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Assessing Benefits of Wastewater Treatment Plant Nutrient Control Upgrades on Toxic Contaminants

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Purpose of Study

1. Investigate co-benefits of nutrient removal upgrades at WWTP to the reduction of other toxic contaminants, particularly PCBs, in the Chesapeake Bay watershed.
2. Assess another large estuary watershed in the US that may have WWTPs that have implemented nutrient removal upgrades and whether there were any other toxic contaminant reduction benefits.
3. Evaluate peer-reviewed literature for direct studies of reductions in toxic contaminants due to implementation of nutrient removal upgrades or specific type of upgrade at WWTP

Facility Data Compilation and Review Methods

Grade	Study/Site Location	Sampling Characteristics	Dataset QA/QC
High (3)	Chesapeake Bay Watershed	Frequent, flow-based composites or representative grab samples	Peer-reviewed, published
Medium (2)	Eastern US	Frequent (at least quarterly for one year) composite samples	Published, but not peer-reviewed
Low (1)	Other	Infrequent/irregular composite or grab samples	Unpublished (e.g., Discharge Monitoring Report (DMR) data)

Literature Survey Methods

Grade	Type of WWTP	Constituents Measured	Media Sampled
High (3)	Non-ENR and ENR (i.e., pre- and post-upgrade)	Toxics, including PCBs	Influent, Effluent, Solids
Medium (2)	ENR	PCBs, but no other toxics	Effluent and either influent or solids
Low (1)	Non-ENR	Toxics, not including PCBs	Effluents or Solids Only

Permitted Discharger Reported Data – Chesapeake Bay Watershed

- **Washington, D.C.** – 1 facility
  - Blue Plains Advance Wastewater Treatment Plant
    - Enhanced Nutrient Removal Facilities were placed in operation in 2014
    - 2 of 29 influent, 3 of 28 effluent measurements detected concentrations of PCBs, all detectable measurements were taken in 2010, pre-ENR upgrade
    - 6 PCB detectable sludge measurements since 2015 ENR upgrade, compared to 4 before ENR upgrade

Permitted Discharger Reported Data – Chesapeake Bay Watershed

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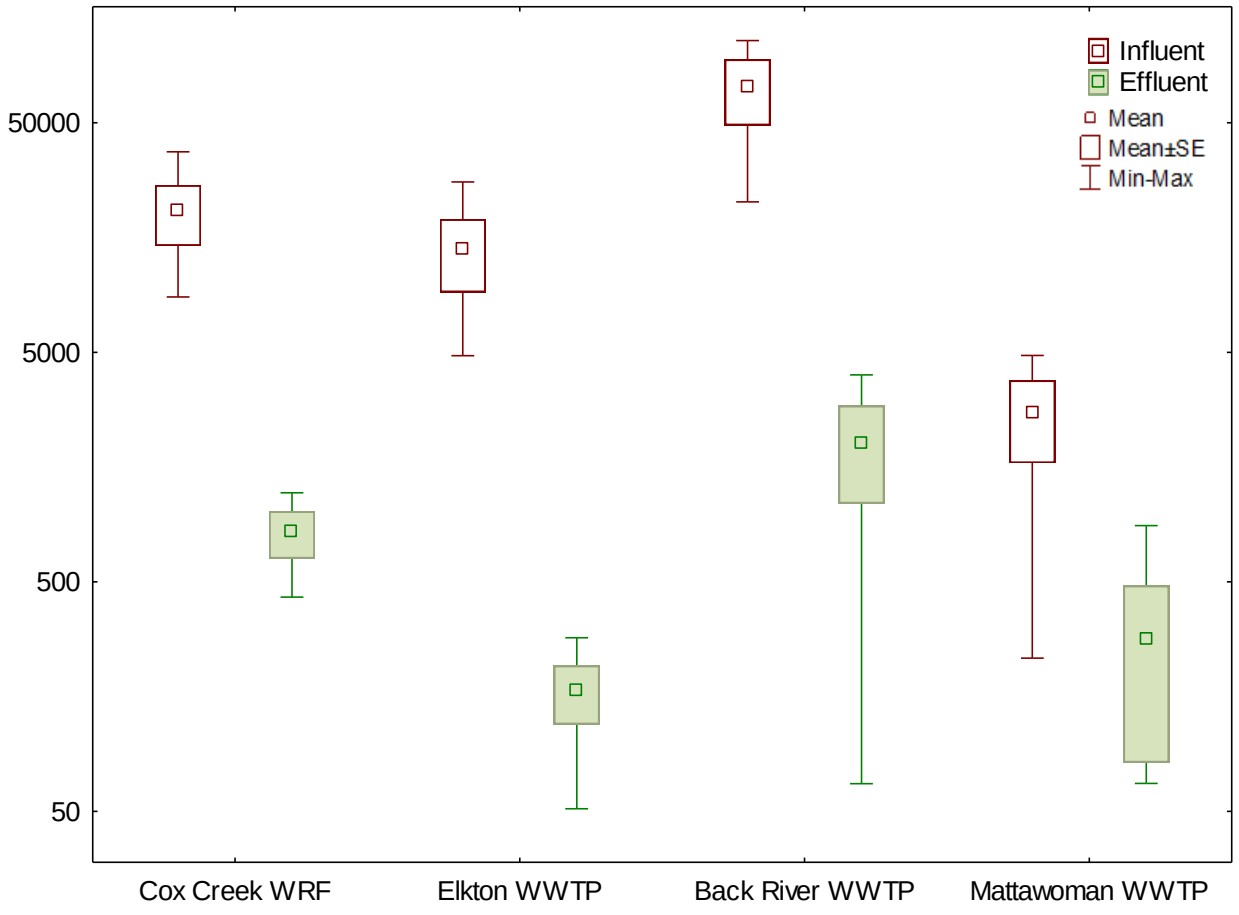
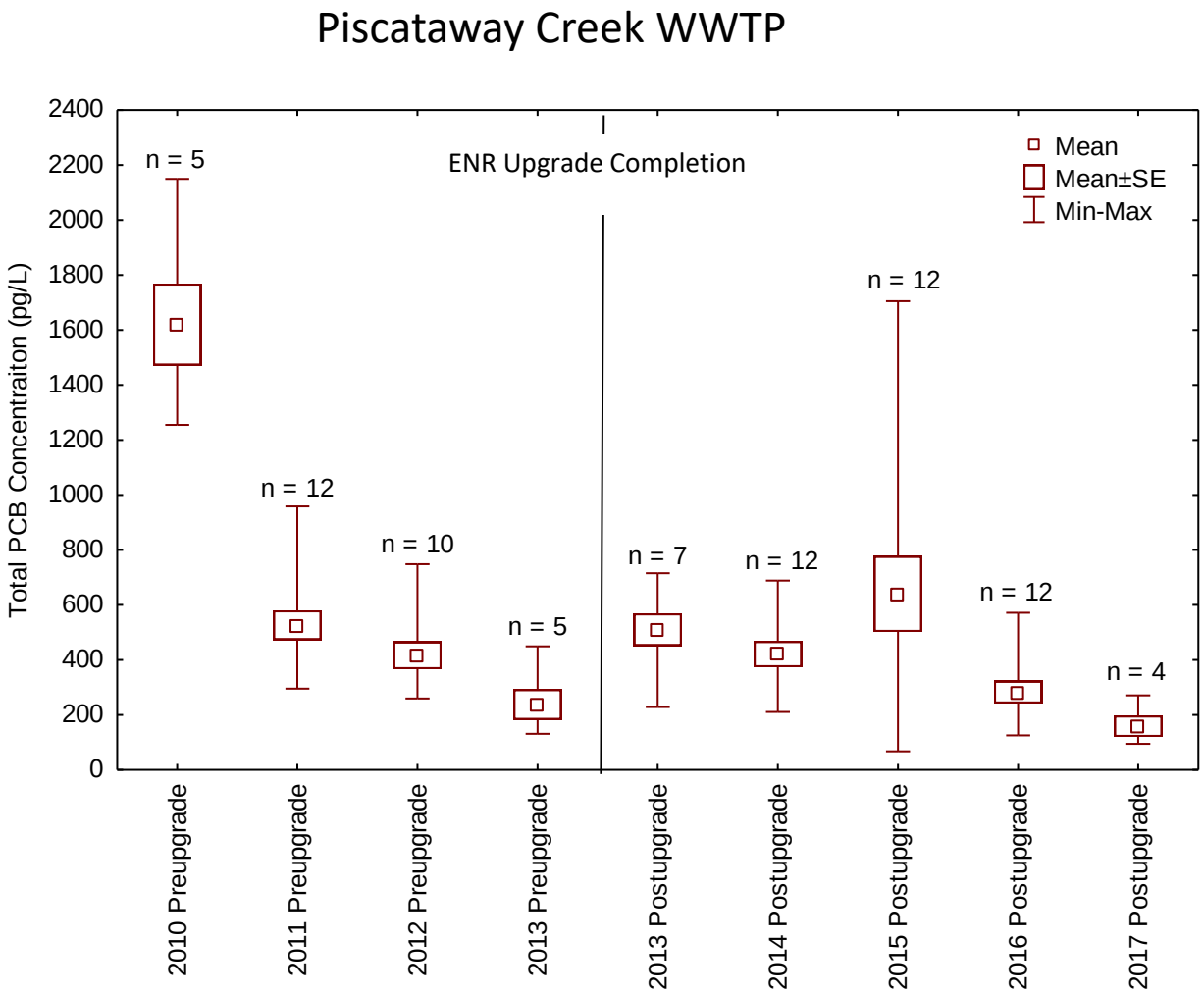
- **Maryland** – 66 facilities underwent or currently undergoing ENR upgrade, 8 with PCB data
  - MDE Enhanced Nutrient Reduction PCB Project – 4 sites
    - Back River WWTP: Biological Nutrient Removal (BNR) facility, **reduction of greater than 96%** in the concentration of PCBs in the effluent
    - Cox Creek Water Reclamation Facility (WRF): BNR process reactors, **reduction of greater than 86%** in the concentration of PCBs in the effluent
    - Elkton WWTP: BNR and ENR facilities, **reduction of greater than 94%** in the concentration of PCBs in the effluent
    - Mattawoman WWTP: ENR technology, **reductions in the range of 49%-98%** in the concentration of PCBs in the effluent

Permitted Discharger Reported Data – Chesapeake Bay Watershed



Permitted Discharger Reported Data – Chesapeake Bay Watershed



Permitted Discharger Reported Data – Chesapeake Bay Watershed

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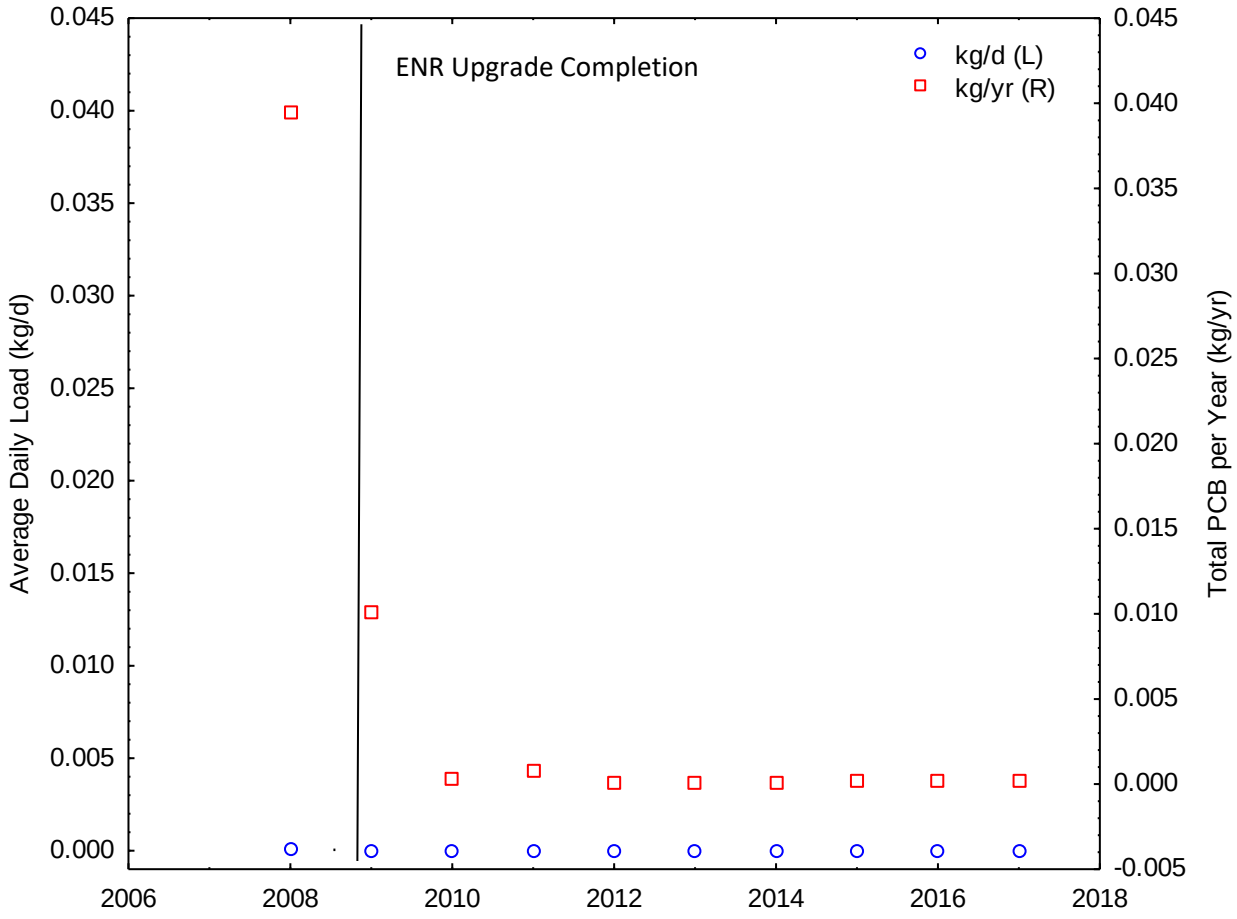
Naval Support Facility – Indian Head



Permitted Discharger Reported Data – Chesapeake Bay Watershed

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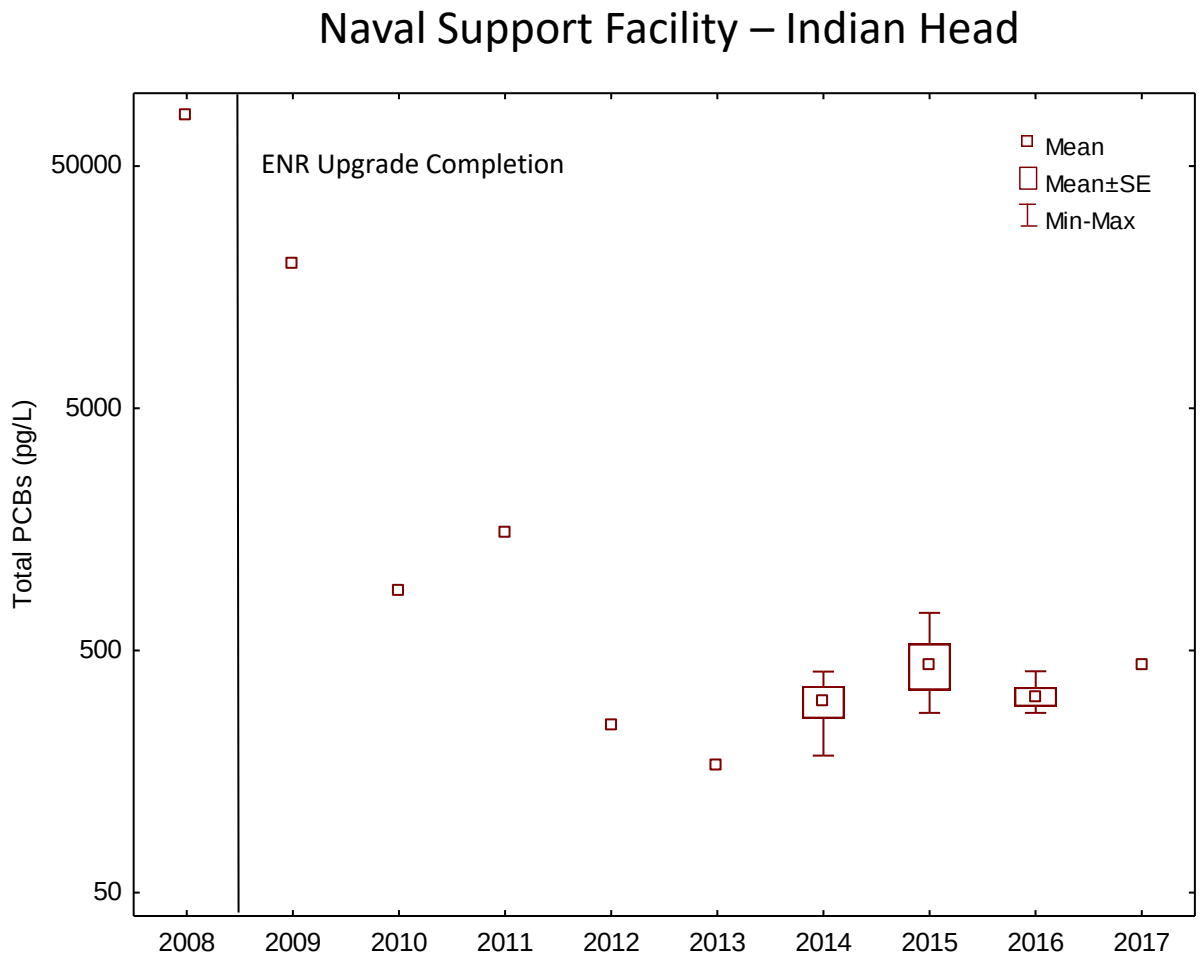

Permitted Discharger Reported Data – Chesapeake Bay Watershed

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- **Virginia** – 64 facilities underwent or currently undergoing ENR upgrade, 16 with PCB data
  - 9 facilities collected data pre-upgrade, 7 facilities collected data post-upgrade
  - An approximate 13% reduction in total PCB concentrations between facilities that were upgraded and those that were not was not significant (t-test p=0.05)
  - The bulk of the reduction was in the tetra-chlorinated and higher PCBs
  - Mono-, di-, tri-chlorinated congeners indicated an increase in effluent concentration after upgrade

Permitted Discharger Reported Data – Chesapeake Bay Watershed

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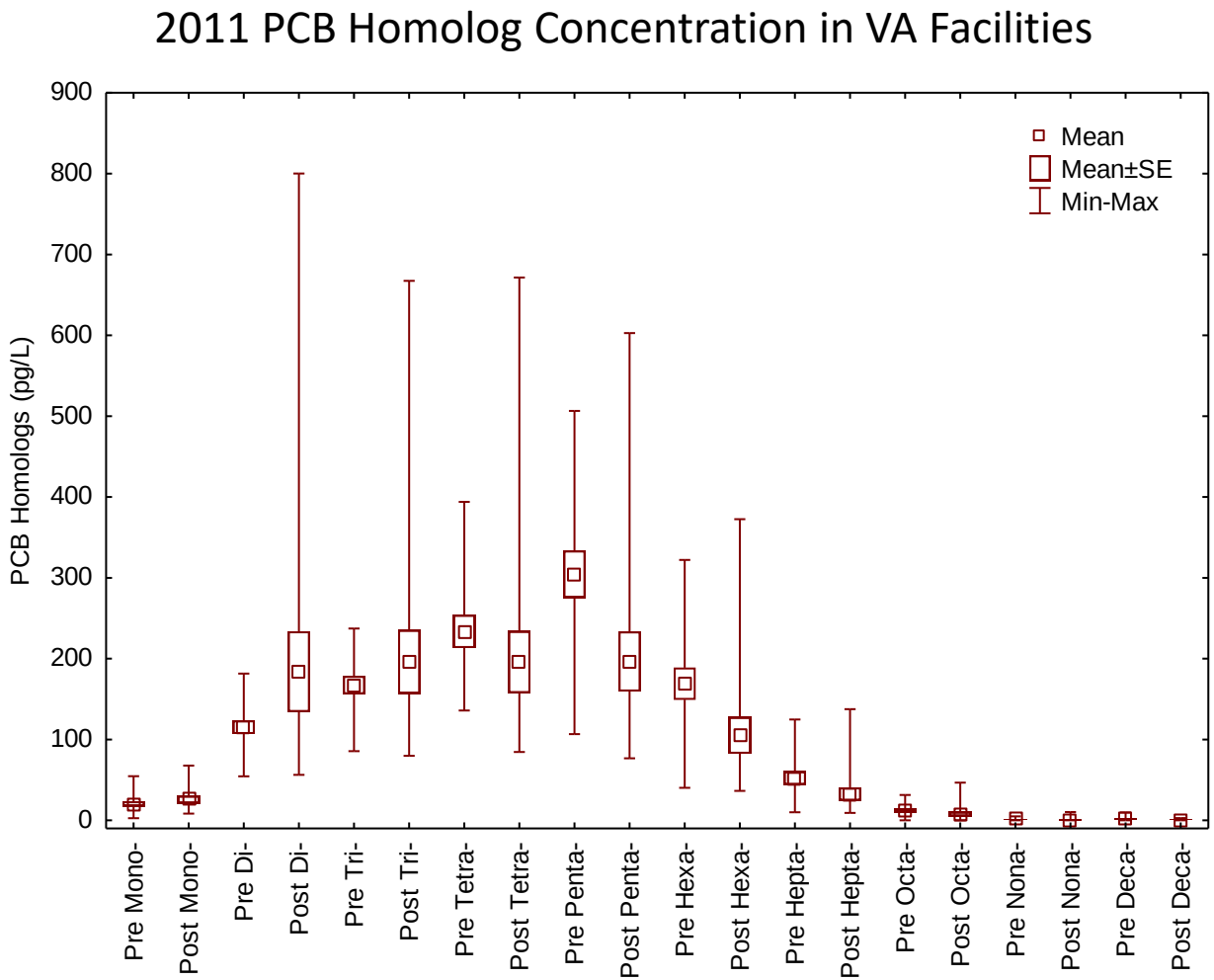
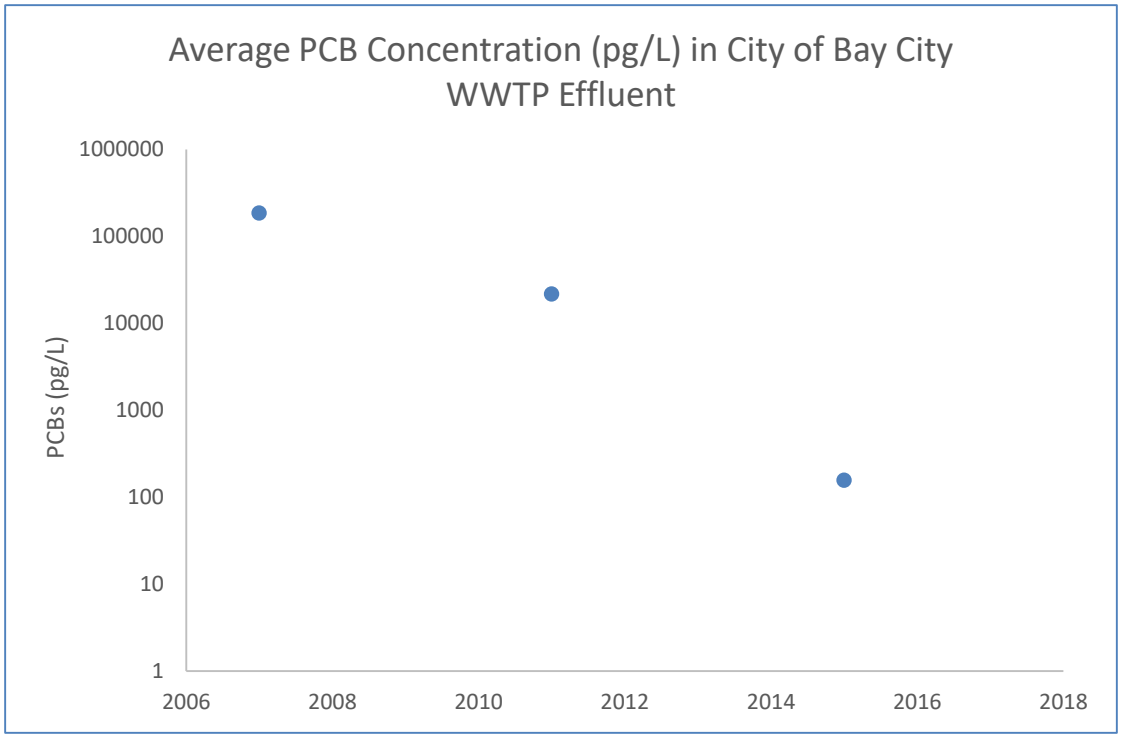
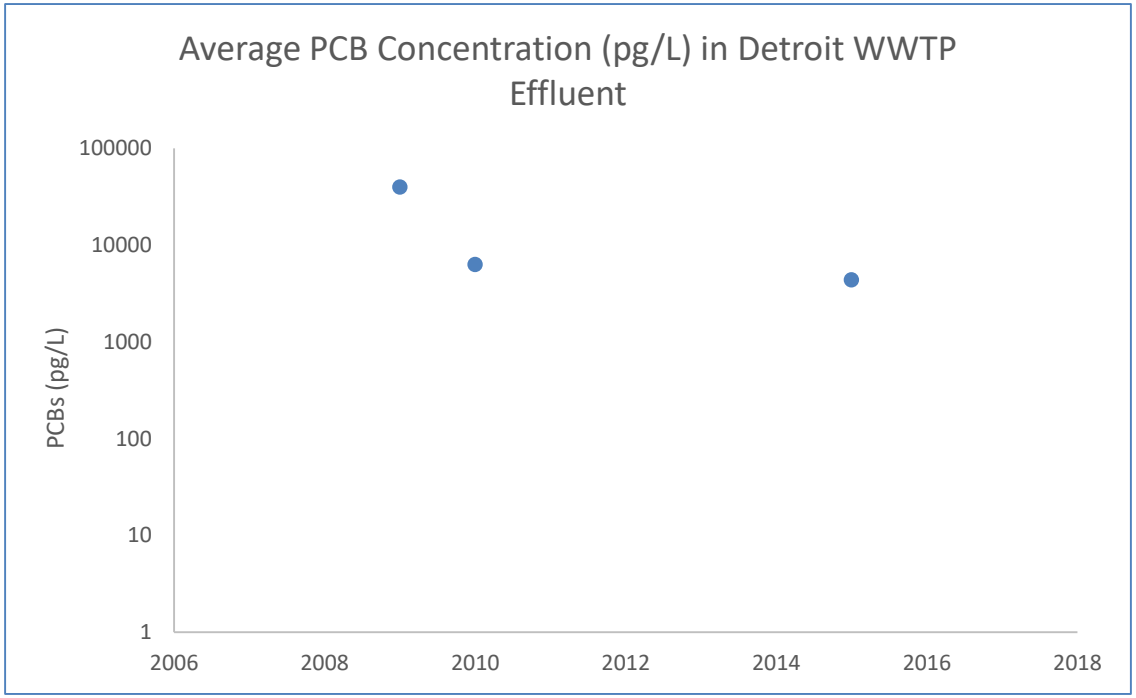


Permitted Discharger Reported Data – Other US Watersheds



Permitted Discharger Reported Data – Other US Watersheds



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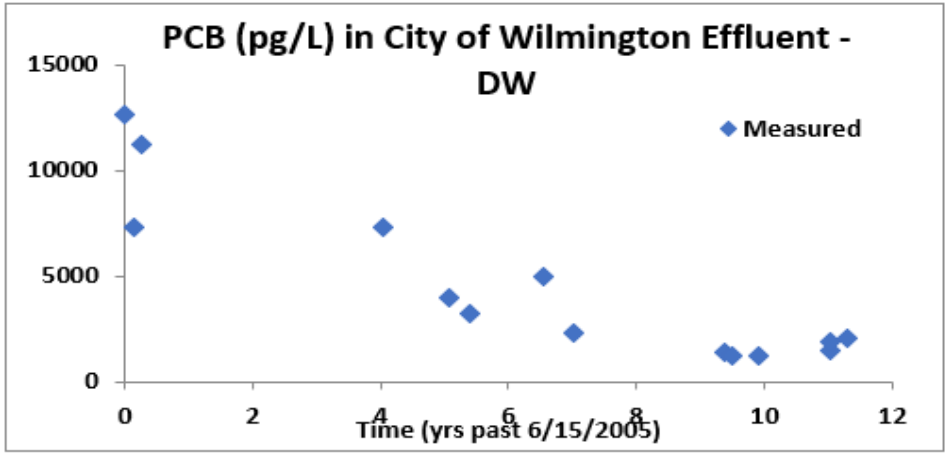

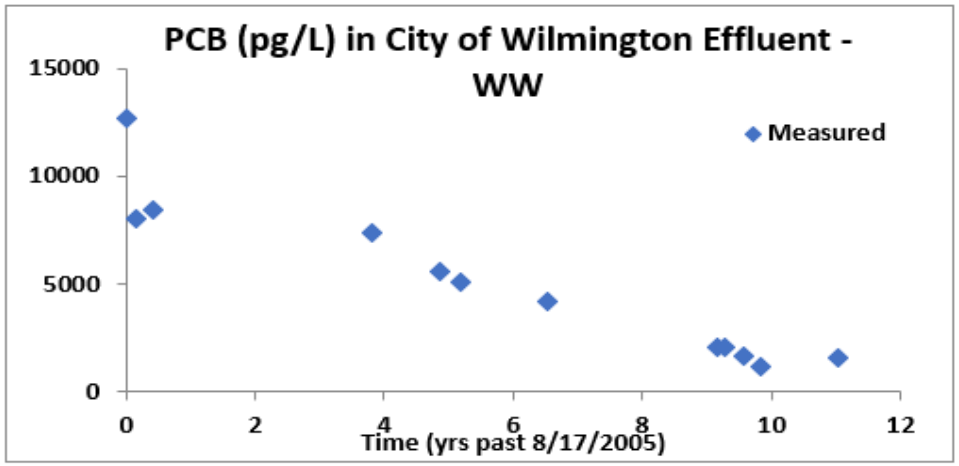

Peer-Reviewed Literature Survey

- 33 pieces of peer-reviewed literature were considered for the survey
  - The literature considers WWTPs in Italy, France, Sweden, Canada, Lithuania, China, Greece, Poland, and the US
- Most published data varies widely in terms of both technical detail and reporting format, complicating analysis
  - Conventional activated sludge treatment
  - Physio-Chemical Treatment Processes
  - Multiple/Unknown Treatment Processes
  - Advanced Treatment Processes
  - Pre- and Post-Upgrade Studies
  - Modeling Efforts
  - Lab Scale Studies
  - Watershed-scale PCB management efforts

Discussion

- Permitted Discharger Data
  - When evaluating whether upgrades for nutrient removal were effective in reducing total PCBs, having total PCB measures in influent, effluent, and sludge is critical
    - Often times unable to quantify and attribute to the source of reduction
  - Appears that nutrient upgrades have a reducing effect on discharge of total PCBs and perhaps other toxics

Discussion

- **Published Literature**
  - Limited information about WWTP operational characteristics affecting PCB removal
  - Much of the literature addressing PCBs in WWTPs focuses on:
    - Sources of PCBs in WWTP influents and potential source controls
    - The strong affinity of PCBs and other toxics to solids
    - Evidence of significant biodegradation of PCBs (e.g., activated sludge)
  - No references directly address the impact of ENR upgrades on PCB or other toxic compound reductions in WWTP effluents
  - Little direct comparison of ENR systems vs. conventional activated sludge treatment

Discussion

- Potential Method for Estimating PCB Reduction Due to ENR Upgrade
  - Literature shows that PCB reductions are related to total suspended solid (TSS) reductions in WWTPs
    - Methodology that quantitatively estimates PCB reductions as a function of WWTP TSS reductions may be warranted as a gross approximation
    - The correlation between TSS and PCB reductions is likely to vary depending on specific WWTP characteristics (e.g., redox conditions)
  - Different redox conditions affect different methods of PCB biodegradation
    - We can therefore infer that WWTPs featuring a range of redox conditions (e.g., ENR) affect higher levels of PCB/toxics reduction
  - Suggested matrix of *WWTP sludge retention time (SRT)* vs. *redox conditions* to estimate *PCB reduction percentage* and *sludge partitioning*

SRT		Conventional AS	Bio. N Removal	Bio. P Removal	Bio N&P Removal
0-8 days	Effluent red. %	0.5*(TSS rem.%)	0.7*(TSS rem.%)	0.7*(TSS rem.%)	0.8*(TSS rem.%)
	PCBs in sludge	95% in sludge	90% in sludge	90% in sludge	85% in sludge
8 or more days	Effluent red. %	0.6*(TSS rem.%)	0.9*(TSS rem.%)	0.9*(TSS rem.%)	1.0*(TSS rem.%)
	PCBs in sludge	90% in sludge	80% in sludge	80% in sludge	70% in sludge

SRT = sludge retention time

Discussion

Identification of Data Gaps

Discharger Compiled Data

- Upgraded WWTPs
  - Lack of measured PCBs in effluent
  - Only effluent is measured for contaminants
  - Facilities either did not measure or were unable to locate total PCBs prior to or after upgrade
- PCBs not routinely measured, if at all, in effluent of potentially upgraded facilities
- Only effluent PCBs measured in other facilities so that change in concentration cannot be determined
- Lack of reporting analytical methods used for PCB analysis

Compiled Published Literature

- Limited data on the quantification of PCB and other toxics reductions attributable to WWTP BNR upgrades

Conclusion

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It is highly likely that nutrient removal upgrades aid in the reduction of toxic compounds, including PCBs, in WWTP effluents

- Limitations: quantitative evidence to support this conclusion is limited and thus overall confidence is low
- Important Findings/Qualifiers:
  - PCB reductions should be differentiated from that of other toxics
  - Hydrophobicity is an important, potentially dominant characteristic of PCBs and other organic pollutants as it pertains to overall liquid phase (i.e., effluent) reductions during wastewater treatment
  - Lighter, lesser chlorinated PCB congeners are more biologically degradable than heavier, more chlorinated congeners
- Other indications:
  - Increased solid volume should increase toxics reduction
  - Increased contact time with biologically active solids should affect higher levels of biodegradation

Recommendations

It is recommended that the CBP and its partners make efforts to better quantify such reductions by

1. Continuing to stay abreast of the most recent literature on the topic;
2. Supporting proactive characterization of remaining WWTPs within the Chesapeake Bay Watershed (and elsewhere) pre- and post-upgrade to BNR; and
3. Supporting other proactive efforts to document the science behind PCB reductions at conventional and BNR WWTPs

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Thank you!

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