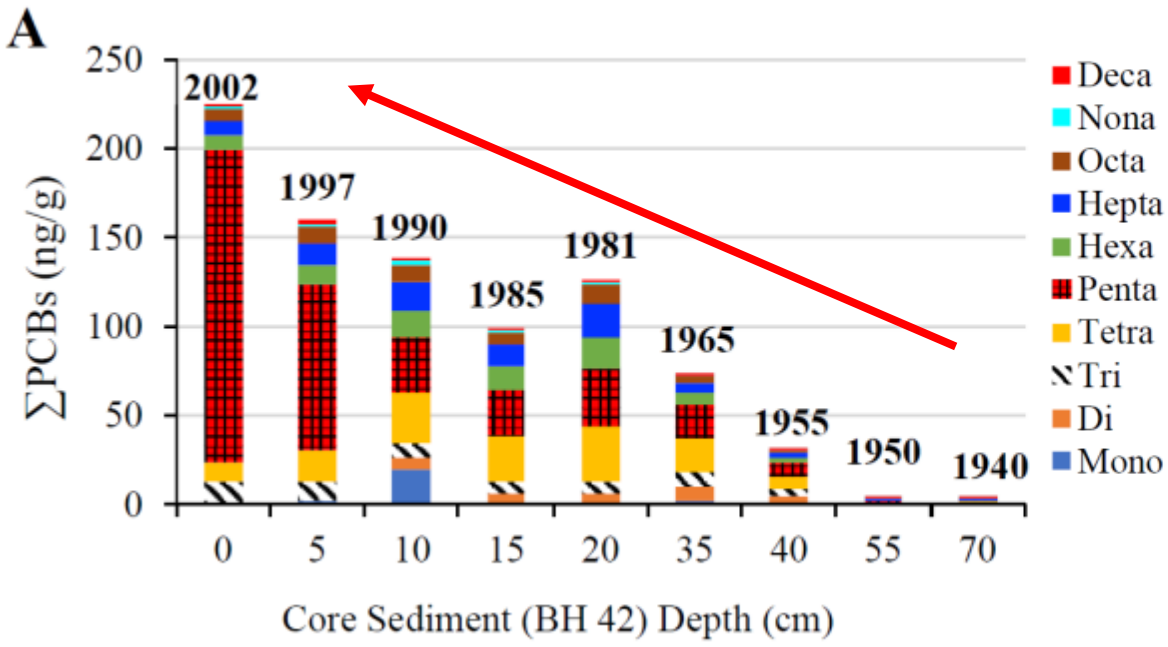
Core sample:

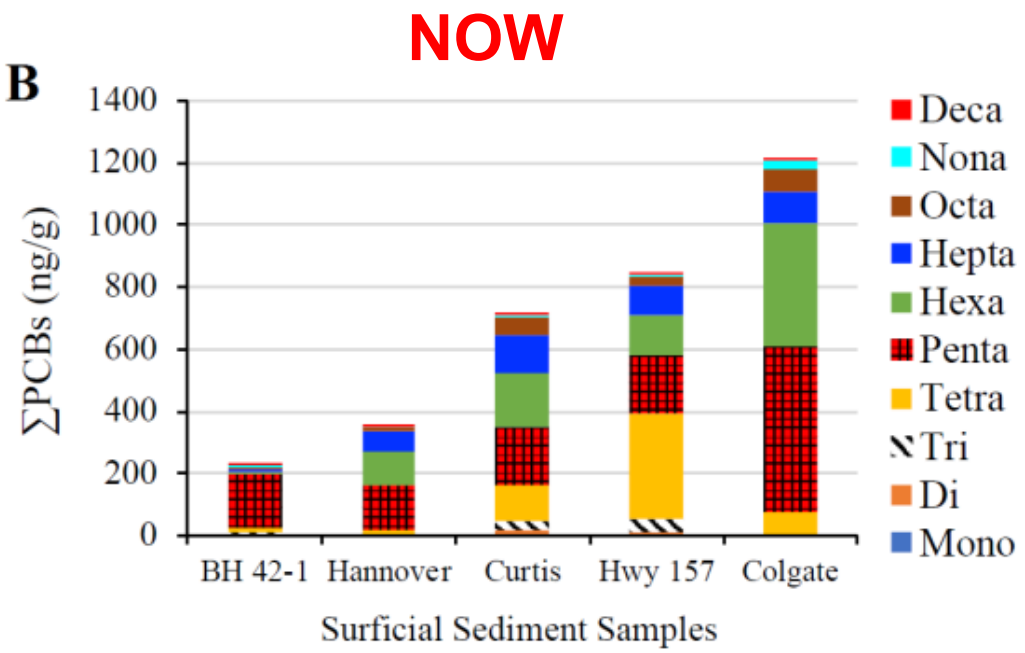
4) BH 42

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

Kaya et al (2019), SOTE

Legacy contamination or current sources?





Conclusion:

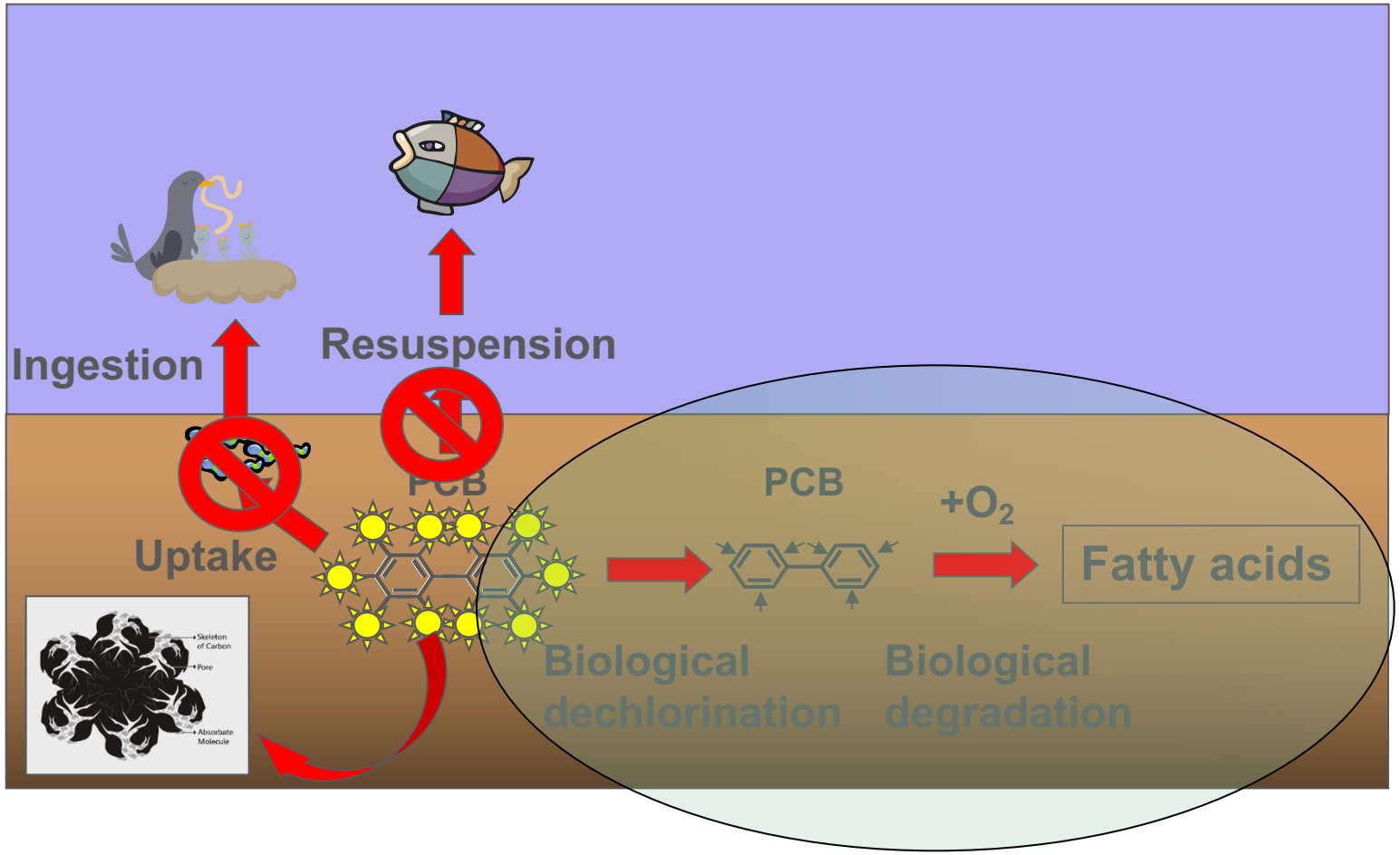
Not only legacy PCBs (Example of Baltimore Harbor)

⇒ **Current sources** are increasing the contamination level

⇒ **TMDLs in place** for watersheds in the Chesapeake Bay

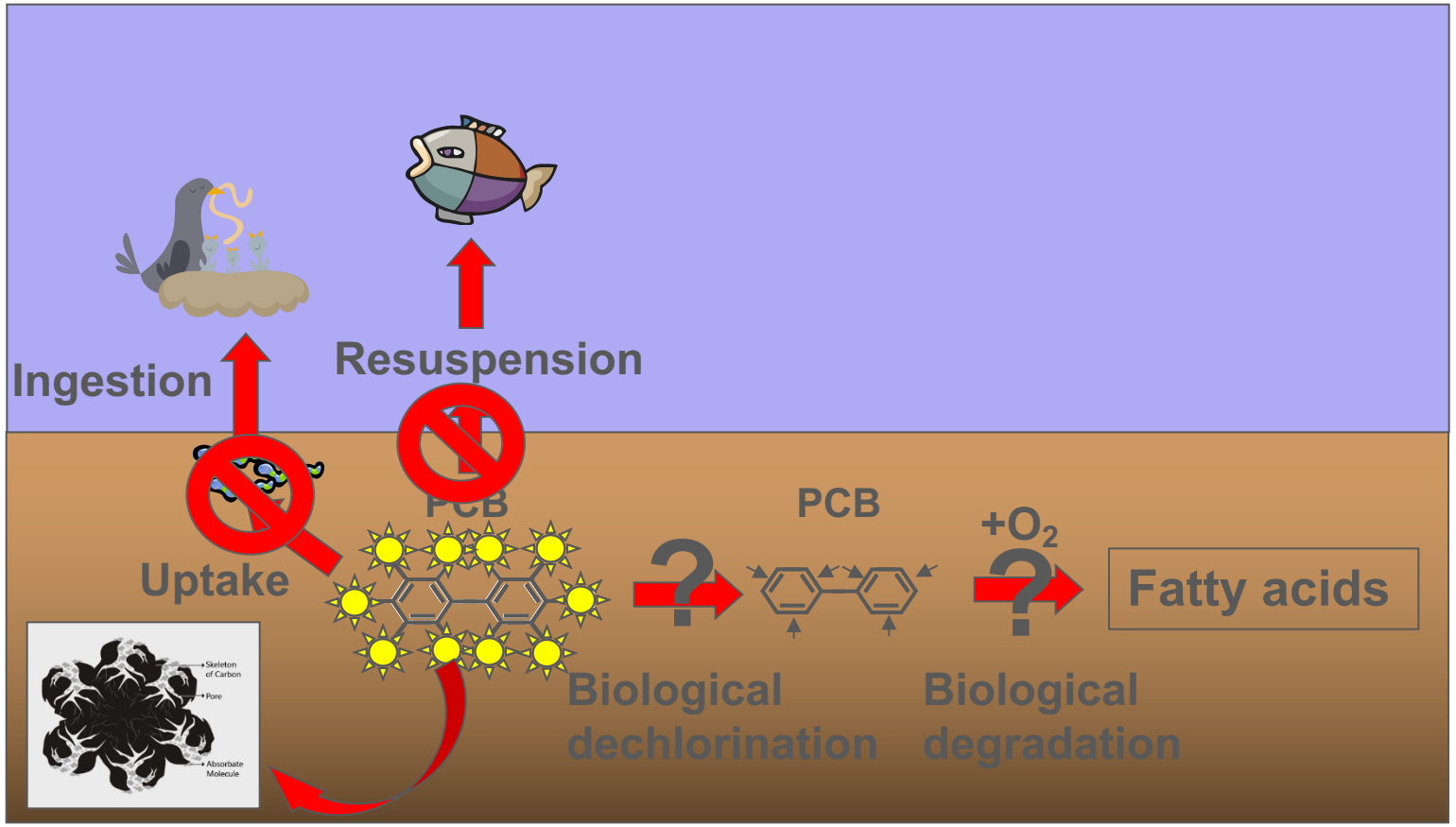
Kaya et al (2019), SOTE

PCBs - Processes in sediment



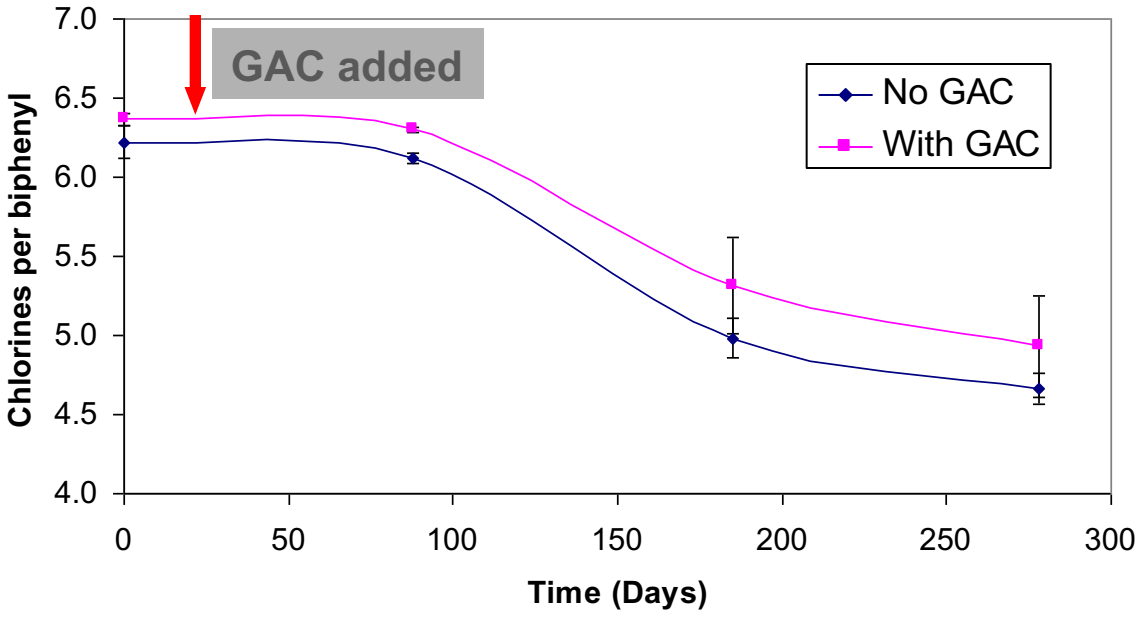
> 50 years

PCBs - Processes in sediment



Are PCBs available for bacteria?

ER-1492



Average chlorine content

Conclusion: Good news

- Dechlorination of Aroclor 1260 in sediment with GAC

⇒ No effect of GAC based on average chlorine content

Kjellerup et al, Water Res (2014)

Effect: Sorption capacity & conductivity?

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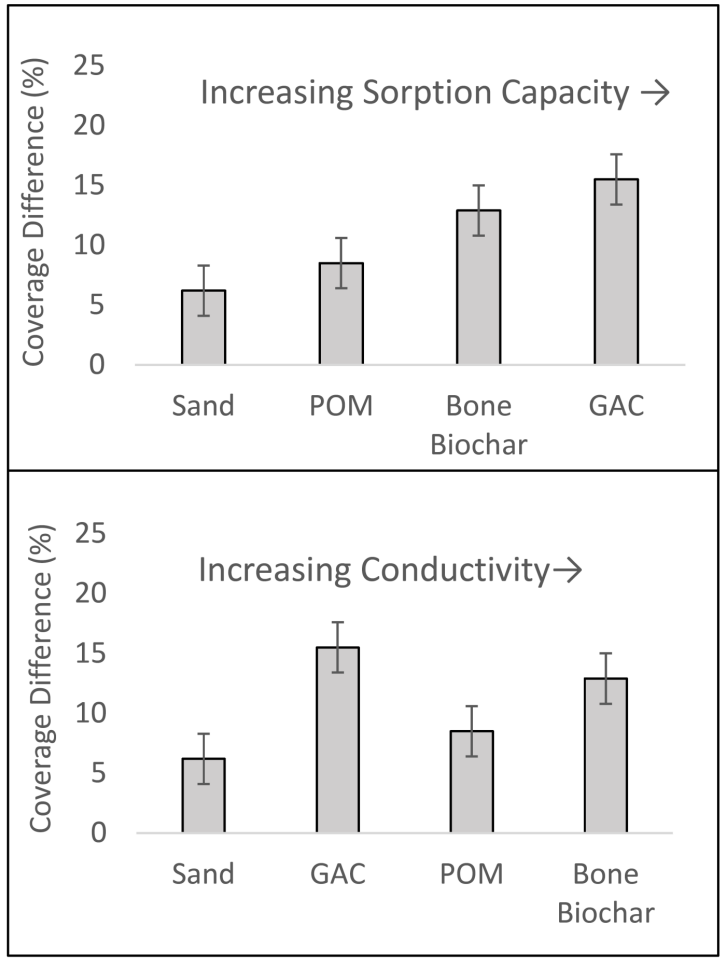


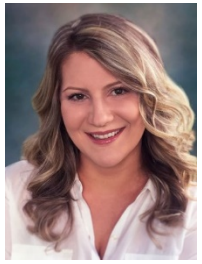
Increased **biofilm coverage** with increasing **sorption capacity**

No increased **biofilm coverage** with increasing **conductivity**

Summary:

- Increased sorption capacity increases biofilm formation

→ Existing PCB contamination can be treated



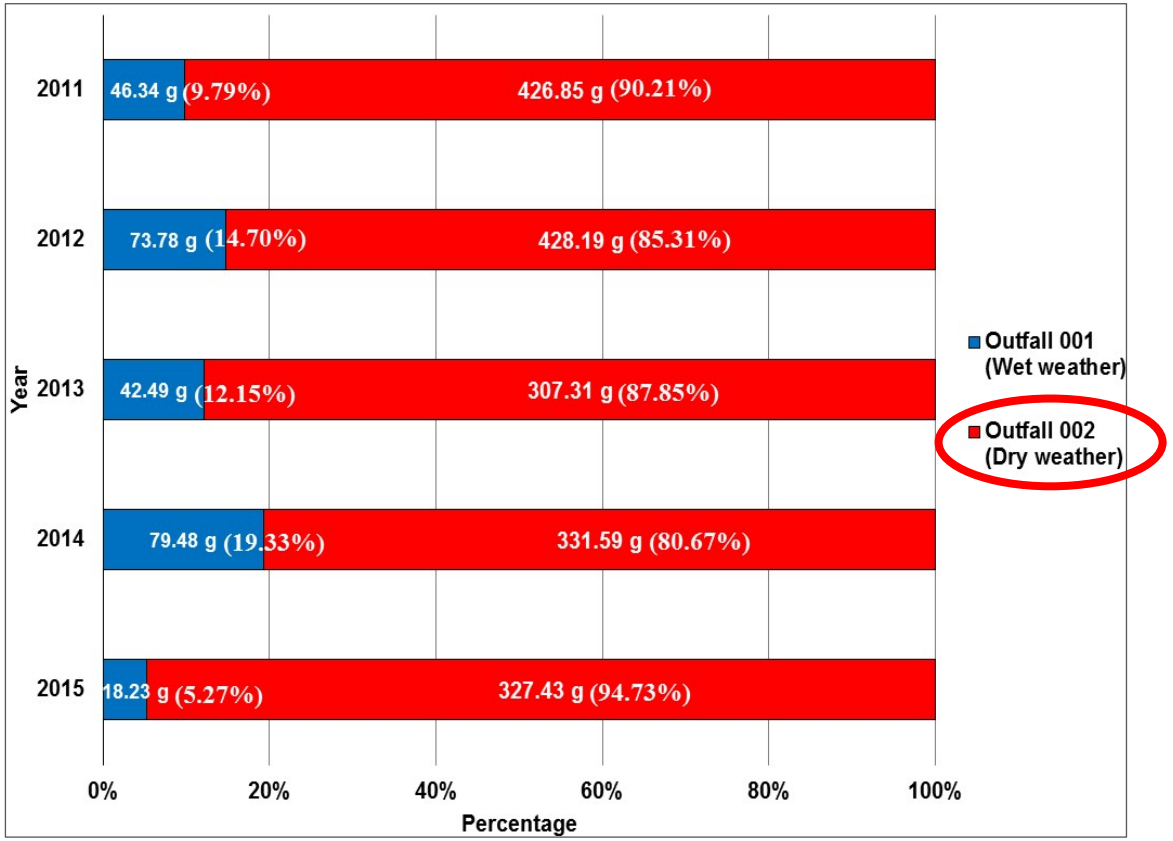
S. Capozzi et al, Biofouling, 2019

We can remediate contaminated sediments!

Why is recontamination still occurring?

Wastewater: Annual PCB Discharge

ER-2135



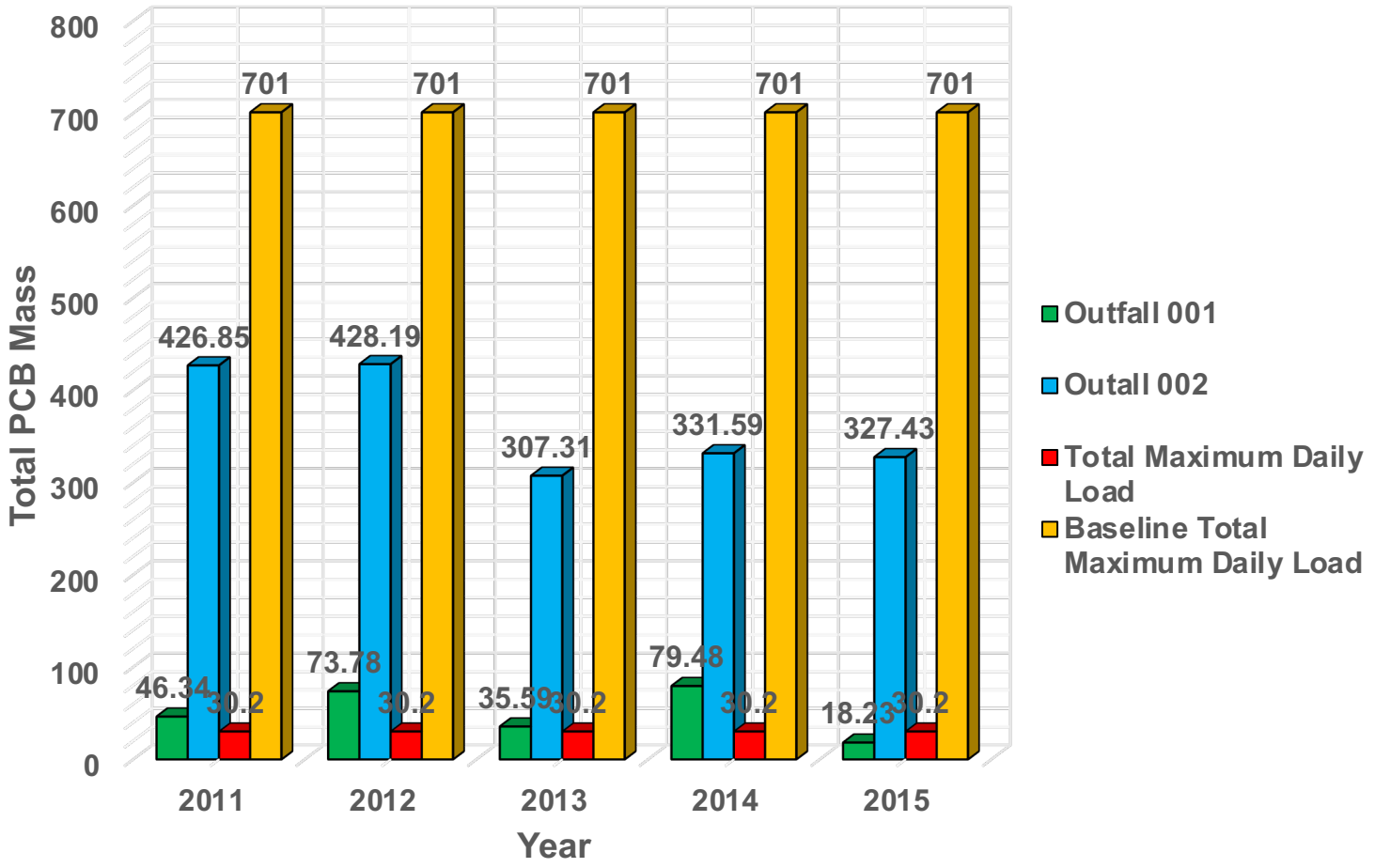
Normal operation

Conclusion: The majority of the PCB mass comes from ”real” wastewater during all seasons, not stormwater overflow.

Jing and Kjellerup (2018), JES

Annual PCB discharge vs. TMDL

ER-2135



Stormwater overflow

Normal operation

Current TMDL

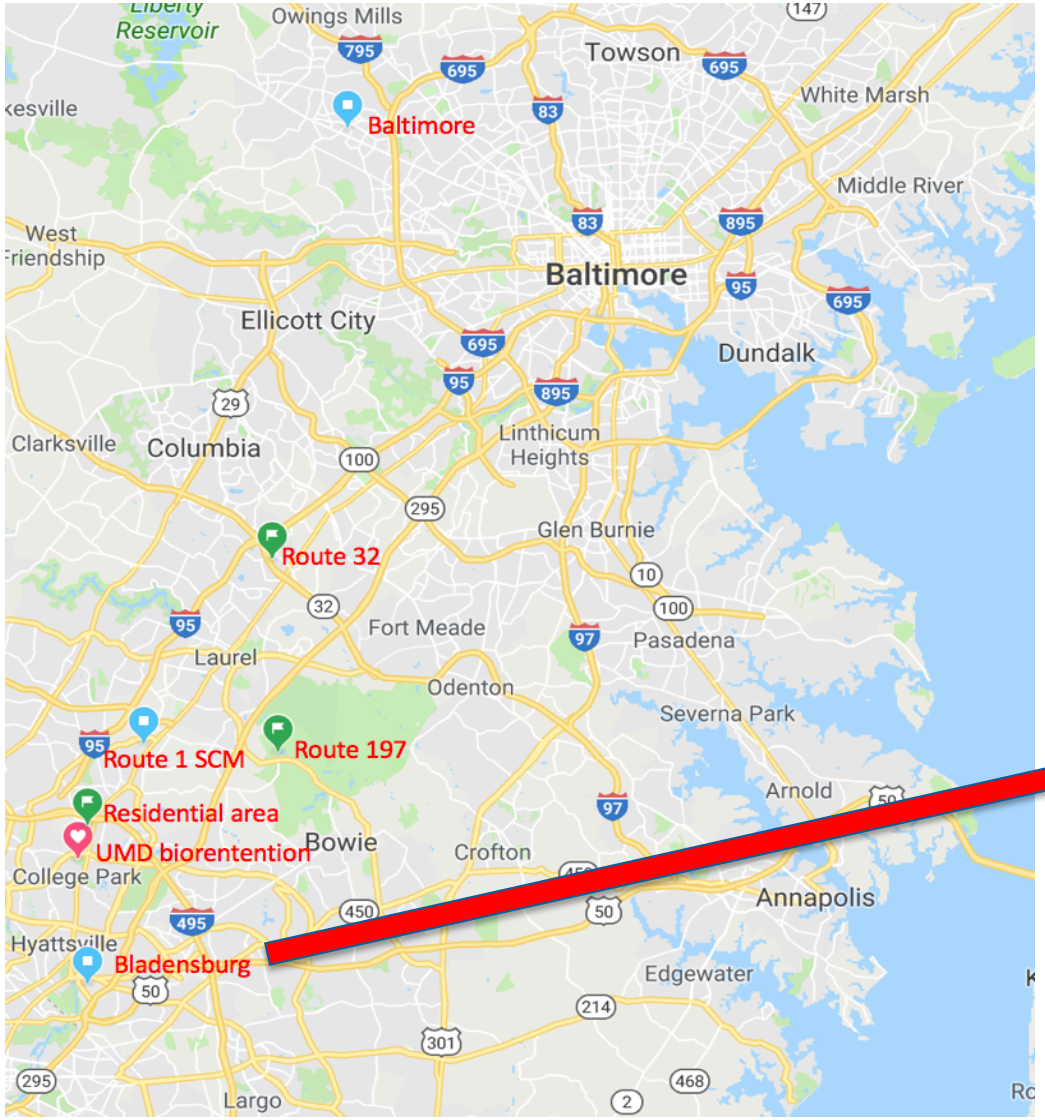
Estimate prior to current TMDL

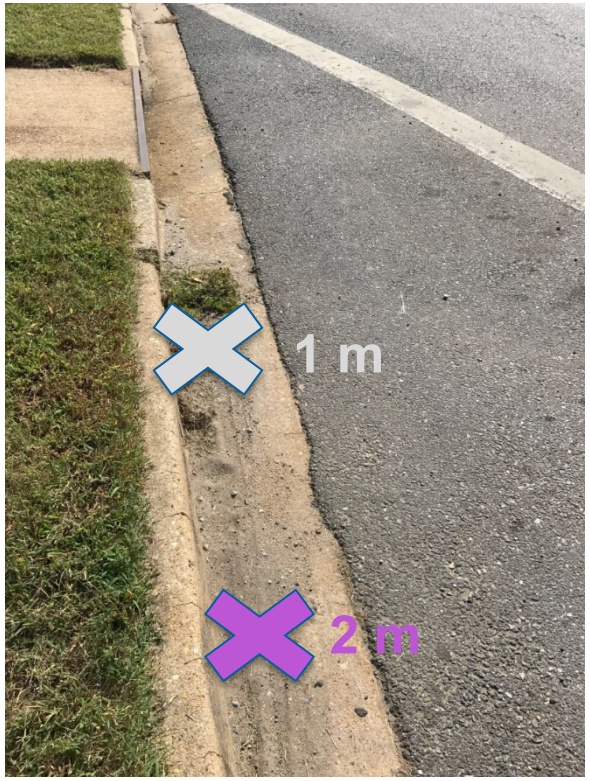
The *Total Maximum Daily Load* (TMDL) was exceeded every year

→ Actions should be taken

Jing and Kjellerup (2018), JES

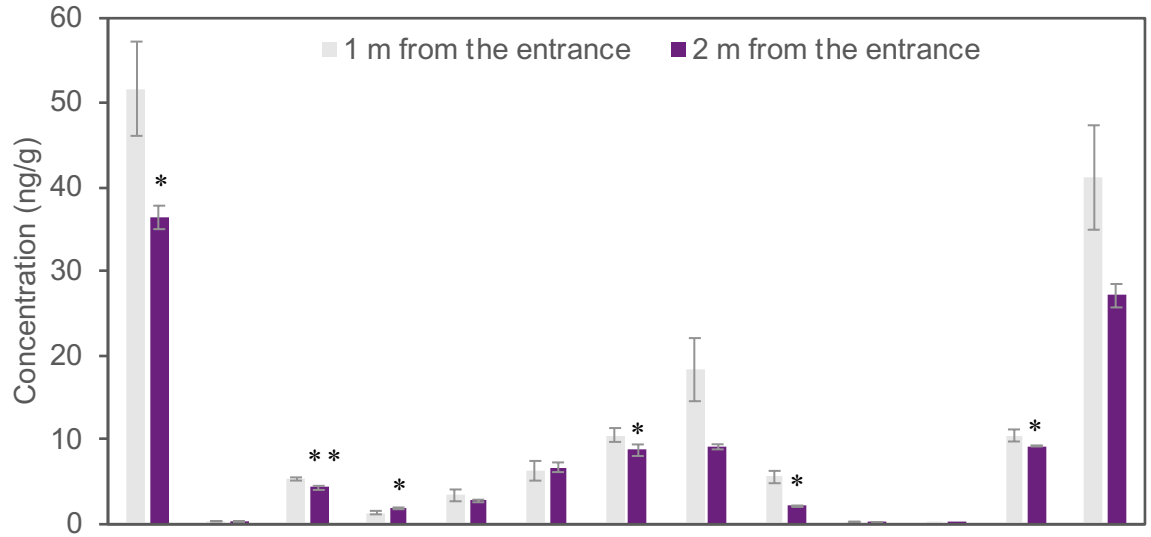
Run-off from Maryland Highways

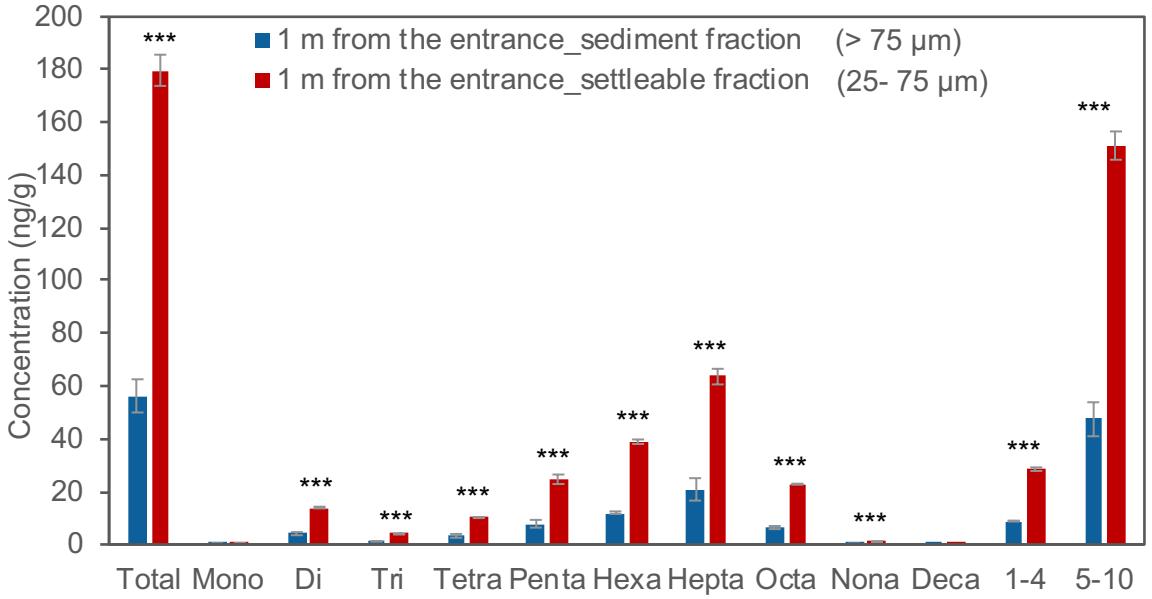




Cao et al (2019), Water Research

Run-off from Maryland Highways





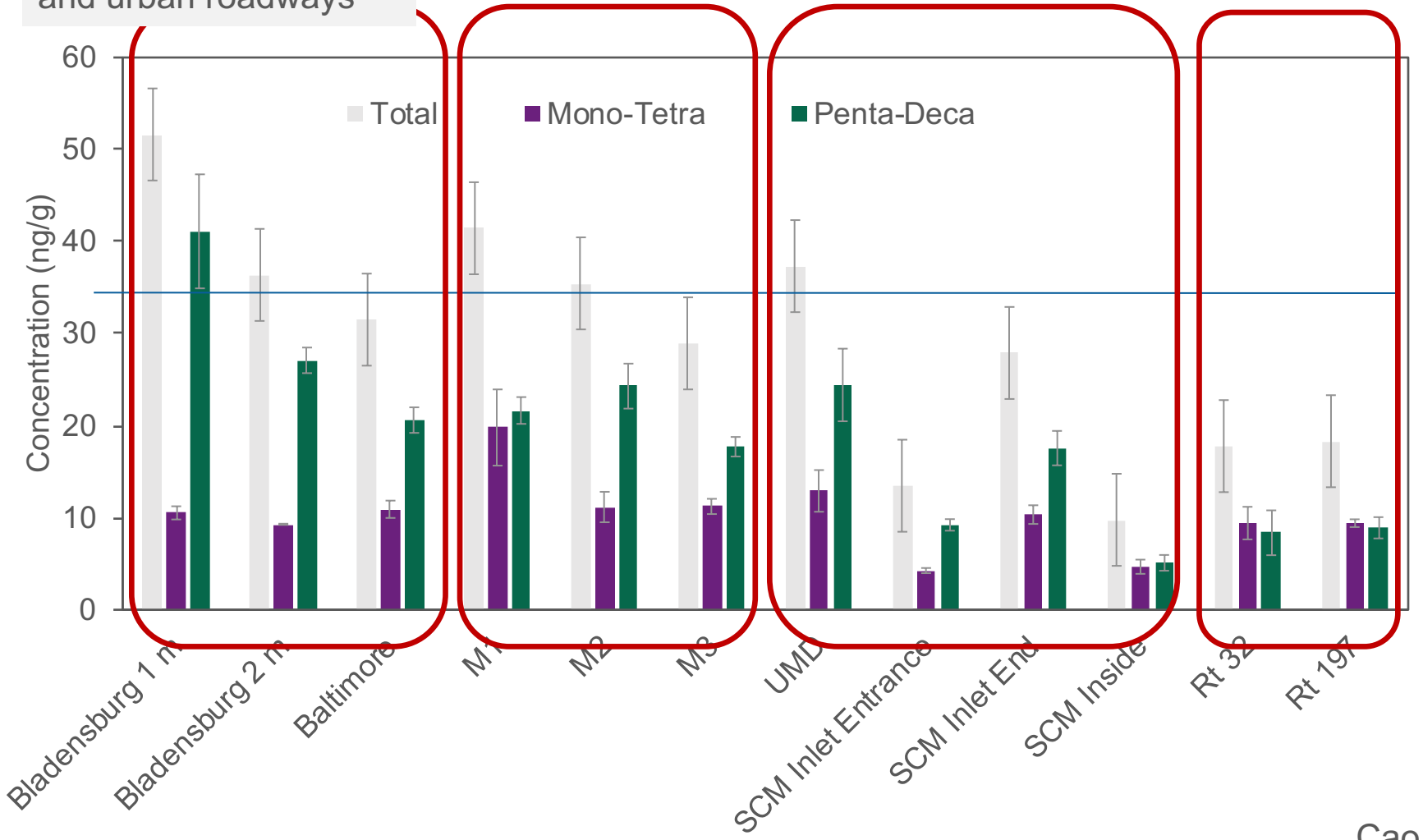
Summary:

- 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

Cao et al (2019), Water Research

PCBs in urban areas around highways

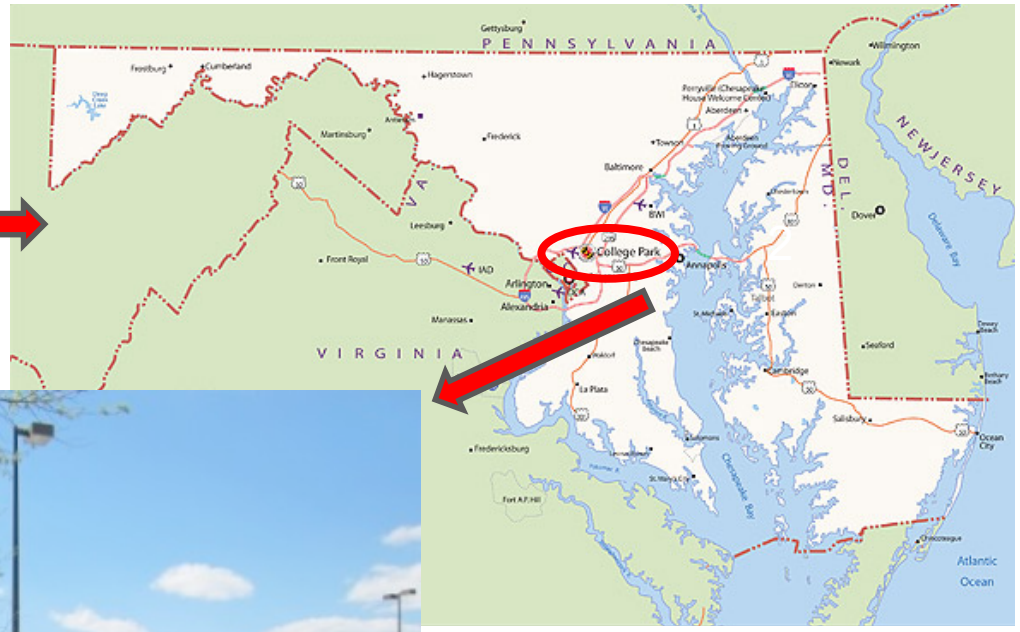
High Concentrations: Around old buildings and urban roadways



Low concentrations: At highway locations (different homologue patterns)

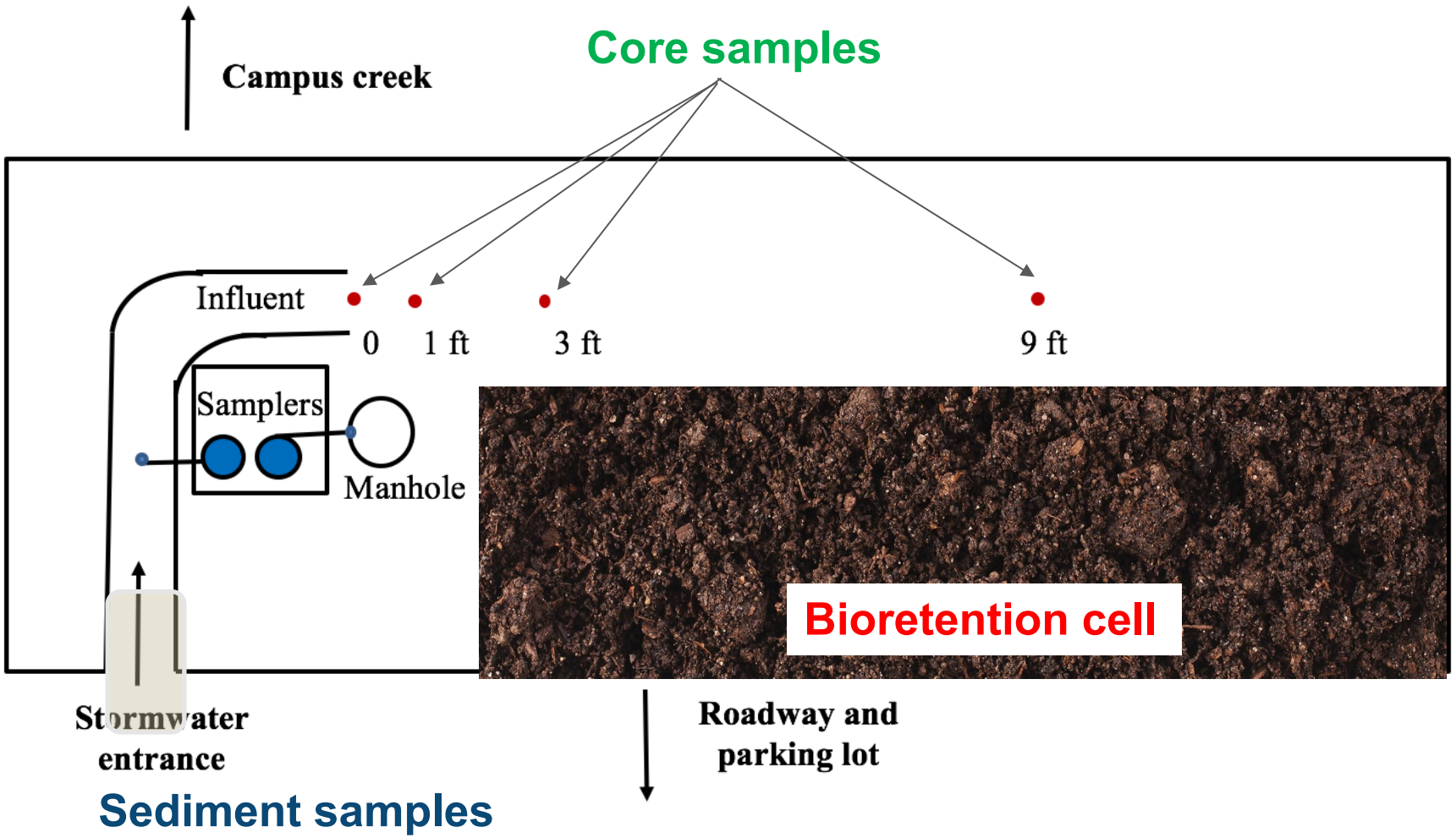
Cao et al (2019), Water Research

PCBs in urban bioretention cell



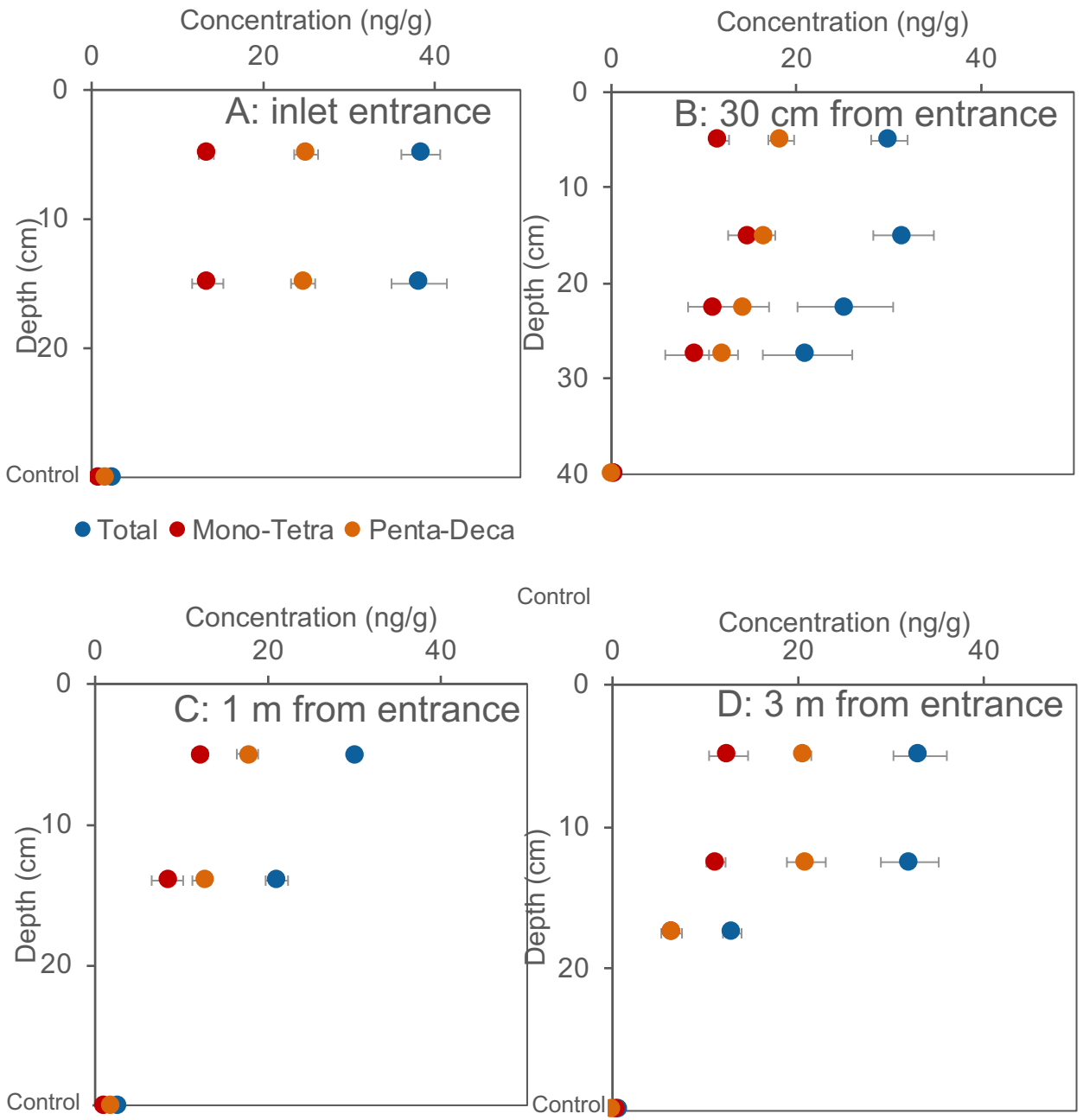
Cao et al (2019), Water Research

PCBs in urban bioretention cell



Cao et al (2019), Water Research

PCBs in urban bioretention cell



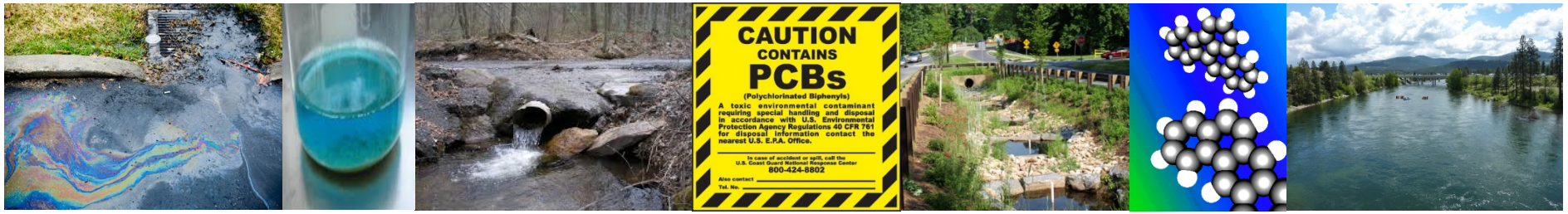
Summary:

- Depth ↑, PCB concentrations ↓

- Distance from the entrance ↑, PCB concentrations ↓

Cao et al (2019), Water Research

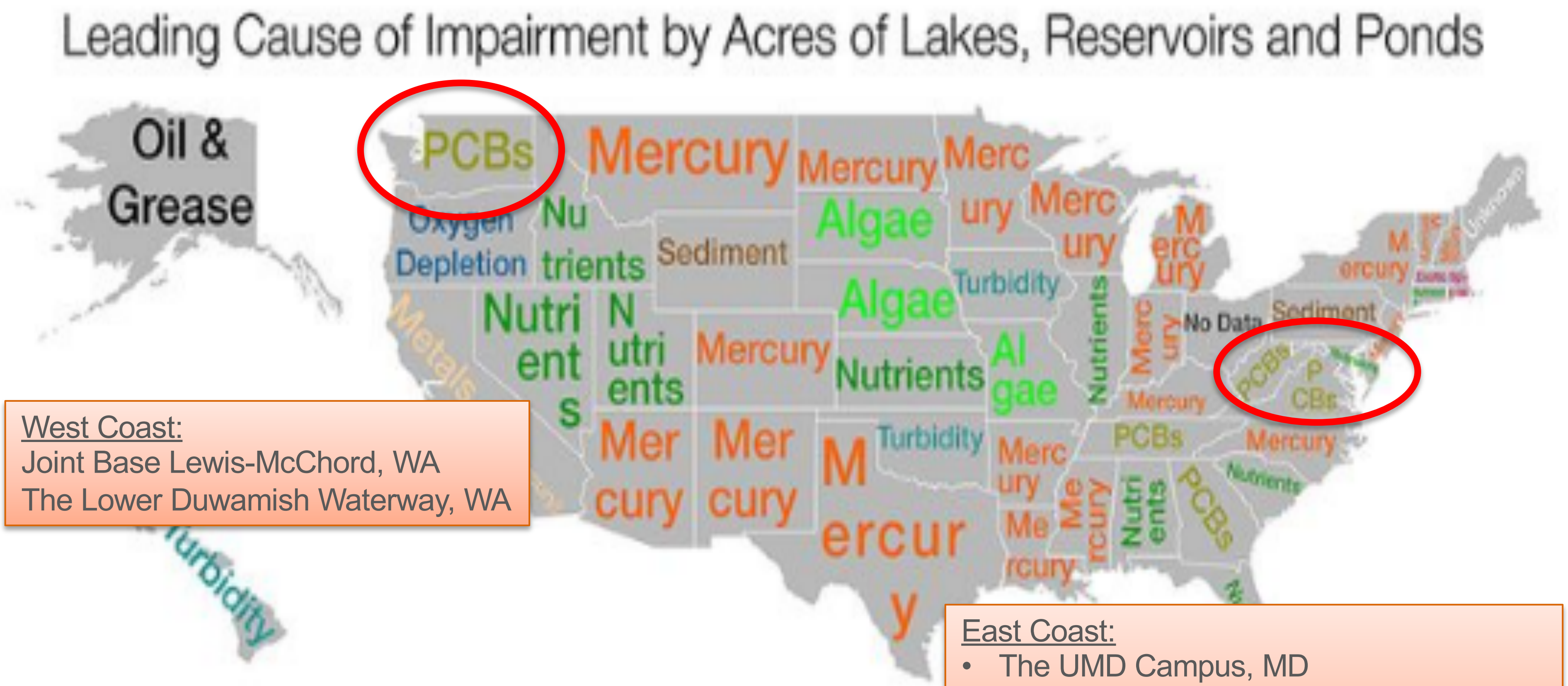
Treatment Media for Control of Persistent Organic Pollutants and Metals in Stormwater (New Start: ER18-1303)



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

Performers (ER18-1303)

- **Dr. Birthe Kjellerup (UMD**), Specialist in biofilms, microbial degradation of PCBs/PAHs
- **Dr. Allen P. Davis (UMD), PE**, Specialist in treatment of pollutants in urban stormwater/bioretention
- **Dr. Ed Kolodziej (University of Washington, Tacoma/Seattle)**, Specialist in chemical characterization and contaminant fate
- **Mr. Chris Streb (Biohabitats), PE**, Specialist in implementation of stormwater management solutions
- **Dr. Marc Mills (USEPA),** Specialist in contaminant fate/transport; assessment of contaminated sediment remediation
- **Dr. Kristen Kerns (USACE),** Specialist in toxicology, bioavailability and risk assessment
- **Dr. Mandy Michalsen (ERDC),** Specialist in design and implementation remediation strategies for hazardous waste sites
- **Dr. Rebecca Kowalski (Environmental Division at Joint Base Lewis-McChord, WA),** Stormwater Program Manager
- **Mr. Brian Murray (Naval Facilities Engineering Command, Mechanicsburg, PA),** Environmental Restoration Remedial Project Manager



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

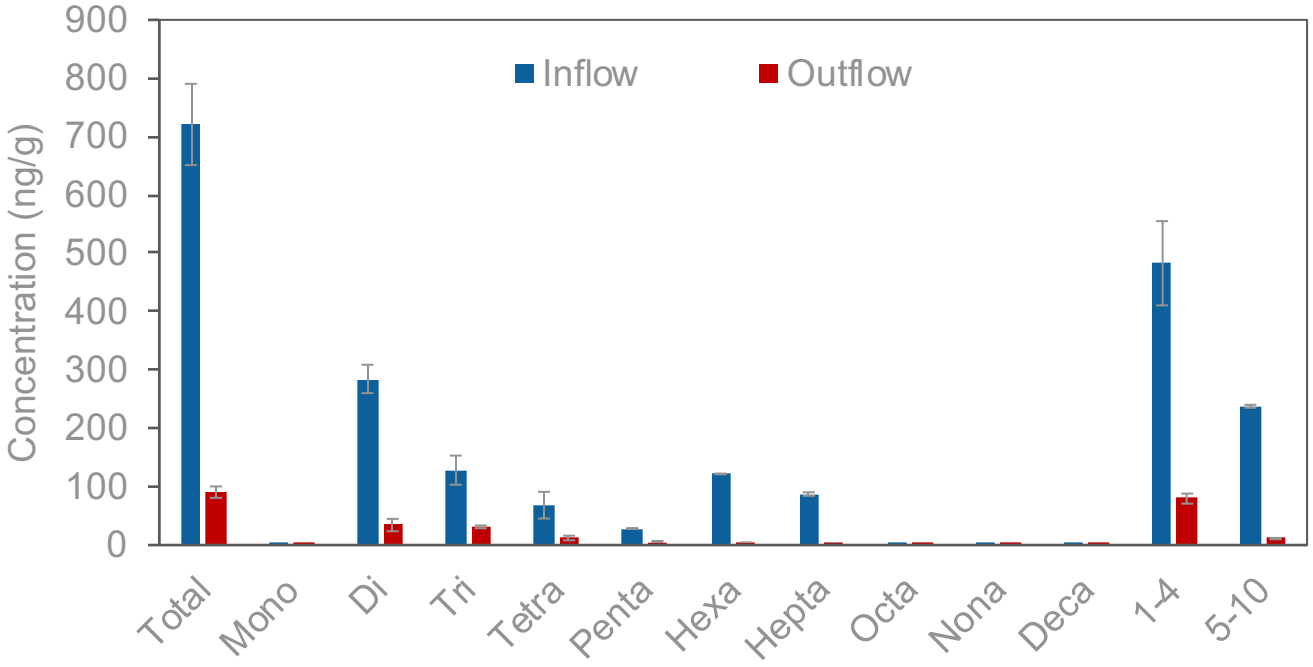
Technical Objective (ER18-1303)

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)

ER18-1303

Stormwater Collection and Analysis



	Influent	Effluent
pH	7.72	6.77
	7.82	6.70
Particle size (µm)	36 – 2346 (median: 485)	
	5 – 400 (median: 66)	
TSS (0.7 µm filter, mg/L)	66.3 ± 5.52	4.60 ± 0.53
Total PCBs (ng/L)	720 ± 69.6	90.6 ± 0.05
PCB 11 (ng/L)	148 ± 32.9	13.2 ± 2.92
Cl per biphenyl	3.38 ± 0.06	2.87 ± 0.10

Summary:

- 2 storms collected (dry summer in MD)
- Dissolved PCB conc. reduced by 85% in bioretention
- Still 91 ng/L dissolved PCBs left
- PCB-11 (3,3'): 20% of total PCBs
- Particle size: varies with storm (5-2346 µm)

EPA Research on Remediating Contaminated Soils

Mark G. Johnson, Ph.D. U.S. EPA, ORD, CPHEA, PSED (Corvalis, OR)

Multiple problems exist at numerous sites

- Contaminated soils require intervention and remediation!
- There are 1300+ Superfund sites and approximately 500,000 abandoned mines across the U.S. that pose a considerable and pervasive risk to human health and the environment

Strategic use of biochar and other soil amendments at contaminated sites can address these problems

Biochar and other soil amendments

- Reduce contaminant exposure by limiting the exposure pathways and immobilizing contaminants by changing the chemistry of contaminated soils and removing contaminants from water
- Help restore soil quality and health of degraded soils
- Enable *in situ* site remediation, re-vegetation and revitalization, and reuse of contaminated soils
- Lead to sustainable site recovery while reducing the cost of remediation

Formosa Mine Superfund Site: Abandoned Cu and Zn Mine, Riddle, OR

What is Biochar?

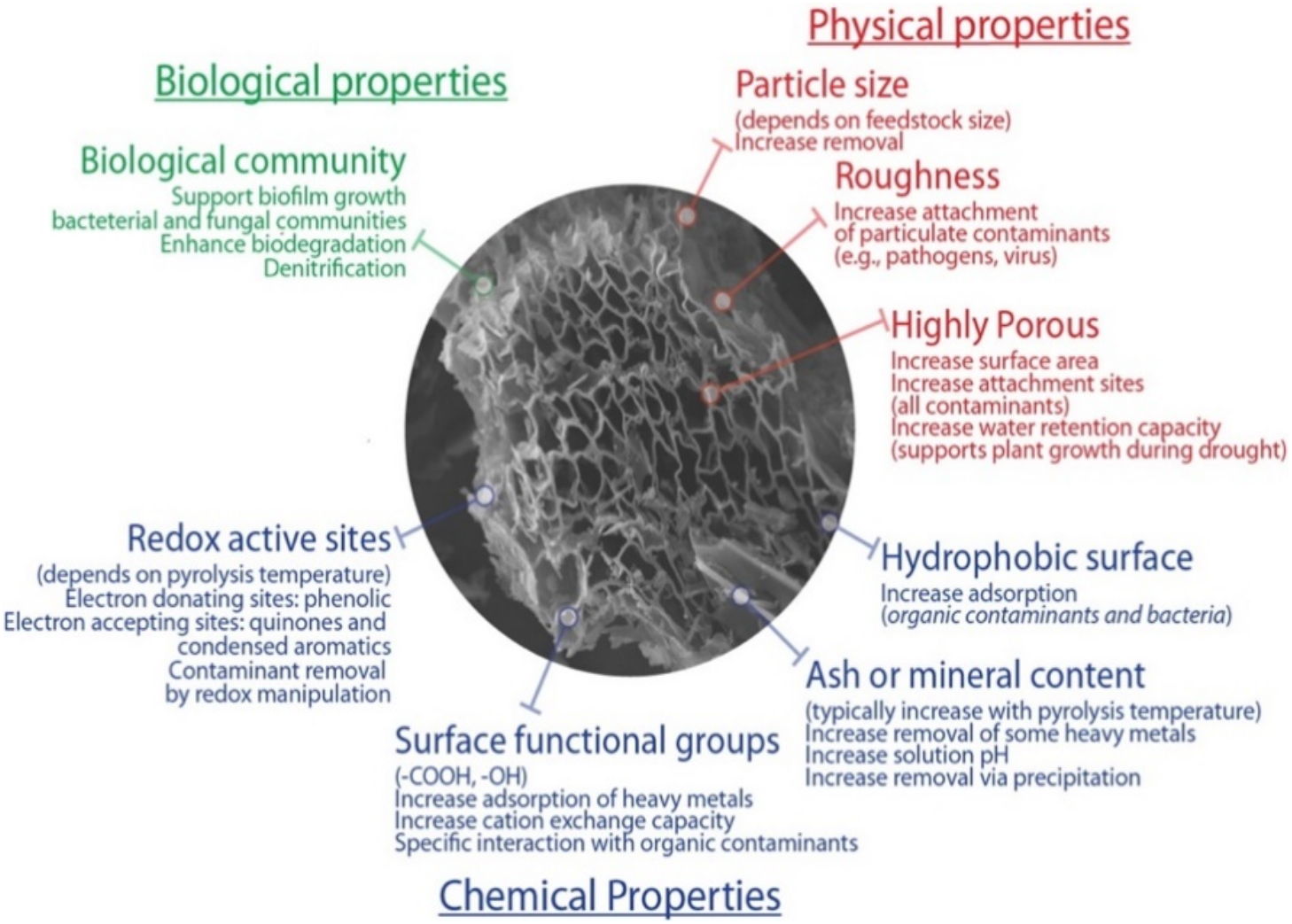
- Biochar is carbon-rich solid derived by heating waste biomass in the absence of oxygen (pyrolysis)
- It is a porous solid with a number of beneficial properties that are can be used to sorb, complex or precipitate toxic contaminants in soil, sediments and water to:
  - Reduce hazards
  - Reduce exposure
  - Restore ecosystem function and services
- Biochar properties are tunable and are controlled by feedstock selection, pyrolysis conditions, blending and various methods of activation

EPA/ORD/SHC Research On Biochar and Soil Amendments

- Research is being conducted to engineer biochar to have specific remedial properties to address site specific contaminants and generally used with other appropriate soil amendments
  - Metal-contaminated mining residuals including: Zinc, Copper, Cadmium, Lead, Manganese
  - Lead-contaminated soils and sediments (From mining, smelting and industrial processes)
  - Phosphorus-contaminated soils on the Delmarva Peninsula to protect Chesapeake Bay water quality
  - Mercury-contaminated soils, wetlands and waters
  - DDT-contaminated soils and sediments
  - PFAS-contaminated soils
- Biochar is effective at reducing exposure to inorganic and organic contaminants
- Engineered Biochar provides a set of new, tunable materials that can be utilized in a variety of remedial situations
- Using biochar in remediation is meeting real environmental needs!

Biochar made from softwood chips

Selection of Geomedia



Pragmatic selection criteria:

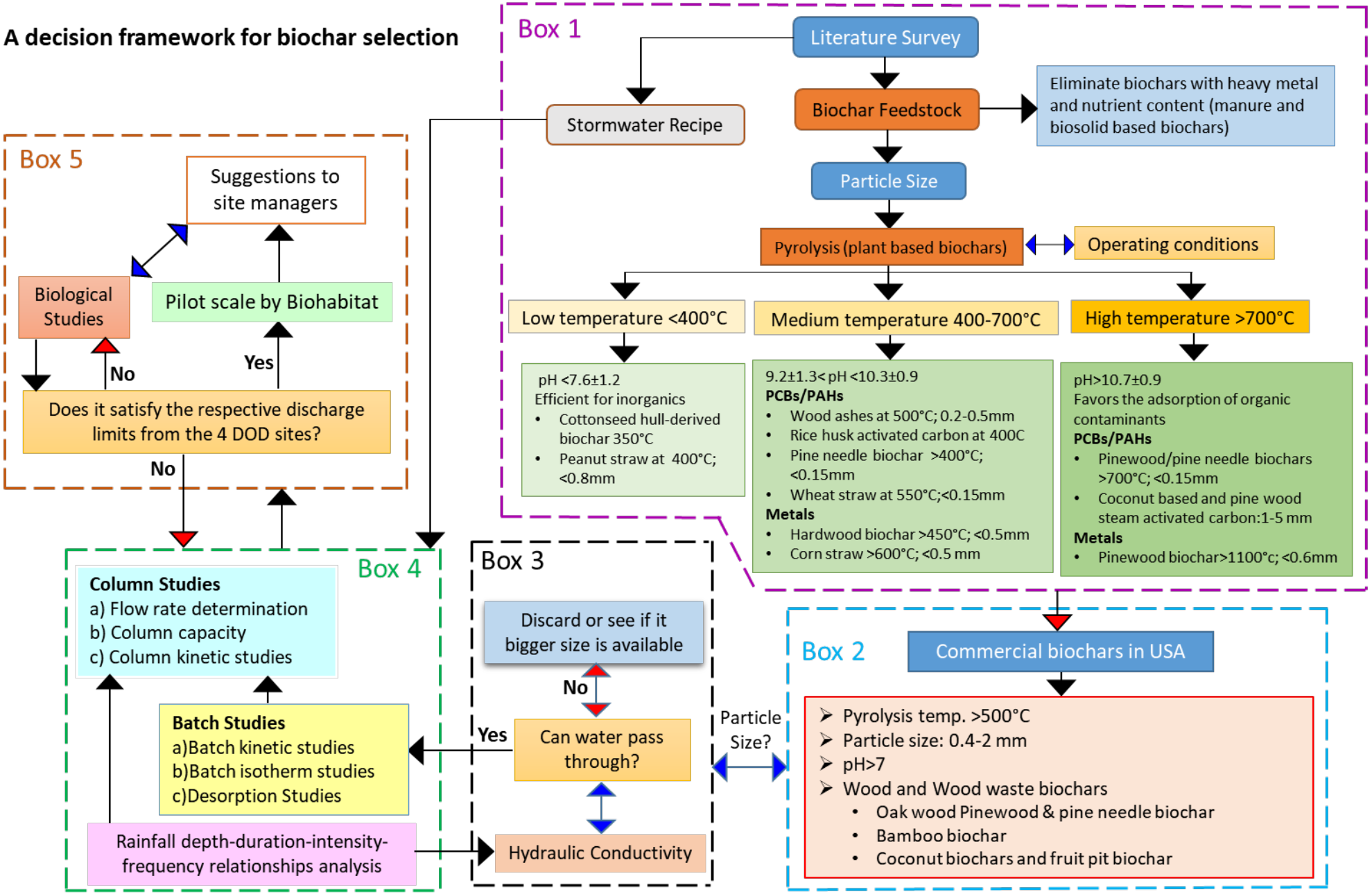
1. Adsorption capacity
2. Adsorption kinetics
3. Hydraulic conductivity
4. No leaching of contaminants of concern
5. Easy to produce and handle
6. Biodegradation potential of COC

Mohanty et al., (2018)

SERDP
DOD • EPA • DOE

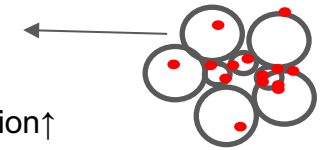
ER18-1303

A decision framework for biochar selection

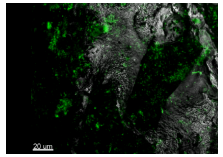


Summary

- PCBs are not only legacy contaminants → current sources exist (stormwater, wastewater)
- PCB 11 (3-3'-PCB) was detected in highway samples → Marker of non-legacy PCB contamination
- Larger stormwater particles contribute most to contaminant mass → Sediment capture may be a treatment for majority of PCB mass – Is the remaining dissolved portion still too high (Puget Sound)?
- Biofilm on sorptive materials is effective for PCB degradation
- Biochars: Need for performance standardization? Regulatory aspects?



Particle size↓ - sorption↑



Rice husk biochar

→ Potential for on-site bioremediation and clean-up of stormwater contaminants??

Acknowledgements

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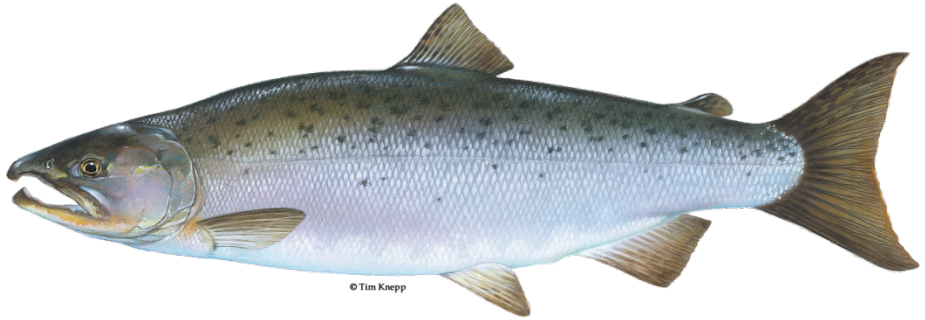
Dr. Upal Ghosh, Ph.D. (UMBC)

THANK YOU

QUESTIONS?



Coho Salmon