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

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Date: September 12, 2019

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The following is a list of common acronyms used throughout the text:

BAC	Biological Activated Carbon
BNR	Biological Nutrient Removal
BOD	Biochemical Oxygen Demand
CAS	Conventional Activated Sludge
CBP	Chesapeake Bay Program
CBT	Chesapeake Bay Trust
CEC	Chemicals of Emerging Concern
cmd	Cubic meters per day
cms	Cubic meters per second
CTP	Conventional Treatment Plants
DeDNREC	Delaware Department of Natural Resource and Environmental Control
DMR	Discharge Monitoring Report
DOC	Dissolved Organic Carbon
DRBC	Delaware River Basin Commission
DW	Dry Weight
DWSD	Detroit Water and Sewerage Department
ECHO	Enforcement and Compliance History Online
ENR	Enhanced Nutrient Removal
GAC	Granular Activated Carbon
gpm	Gallons per minute
g/qtr	Grams per quarter
GWTF	Groundwater Treatment Facility
g/yr	Grams per year
HMW	High Molecular Weight
ICIS	Integrated Compliance Information System
kg/d	Kilograms per day
kg/yr	Kilograms per Year
lb/d	Pounds per day
lb/m	Pounds per month
lb/qtr	Pounds per quarter
lb/yr	Pounds per year
LMW	Low Molecular Weight
MBR	Membrane Bioreactor
MBBR-MF	Moving-bed Biofilm Reactor with Membrane Filtration
mcmd	Million cubic meters per day
MDE	Maryland Department of the Environment
MGD	Million gallons per day
mg/L	Milligrams per liter
MLE	Modified Ludzack Ettinger
MLSS	Mixed Liquor Suspended Solids
MUC	Montreal Urban Community
MWCOG	Metropolitan Washington Council of Governments

ng/L	Nanograms per liter
NPDES	National Pollutant Discharge Elimination System
NSFIH	Naval Support Facility – Indian Head
OC	Organochlorine Compounds
PAC	Polyaluminum Chloride
PAH	Polycyclic Aromatic Hydrocarbons
PBDE	Polybrominated Diphenyl Ethers
PCB	Polychlorinated Biphenyls
PCN	Polychlorinated Naphthalene
PCS	Permit Compliance System
pg/L	Picograms per Liter
POC	Particulate Organic Carbon
POP	Persistent Organic Pollutants
QAPP	Quality Assurance Project Plan
QAQC	Quality Assurance/Quality Control
SBR	Sequencing Biological Reactors
SPMD	Semipermeable Membrane Devices
SRT	Solids Retention Time
TMDL	Total Maximum Daily Load
TOC	Total Organic Carbon
TP	Total Phosphorous
TSS	Total Suspended Solids
TT	Tetra Tech, Inc.
US	United States
USEPA	United States Environmental Protection Agency
UV	Ultraviolet
VaDEQ	Virginia Department of Environmental Quality
WLA	Waste Load Allocation
WPCP	Water Pollution Control Plants
WRF	Water Reclamation Facility
WWTP	Wastewater Treatment Plant
µg/kg	Micrograms per kilogram
µg/L	Micrograms per liter

Foreword

This project was developed by the Chesapeake Bay Program (CBP) Water Quality Goal Implementation Team to assess the potential benefits of wastewater treatment plant nutrient control upgrades on toxic contaminants, emphasis on polychlorinated biphenyl (PCB) reductions. The results of this one-year study are summarized in this technical report.

This report examines the concentrations of toxic chemicals particularly PCBs in pre- and post-nutrient control upgrade wastewater treatment plant (WWTP) effluents that discharge within the Chesapeake Bay watershed as well as those in the Delaware River watershed and the San Francisco Bay watershed. This evaluation was completed by examining published WWTP effluent data using established databases (i.e., United States Environmental Protection Agency (USEPA) Enforcement and Compliance History Online (ECHO), USEPA Permit Compliance System (PCS), and USEPA Integrated Compliance Information System (ICIS)). This assessment also evaluated the peer-reviewed literature with respect to any published studies that may have evaluated the benefits of nutrient control upgrades on toxic contaminant reductions.

In compiling this report, the technical jargon and detailed chemistry was kept to a minimum to make the findings more accessible to the general reader. However, due to the topic being evaluated, it is difficult to avoid the complex and technical terminology used to describe toxic contaminants and WWTP nutrient control upgrades.

Acknowledgments

This project was supported by a contract with the Chesapeake Bay Trust (CBT) which developed the project in consultation with the Water Quality Goal Implementation Team. Tetra Tech (TT) would like to thank Hannah Moore (CBT), Greg Allen (USEPA), and Tanya Spano (MWCOG) for their assistance in designing and developing this project. Additional thanks are extended to the members of the Wastewater Work Group, Toxic Contaminant and Water Quality Goal Implementation Teams for their comments and aid in helping focus the direction of this project.

Executive Summary

The evaluation of the potential reduction in PCBs and other toxics in wastewater treatment plants (WWTPs) that have been upgraded for enhanced biological nutrient reduction (ENR) was evaluated in this report. This assessment was completed by evaluating actual discharger data from multiple sources including compilation of discharger monitoring data and peer-reviewed and other literature. Overall, the broad purposes of this study were to:

(1) Investigate the potential benefits of toxic contaminant reduction, particularly PCBs, associated with the implementation of WWTP nutrient removal upgrades for facilities in the Chesapeake Bay watershed.
(2) Research programs for other watersheds in the United States 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 the implementation of nutrient removal upgrades at WWTP or whether there is any correlation between specific types of nutrient removal upgrades and a reduction in toxic contaminants, particularly PCBs.

Chesapeake Bay Watershed

Information on facilities in the Chesapeake Bay watershed that have been upgraded to ENR were compiled through multiple sources including:

1) USEPA Databases – ECHO and PCS/ICIS
2) State NPDES Programs
3) State-sponsored studies

Maryland and Virginia have the most facilities that had been upgraded for nutrient reduction and provided the largest dataset for the evaluation of the potential reduction in toxics associated with these upgrades. Correlations can be made between the timing of upgrades for nutrient removal and reductions in total PCBs in effluent; however, by not having influent or sludge data, these correlations have a low level of confidence. Other states in the Chesapeake Bay watershed including New York, Pennsylvania, and West Virginia either did not track facilities that had had upgrades for nutrient removal or did not have any that had been upgraded.

Other Watersheds

Multiple watersheds in the US were also assessed for a reduction in PCBs and other toxics due to the upgrading of facilities for ENR. It was difficult to find another watershed that had had facilities that had upgraded for nutrient reduction, but facilities with total PCB data were located. For some of these, City of Wilmington, DE, the observed reduction of PCBs in the effluent is attributable to source reduction due to interceptor cleanouts, sewershed trackback sampling, industrial pretreatment actions, waste site cleanups, and separating storm sewers from sewage (Rick Greene, De DNREC, personal communication). Other WWTPs outside the Chesapeake Bay watershed have effluent concentrations that have reduced over time (i.e., City of Bay City, City of Detroit, and City of Monroe, MI). The Michigan facilities, each of which ultimately discharge effluent to Lake Erie, all show a reduction of effluent total PCB concentrations, but may have only had annual measurements over 3 or 4 years out of the last 10 years (i.e., the data are very limited).

Technical Literature

A broad search and review of relevant literature revealed several important points:

- Most efforts to reduce PCB concentrations in WWTP effluents has focused on source control – that is, minimizing the amount of PCB getting into WWTP influents by identifying and controlling PCBs at their source (including legacy sources like contaminated sediments or even contaminated solids within sewer collection systems).
- Because PCBs and many other toxic compounds are hydrophobic, they preferentially partition to solids. Sorption processes are typically the dominant removal mechanisms in wastewater treatment. Improved PCB removal correlates with improved solids removal at WWTPs.
- Biological degradation of PCBs and other halogenated compounds is inversely correlated with the degree of halogenation (more highly chlorinated PBC congeners are less readily degraded than those with fewer chlorine substitutions).
- Biological degradation of PCBs and other toxics is better at solids retention times (SRTs) of 8 days or greater, and in systems that combine aerobic, anoxic and anaerobic conditions. Reductive dechlorination under anoxic or anaerobic conditions appears to be the predominant biochemical transformation, which explains why upgrading conventional aerobic activated sludge systems to BNR (which requires anoxic and/or anaerobic conditions) can have the co-benefit of reducing toxicity, particularly associated with PCBs.
- Biological nutrient removal (BNR), as well as other related, advanced unit processes (e.g., activated carbon), may be effective at removing other constituents including antibiotics and biogenic hormones. In general, the literature consistently demonstrates that treatment processes that vary redox conditions and/or increase contact with sorptive media (e.g., activated carbon and sludge biomass) increase the removal of toxic organics.

Based on these broad findings, we can say with confidence that upgrading WWTPs to ENR should reduce PCBs (and related toxics) in discharged effluents, all else being equal. However, quantifying said reductions cannot be done with confidence. Multiple citations in the literature suggest that PCB reductions are related to TSS reductions in WWTPs, with percent reductions of PCBs being somewhat less than percent reductions of TSS. With these factors in mind, a rough framework was developed for quantitatively estimating PCB reductions as a function of TSS removal percentage for different WWTP types (conventional activated sludge versus biological nitrogen removal versus enhanced biological phosphorus removal versus biological nitrogen and phosphorus removal) and characteristics (high SRT versus low SRT). Estimates of the ratio of degraded versus sorbed (and thus still “present” in the solids) PCBs are also provided, albeit at an even lower level of confidence (based mainly on best professional judgement).

Although the state of knowledge as summarized in this report is significant, confidence vis-à-vis quantitative benefits is limited and would benefit from well-designed, proactive monitoring strategies at WWTPs planned for future ENR upgrades.

1. Introduction

1.1. Background for the Study

The Chesapeake Bay Program's Water Quality Goal Implementation Team is charged with identifying, defining, quantifying, and incorporating nutrient, sediment, and chemical pollutant reduction and conservation practices into the Chesapeake Bay Program (CBP) decision support system.

In 2015, the CBP funded a project to evaluate the potential toxic reduction benefits that could be achieved through the implementation of traditional nutrient and sediment nonpoint source BMPs. This complementary information about wastewater treatment benefits is intended to help local planners make more efficient implementation decisions that provide multiple ecosystem and human health benefits.

The CBP has an interest in better quantifying the potential reductions in toxic contaminants (with a focus on PCBs) that can be achieved through the installation of nutrient control upgrades at wastewater treatment plants (WWTPs). In the Toxic Contaminants Policy and Prevention Work Plan for 2016/2017, the Maryland Department of the Environment (MDE) committed to conducting a PCB monitoring survey on pre- and post- Enhanced Nutrient Removal (ENR) WWTPs in Maryland to determine if there is an increase in removal efficiency from the ENR treatment technology. This project built upon the data collected by MDE by compiling other data available in the literature or collected by WWTPs in the Chesapeake Bay watershed.

This report provides the CBP partnership with available data on the toxic contaminant reduction benefits (emphasis on PCB reductions) that can be achieved through the installation of nutrient control upgrades at WWTPs to facilitate the Partnership's goal of considering multiple benefits when planning management scenarios.

Therefore, the broad purpose of this study was to:

(1) Investigate the potential benefits of toxic contaminant reduction, particularly PCBs, associated with the implementation of WWTP nutrient removal upgrades for facilities in the Chesapeake Bay watershed.
(2) Assess another large estuary watershed in the United States 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 the implementation of nutrient removal upgrades at WWTP or whether there is any correlation between specific types of nutrient removal upgrades and a reduction in toxic contaminants, particularly PCBs.

1.2. Compilation of Facility Data and Peer-Reviewed Published Literature

To obtain wastewater treatment facility data for this project, Chesapeake Bay watershed jurisdictions were contacted to identify the nutrient removal technologies used by WWTPs and to determine if the upgrades reduced the discharge of PCBs by the facilities. Initially, the compilation of facility data started at higher levels (e.g., State National Pollutant Discharge Elimination System (NPDES) contacts) and eventually specific facilities were contacted as needed to make the effort most efficient and thorough.

Other collated data sources (e.g., EPA's Environmental Compliance and History Online (ECHO) database, USEPA's Permit Compliance System (PCS) and USEPA's Integrated Compliance Information System (ICIS)) were also mined for relevant data. Given that such data are likely to be of unknown quality (thus likely ranking lower in our data quality assessment criteria), an extensive peer-reviewed literature review was also conducted which focused on WWTPs, particularly those that have before and after nutrient reduction upgrade monitoring data to assess the efficacy of nutrient removal upgrades on reducing toxics, particularly PCBs.

Overall the facility data compilation and literature survey focused on the following:

- Collection and review of general information regarding PCB and toxics removal technologies from WWTPs;
- Identification and description of approaches from other research being conducted in similar evaluations of WWTPs, if available;
- Collection and review of data on PCB reductions resulting from WWTP nutrient removal upgrades available in peer-reviewed or government-sponsored literature (including the MDE study of which greater than 50% of the data was provided by MDE);
- Collection and review of PCB data reported by permitted dischargers that demonstrates changes in concentrations of PCBs in effluent both within the Chesapeake Bay Watershed and other watersheds in the US (Delaware – Delaware River; Great Lakes - Michigan);
- Identification of data gaps and future research needs including additional monitoring studies that could specifically focus on generating the needed results.

2. Methods

The facility data review and compilation and the peer-reviewed literature survey were used to determine the breadth of data and whether the data may indicate that toxics, particularly PCBs, may be reduced when a WWTP is upgraded to remove nutrients. Key searches were conducted using online USEPA databases that routinely house discharge monitoring report data as required under the NPDES program, as well as leading search engines for peer-reviewed literature (i.e., Google, Google Scholar, Web of Science).

Available data from the literature review including both project-specific sources and databases were evaluated using the guidance: Quality Assurance Project Plan (QAPP) Requirements for Secondary Data Research Projects (https://www.epa.gov/quality/quality-assurance-project-plan-requirements-secondary-data-research-projects) and the project specific QAPP developed under during this project (Attachment A). Results originating from federal reports or from peer-reviewed journals were assumed to have been evaluated for data quality by comparison against performance criteria from companion quality assurance project plans. Results originating from other sources were evaluated for data quality suitability based on comparison with quality assurance requirements from the project-specific QAPP. A statement on data quality suitability for these other data sources is included in the relevant sections below for the data summarized.

2.1. Facility Data Compilation and Review – Chesapeake Bay and Other Estuary Watersheds

Facility data were compiled by reviewing central online databases that are administered by the USEPA including ECHO, PCS, and ICIS. Additional facility data were compiled by communicating directly with the NPDES permitting authority of the states and regions within the Chesapeake Bay watershed including:

- Delaware (Department of Natural Resources and Environmental Control),
- District of Columbia (USEPA Region 3)
- Maryland (Department of the Environment),
- New York (Department of Environmental Conservation),
- Pennsylvania (Department of Environmental Protection),
- Virginia (Department of Environmental Quality), and
- West Virginia (Department of Environmental Protection).

Key searches were conducted to determine the facilities that have been upgraded for nutrient removal in the past 15 years and have reported PCB data, ideally, for years prior to and after the completion of the upgrade. Compiled data were aggregated by State and discharger and reviewed and scored based on the qualifications described in the project-specific QAPP (Appendix A) and included in Table 2-1.

Table 2-1. Summary of data qualification protocol used to screen facility data compiled from USEPA online databases, state agencies, and facilities.

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)

The scoring matrix for discharger data was a 3x3 matrix as noted in Table 2-1, that scored three metrics:

- **Study/Site Location** – three available scores were allotted under this metric including high (3) for those facilities/sites within the Chesapeake Bay watershed; medium (2) for those in the Eastern US and low (1) for those outside of the Eastern US.

- **Sampling Characteristics** – High (3) for frequent, flow-based composite samples typically collected either monthly or perhaps even weekly; medium (2) were facilities that sampled at least quarterly but sometimes less frequently but no less than annually; and low (1) if the sampling was completed infrequently, for instance, only when the permit is being renewed (i.e., every 5 years).

- **Dataset QA/QC** - for many dischargers the quality assurance and quality control that accompanies data may range from high (3) peer-reviewed, published studies that may have been part of larger reviews or other projects, to medium (2) published but not peer reviewed; due to constraints on the overall project, data may have been published in reports but did not have any type of external peer review of the quality of the data; and low (1) unpublished, nor peer reviewed, which for most of the data available through USEPA databases for Discharge Monitoring Reports (DMR) data is the case. These data may be consultant or discharger data entered into the DMR database and there has been no review of the lab results including analytical and sampling methodology.

The scoring of facility data was used to qualify the data quality with respect to relevance to the Chesapeake Bay region; the frequency of sample collection; and the overall QA/QC of the data. The overall scores were used to determine the suitability of data for evaluation, the higher the score the more suited the data. Overall scores ranged from 3 – 7, with no facility dataset scoring a 9 (3's in all 3 categories).

2.2. Published Literature Compilation and Review

Published literature, both peer-reviewed and not peer-reviewed, were compiled and reviewed for key pieces of research literature that may have assessed the reduction of PCBs and other toxic contaminants due to ENR upgrades to a WWTP. The relevance of each piece of literature that was identified was rated based on meeting certain qualifications as detailed in the project specific QAPP, per Table 2-2.

Table 2-2. Summary of data qualification protocol used to screen peer-reviewed published literature.

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	Effluent or Solids only

Over 25 research papers (peer-reviewed or not peer-reviewed) were compiled and evaluated during this review. A spreadsheet was developed with summaries of critical information including the volume of data in the paper, what type of WWTPs were evaluated, location of the WWTP, constituents evaluated, and qualifications score for each category. The scoring matrix for peer-reviewed literature was a 3x3 matrix as noted in Table 2-2, that scored three metrics:

- **Type of WWTP** – did the research evaluate non-upgraded facilities (1); only upgraded facilities (2); or did the research look at facilities both before and after the implementation of nutrient reduction upgrade strategies (3)? Those reports that looked at pre- and post-nutrient reduction upgrade were scored the highest.
- **Constituents Measured** – were toxics including PCBs measured in the published literature (3); or did the research only look at PCBs (2) or some other toxic (1)? Those reports that include PCBs as one of the number of toxics evaluated were scored the highest.
- **Media Sampled** – the highest preference of published peer-reviewed literature was those studies that measured influent, effluent, and solids concentration of toxics including PCBs (3). Those that measured effluent and at least one other, either influent or solids, were also preferred (2) over those that only measured effluent data (1).

The scoring of published literature data was used to qualify the data quality with respect to relevance to the status of the facility upgrade evaluated; whether PCBs were included in the constituents evaluated; and the number of media (i.e., influent, effluent, and/or solids) that were measured. The overall scores were used to determine the suitability of data for evaluation, the higher the score the more suited the data. Overall scores ranged from 4 – 9, with only one study (Bolzonella e al., 2010) scoring a 9 (3’s in all 3 categories).

3. Compiled Data Results

The compiled data results for both the permitted discharger reported data and the published literature review are presented in this section. The score for each permitted discharger reported dataset is included in each relevant section based on the three aforementioned metrics: study/site location; sampling characteristics; and dataset quality assurance/quality control (QA/QC). The published peer-reviewed and not peer-reviewed reports were also scored, and their results are summarized in Appendix B including the score for all three metrics: type of WWTP; constituents measured; and media sampled.

3.1. Permitted Discharger Reported Data

Permitted discharger data was obtained through searches of EPA databases including ECHO and PCS/ICIS. State permitting agencies were also contacted including those states within the Chesapeake Bay watershed. In many instances, the state permitting agencies provided facility data including effluent, influent, and/or sludge data with respect to PCB concentration. For some states, facilities that are being upgraded to enhanced nutrient reduction technologies are being actively tracked and PCB data was compiled for some of those facilities. For other states, even some within the Chesapeake Bay watershed, the state agencies did not track which facilities were being upgraded for the reduction of nutrients. In the following sections, the compiled data for the states in the Chesapeake Bay watershed are summarized, as well as data from some other estuary watersheds in the US.

3.1.1. USEPA ECHO Database

The USEPA Enforcement and Compliance History Online (ECHO) database located at https://echo.epa.gov/trends/loading-tool/get-data/custom-search/ provides integrated compliance and enforcement information for over 900,000 regulated facilities nationwide according to the website. Per EPA's ECHO website, ECHO's features range from simple to advanced, catering to users who want to conduct broad analyses, as well as those who need to perform complex searches. USEPA's ECHO database returns data that may indicate that facilities have a permit limit for PCB and if they were out of compliance with the permit limit.

USEPA's ECHO database was searched for facilities with effluent PCB data from major watersheds. Treatment facilities with potential effluent PCB non-compliance were searched for and located across eight watershed restoration programs including the Chesapeake Bay Program, as well as the Columbia River Basin Program, Great Lakes Program, Gulf of Mexico Program, Long Island Sound Program, Mid-Atlantic, Puget Sounds – Georgia Basin, and the San Francisco Bay Delta. Effluent PCB data were available for 45 treatment facilities across 18 states, including CA, CT, DC, ID, IL, IN, LA, MA, MD, MI, MN, MT, NY, OH, PA, TX, WA, and WI. Effluent PCB data was available for multiple years across all watersheds, with data from 7 facilities showing a possible decreasing trend in reported PCB concentrations. Of these 7 facilities, two facilities, the Piscataway WWTP and the Naval Support Facility in Maryland are known to have completed ENR upgrades, but only the Piscataway WWTP had pre- and post-upgrade effluent data available. Information for the 7 facilities with multi-year data are presented in Table 3-1. Details on each of these facilities and the data will be presented in the state-specific sections to follow.

The PCB data available from USEPA's ECHO database received a score of 3 – 5 under the proposed data qualification criteria. Some of the sites are in the Chesapeake Bay watershed, the Eastern US, and other locations, thus this qualifier ranged from 1 – 3; for all facilities there were infrequent/irregular composite or grab samples (1), and the data are unpublished (e.g., DMR data) (1).

Table 3-1. Facilities with multi-year PCB datasets from USEPA's ECHO database.

State	Facility Name	ENR Date	PCB Data Date Range
MD	Naval Support Facility	12/30/2008	2008-2017
MD	Piscataway WWTP	5/30/2013	2010-2017
MI	City of Bay City WWTP	NA	2007-2017
MI	Detroit WWTP	NA	2007-2017
MI	Monroe Metro WWTF	NA	2007-2017
MA	General Electric	NA	2010-2017
NY	GM Powertrain – Massena Plant	NA	2007-2017

3.1.2. USEPA PCS/ICIS Database

USEPA's Permit Compliance System (PCS) and Integrated Compliance Information System (ICIS) located at https://www.epa.gov/enviro/pcs-icis-customized-search provides information on companies which have been issued NPDES permits for discharging wastewater into US rivers. Example information that is provided includes when a permit was issued and expires, how much the discharger is permitted to discharge, and the actual monitoring data showing the concentration of pollutants in the discharge. All states except Wyoming are currently reporting data in PCS/ICIS.

PCB data were compiled from USEPA's PCS/ICIS database for 61 facilities across 5 states in the Chesapeake Bay watershed, including DC, MD, NY, PA, and WV. In terms of facilities with ENR upgrades, the data supplement and overlap with the data that were downloaded from USEPA's ECHO database. Of the 61 facilities for which PCB data were available from the ICIS database, 5 facilities, all located in MD, are known to have ENR upgrades (Table 3-2). These facilities are the Naval Support Facility, La Plata, Piscataway WWTP, Mattawoman WWTP, and Swan Point facilities. Of these 5 facilities, Piscataway WWTP is the only one with available PCB data pre- and post-ENR upgrade. Details on each of these facilities and the data will be presented in the state-specific sections to follow.

The PCB data that were downloaded from USEPA's ECHO database received a grade of 6 under the proposed data qualification criteria. The sites are in the Chesapeake Bay watershed (3), there were frequent (at least quarterly for one year) composite samples (2), and the data are unpublished (e.g., DMR data) (1).

Table 3-2. Facilities with known ENR upgrades and PCB datasets from USEPA's ICIS database.

State	Facility Name	ENR Date	PCB Data Date Range
MD	La Plata	3/30/2014	2016-2017
MD	Naval Support Facility	12/30/2008	2008-2017
MD	Piscataway WWTP	5/30/2013	2010-2017
MD	Mattawoman WWTP	11/8/2007	2010
MD	Swan Point	5/3/2007	2011-2017

3.1.3. Chesapeake Bay Watershed

Of the six states (DE, MD, NY, PA, VA, and WV) and the District of Columbia within the Chesapeake Bay watershed, data with respect to PCBs and their potential reduction due to nutrient removal upgrades at wastewater treatment facilities were only located for three states: Washington, DC; Maryland, and Virginia. Although, DMR PCB data were compiled for facilities in Delaware, New York, Pennsylvania, and West Virginia, state agencies indicated that they either did not track WWTP upgrades or that there were not any facilities that had been upgraded for nutrient reduction in the state. Therefore, the following sections are focused on those states/district that had both PCB data and had facilities that had been upgraded for nutrient reduction.

Washington DC

The Blue Plains Advanced Wastewater Treatment Plant in the District of Columbia receives wastewater flows from the District and from Montgomery and Prince George's Counties in Maryland and Fairfax and Loudoun counties in Virginia. The Blue Plains Advanced Wastewater Treatment Plant uses primary and secondary treatment, denitrification, multimedia filtration and chlorination/dichlorination during the treatment process. The Enhanced Nutrient Removal Facilities at the Blue Plains Advanced Wastewater Treatment Plant were placed in operation in 2014 to comply with more stringent nitrogen discharge requirements beginning in January of 2015. The upgrades included over 40 million gallons of additional capacity for nitrogen removal, an 890-million gallon per day (mgd) lift station, new post-aeration facilities, conveyance structures, channels, and facilities to store and feed multiple carbon sources.

The available PCB data for the Blue Plains Advanced WWTP consists of quarterly influent and effluent monitoring from 2010 through 2016 and more frequent monitoring (129 samples) of total PCB concentration in the sludge from 2000 - 2016. Data available for total PCBs are reported in milligrams per liter (mg/L) for influent and effluent, which was converted to picograms per liter (pg/L) for convenience of analysis, and mg/kg for sludge (Table 3-3). Of the 29 influent measurements only 2 resulted in a detected concentration of total PCBs both of which were from 2010 (pre-ENR upgrade); and the detected total PCB concentration ranged from 5,030 to 7,630 pg/L. The non-detects were reported as less than the detection limit, which ranged from 350,000 to 5,600,000 pg/L, but the methods were not reported. Of the 28 effluent measurements only 3 resulted in a detected concentration of total PCBs, all of which were from 2010 (pre-ENR upgrade); the detected total PCB concentration ranged from 690 – 1,350 pg/L. Less than 10% of the sludge samples resulted in detected concentration of total PCBs, with 4 detections before ENR upgrades were completed and 6 detected concentrations since the Blue Plains facility has been operating under ENR upgrade as of 1/1/2015. Most of the reported PCB influent, effluent, and sludge concentrations are non-detects with a "<" qualifier. Unfortunately, for many of the samples, particularly influent and effluent, the reported detection limit may have been too high to quantify the concentration of total PCBs in the samples (Table 3-3). The analytical method used was not provided and may need to be reviewed to determine if the detection level is suitable based on the number of non-detects and the varying detection level reported.

The Blue Plains data received a grade of 7 under the data qualification criteria (Table 2-1). The site is located within the Chesapeake Bay watershed (3) with frequent sampling being composed of frequent, flow-paced composites or representative grab samples (3). These data are unpublished (e.g., DMR data) (1).

Table 3-3. Number of detections, non-detections, and total PCB range per year from 2010 to 2016 at the Blue Plains WWTP.

Influent

Year	# of Detections	PCB Range (pg/L)	# Non-detects	Range of Detection Limits Reported (pg/L)
2010	2	5030 - 7630	3	350,000 – 1,700,000
2011	0	NA	4	510,000 – 4,700,000
2012	0	NA	4	550,000 – 5,600,000
2013	0	NA	4	470,000 – 530,000
2014	0	NA	4	470,000 – 500,000
2015	0	NA	4	490,000 – 580,000
2016	0	NA	4	350,000 – 390,000

Effluent

Year	# of Detections	PCB Range (pg/L)	# Non-detects	Range of Detection Limits Reported (pg/L)
2010	3	690 - 1350	1	430,000
2011	0	NA	4	510,000 – 600,000
2012	0	NA	4	510,000 – 540,000
2013	0	NA	4	480,000 – 530,000
2014	0	NA	4	470,000 – 750,000
2015	0	NA	4	480,000 – 580,000
2016	0	NA	4	310,000 – 350,000

Sludge

Year	# of Detections	PCB Range (mg/kg)	# Non-detects	Range of Detection Limits Reported (mg/kg)
2000	0	NA	3	3.5
2001	0	NA	2	1 - 3.1
2002	0	NA	3	1 - 1.2
2003	0	NA	3	1 - 1.416
2004	1	0.17	3	0.05 - 4.2
2005	0	NA	1	3.2
2010	0	NA	4	0.037 - 0.11
2011	0	NA	12	0.09 - 0.2
2012	1	0.15	11	0.08 - 0.23
2013	0	NA	12	0.085 - 0.17
2014	2	0.13 - 0.42	11	0.096 - 0.28
2015	6	0.1 - 0.33	42	0.082 - 0.53
2016	0	NA	38	0.0095 - 0.3

Maryland

Polychlorinated biphenyl data from wastewater treatment facilities in the state of Maryland were located from multiple sources. Maryland Department of the Environment provided a compiled list of WWTP that have undergone or are currently undergoing facility upgrades for the reduction of nutrient in their discharge on their webpage[1]. The compiled list includes 66 MD facilities. The sources of MD facility PCB data included:

- MDE Enhanced Nutrient Reduction PCB Project
- EPA's ECHO Database (as noted in Section 3.1.1.)
- EPA's PCS/ICIS Database (as noted in Section 3.1.2.)
- PCB TMDL Documents for: Back River and South River

MDE Enhanced Nutrient Reduction PCB Project

Of the 66 MD facilities identified as having undergone or currently undergoing ENR upgrade, four facilities are part of an MDE-sponsored study on the reduction of PCBs with respect to nutrient control upgrades. The identified facilities include Back River WWTP, Cox Creek Water Reclamation Facility (WRF), Elkton WWTP, and Mattawoman WWTP. These facilities have completed 4 rounds of sampling. Back River WWTP and Cox Creek WRF represent the pre-upgrade facilities as sampling was conducted prior to completion of the nutrient reduction upgrade and after, while Elkton and Mattawoman, represent the post-upgrade facilities as upgrades were completed for these facilities in 2009 and 2007, respectively. Table 3-4 summarizes the four facilities in terms of what type of treatment process and the type of upgrade that was completed.

Cox Creek WRF – Cox Creek WRF is completed upgrades in July 2018 for the reduction of nutrients and represents pre-ENR upgrade conditions with two samples pre- and two sample post-upgrades. The total PCB concentration in the influent and effluent were measured in March 2016, April 2016 and twice in October 2018. The influent total PCB concentration ranged from 8,713.7 pg/L (March 2016) to 37,324 pg/L (October 11, 2018) while the effluent total PCB concentration was significantly reduced and ranged from 429 pg/L (October 11, 2018) to 1,222.3 pg/L (March 2016) (Figure 3-1). This represents a reduction of greater than 86% in the concentration of PCBs in the Cox Creek WRF effluent.

Elkton WWTP –Upgrades to the Elkton WWTP were completed in December 2009. The total PCB concentration in the influent and effluent were measured in April, May, June, and July 2016. The influent total PCB concentration ranged from 4,8309.5 pg/L (June 2016) to 27,622.2 pg/L (July 2016), while the effluent total PCB concentration was significantly reduced and ranged from 51.4 pg/L (July 2016) to 285.4 pg/L (June 2016) (Figure 3-1). This represents a reduction of greater than 94% in the concentration of PCBs in the Elkton WWTP effluent.

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[1] http://mde.maryland.gov/programs/Water/BayRestorationFund/Documents/3-BRF-WWTP%20Update%20for%20BayStat%20(1).pdf

Table 3-4. Summary of WWTP in Maryland that have completed an upgrade aimed at the reduction of nutrients from their discharge but also have records for PCB concentration in their influent, effluent, and/or sludge.

Facility	**Details of Treatment Process and Upgrade**	**Estimated Nutrient Load Reduction (lbs/year)**[1]		**PCB Data? What type (i.e. effluent, influent, sludge) and When (pre-, post-upgrade)**
		Nitrogen	**Phosphorous**	
Back River WWTP	Back River WWTP currently receives four levels of treatment including preliminary, primary, secondary, and tertiary treatment. Preliminary treatment includes six fine screens and four grit removal basins. Primary treatment consists of sedimentation tanks for sludge removal. Secondary treatment includes activated sludge processing which has been retrofitted to operate as **Biological Nutrient Removal (BNR) facility**, which allows single stage nitrification/denitrification. Advanced, tertiary, treatment includes sand filtration with just over 2 acres of total filter surface. Final treatment includes disinfection, dechlorination, and aeration before discharge.	1,852,083	NA	• Influent/Effluent PCB Data • Pre-Upgrade Completion • March and April 2016, October 11 and 23, 2018 • Total PCBs by Congener, Homolog, and Aroclor and Individual Congener Data
Cox Creek WRF	The facility provides wastewater treatment using the following process units in sequence: mechanical bar-screen for the large solids removal from the influent, aerated grit removal chamber, primary clarifiers (two rectangular and four circular units) running parallel, **BNR process reactors** (seven units) running parallel, secondary clarifiers (two circular and four rectangular units) running parallel, chlorine contact chamber for disinfection, post-aeration chamber, and dechlorination and final effluent collection chamber. The ferrous sulfate (FeSO4) is added in the BNR reactors for the phosphorous removal. Each of the BNR reactors consists of the oxic, anoxic and aeration basins. Chemicals are added to the wastewater at several spots during treatment process: caustic soda for pH adjustment, liquid chlorine for disinfection, and sodium sulfate for dechlorination.	135,374	57,534	• Influent/Effluent PCB Data • Pre-Upgrade Completion • March and April 2016, October 11 and 23, 2018 • Total PCBs by Congener, Homolog, and Aroclor and Individual Congener Data
Elkton WWTP	The project at the Elkton wastewater treatment plant (WWTP) consists of planning, designing and constructing the replacement for the existing 2.7 million gallons per day (mgd) Rotating Biological Contactors WWTP with **biological nutrient removal and enhanced nutrient removal facilities** that will reduce the plant's total nitrogen removal to a yearly average of 3 milligrams per liter and 0.3 milligrams per liter for phosphorus. That is an 80 percent reduction in nitrogen and a 70 percent decrease in phosphorus to the receiving Big Elk River. This project also includes expanding the capacity of the facility from 2.7 mgd to 3.2 mgd.	72,977	8,861	• Influent/Effluent PCB Data • Post-Upgrade Completion • April, May, June, July 2016 • Total PCBs by Congener, Homolog, and Aroclor and Individual Congener Data
Mattawoman WWTP	The Mattawoman WWTP is a four-stage Bardenpho process and utilizes mechanical bar screen, grit removal chamber, primary clarifiers, oxidation reactor, secondary clarifiers, tertiary clarifiers, sand filter bed, and UV disinfection. The excess sludge is treated on site using sludge digester and belt filter press to produce class B biosolids. According to MDE, the Mattawoman WWTP began operating with ENR technology on 11/8/2007.	462,296	NA	• Influent/Effluent PCB Data • Post-Upgrade Completion • April, May, June, July 2016 • Total PCBs by Congener, Homolog, and Aroclor and Individual Congener Data

Table 3-4. Continued.

Facility	**Details of Treatment Process and Upgrade**	**Estimated Nutrient Load Reduction (lbs/year)[1]**		**PCB Data? What type (i.e. effluent, influent, sludge) and When (pre-, post-upgrade)**
		Nitrogen	**Phosphorous**	
Piscataway WWTP	Expansion of the existing Piscataway WWTP increasing plant capacity from 60 MGD to 120 MGD. Construction of new Headworks facilities which include an Influent Distribution Box, Screen Chamber, Grit Removal System, Storm Diversion Chamber. Sludge removal and rehabilitation of existing Storage Ponds. New 5 million gallon concrete Storage Tank and Emergency Storage Pond with geomembrane lining system. Other work includes Process and Chemical Piping, Electrical and Instrumentation systems to support new facilities. Piscataway **WWTP Enhanced Nutrient Removal Project** included construction of supplemental carbon storage/distribution facilities and baffle modifications inside the reactor basins. According to MDE, the Piscataway WWTP began operating with ENR technology on 5/30/2013.	268,801	NA	• Effluent PCB Data • Pre- and Post-Upgrade Completion
Naval Support Facility – Indian Head	The improved wastewater treatment plant also includes new headworks (screening and grit removal), influent pump station, continuous inflow SBRs, Blue Water upflow filters, UV disinfection, post aeration tanks, and a new control/laboratory building. In addition, the old aeration basins were converted to new aerobic digesters and most of the old wastewater treatment plant was demolished to avoid increasing the impervious area at the site. According to MDE, the Naval Support Facility began operating with ENR technology in December 2008.	16,281	6,920	• Effluent PCB Data • Pre- and Post-upgrade Completion
Swan Point WWTP	According to MDE, the Swan Point WWTP began operating with ENR technology on 5/30/2007.	5,021	610	• Effluent PCB Data • Post-upgrade Completion

[1] – Estimated nutrient load reductions as reported by MDE at http://mde.maryland.gov/programs/Water/BayRestorationFund/Documents/3-BRF-WWTP%20Update%20for%20BayStat%20(1).pdf

Back River WWTP – Back River WWTP completed upgrades for the reduction of nutrients in September 2017 and represents pre-ENR upgrade conditions. The total PCB concentration in the influent and effluent were measured in March 2016, April 2016, and twice in October 2018. The influent total PCB concentration ranged from 22,588 pg/L (October 23, 2018) to 113,965.4 pg/L (April 2016) while the effluent total PCB concentration was significantly reduced and ranged from 66 pg/L (October 11, 2018) to 3,988.6 pg/L (March 2016) (Figure 3-1). This represents a reduction of greater than 96% in the concentration of PCBs in the Back River WWTP effluent.

Mattawoman WWTP –Upgrades to the Mattawoman WWTP were completed in November 2007. The total PCB concentration in the influent and effluent were measured in April, May, June, and July 2016. The influent total PCB concentration ranged from 232.8 pg/L (July 2016) to 4,842.3 pg/L (April 2016), while the effluent total PCB concentration was significantly reduced and ranged from 66.2 pg/L (July 2016) to 879 pg/L (June 2016) (Figure 3-1). In April and May 2016, the Mattawoman WWTP reduced the total PCB concentration in the effluent by over 98%. However, in June a 49% reduction was recorded, while in July a 72% reduction was recorded.

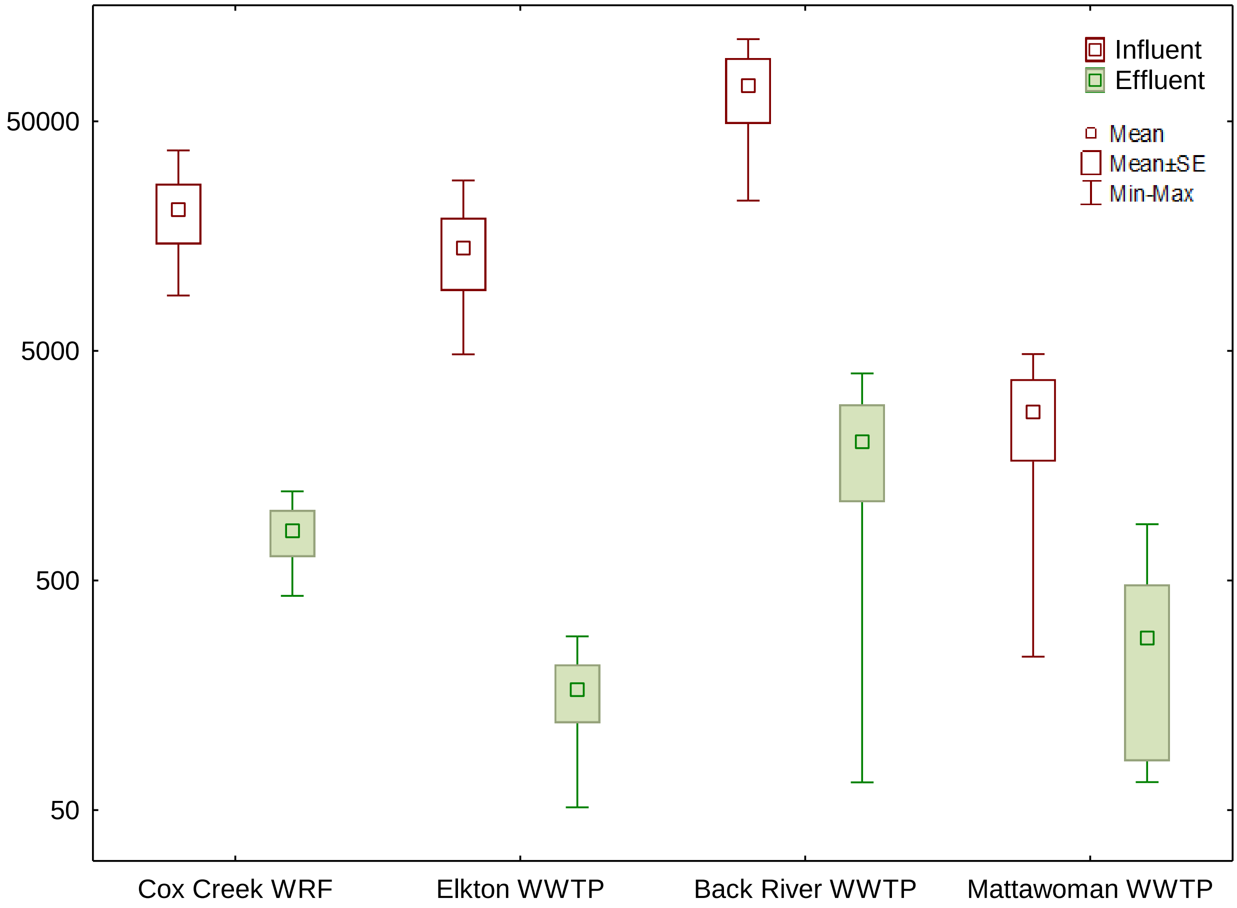

Figure 3-1. Influent and Effluent Total PCB Concentration in four MD facilities, two that have completed ENR-upgrades (Elkton and Mattawoman WWTP) and 2 that have not (Cox Creek WRF and Back River WWTP Box mid-point is the mean concentration, Box is mean plus standard error, and Whisker is min/max concentration. (n = 4 for each facility).

The State of Maryland PCB TMDL Project lab report received a grade of 5 under the proposed data qualification criteria. The site is located within the Chesapeake Bay watershed (3). The sampling was composed of infrequent/irregular composite or grab samples (1), and the data are unpublished (e.g., DMR data) (1).

USEPA ECHO and PCS/ICIS - Piscataway Wastewater Treatment Plant

PCB data for the Piscataway WWTP were available from EPA's ECHO database. The ECHO data for this facility span from 2010 to 2017 and include measurements for PCB load per year and average daily load. Pollutant load per year ranged from 0.006 to 0.05 kilograms per year (kg/yr) and showed a decrease in 2016 and 2017, while average daily load ranged from 0.00002 to 0.0001 kg/day and showed an apparent decreasing trend in recent years.

DMR data for the Piscataway WWTP effluent were also available through PCS/ICIS in a variety of forms, including grams per year (g/yr), pounds per day (lb/d), pounds per month (lb/mo), pounds per year (lb/yr), mg/L, pg/L, and micrograms per kilogram (µg/kg). Ten measurements were reported as g/yr and span through 2016 and 2017, ranging from 0.815 to 9.33 without showing any obvious trends. From 2010 to 2016, there are 75 measurements given in lb/d ranging from 0.000012 to 0.001 that indicate the possibility of a decreasing trend. In lb/mo, 82 measurements were reported between 2010 and 2016 that range from 0.00035 to 0.015 and show an apparent decreasing trend. In 2010, 2011, and 2012 the DMR values were 0.07, 0.03, and 0.02 lb/yr, respectively, which points to a decreasing trend. In 2012 and 2013, DMR values were reported at 624 and 449 mg/L, respectively. Over 70 DMR values (79) were reported in pg/L from 2010 to 2016, ranging from 67.5 to 2150 pg/L and indicate the possibility of a downward trend. Only one measurement was reported in µg/kg. Analysis of Total PCB effluent concentration is restricted to the 79 24-hour composite data points reported as pg/L including 31 pre-upgrade and 48 post-upgrade samples.

Based on approximately monthly samples from August 2010 through April 2017 extracted from PCS/ICIS, the Piscataway WWTP effluent concentration of total PCBs indicates that prior to the nutrient reduction upgrade, the average monthly effluent concentration was 617 pg/L (131 – 2150 pg/L) and after the upgrade the average monthly effluent concentration was 432 pg/L (67.5 – 1705 pg/L) (Figure 3-2). The reduction of total PCB in the Piscataway WWTP effluent does not appear correlated with the completion of nutrient reduction upgrades in May 2013. The total PCB effluent data measured in the Piscataway WWTP effluent in 2015 is an order of magnitude higher than any other effluent measurements except for October 2015 (1705 pg/L). If the 2010 effluent measurements (August – December) are removed from the dataset, the mean monthly effluent total PCB concentration before the upgrade is 432 pg/L which is the same as the average monthly total PCB concentration after the upgrade; therefore, the upgrade does not appear to be a significant source of reducing the total PCB effluent concentration at the Piscataway WWTP.

The Piscataway WWTP ECHO data received a grade of 5 under the proposed data qualification criteria. The site is located within the Chesapeake Bay watershed (3), with infrequent/irregular composite or grab sampling (1), and the data being unpublished (e.g., DMR data) (1). The ICIS data received a grade of 7 because the site is in the Chesapeake Bay Watershed (3), there were frequent, flow-paced composites or representative grab samples (3), and the data are unpublished (e.g., DMR data) (1).

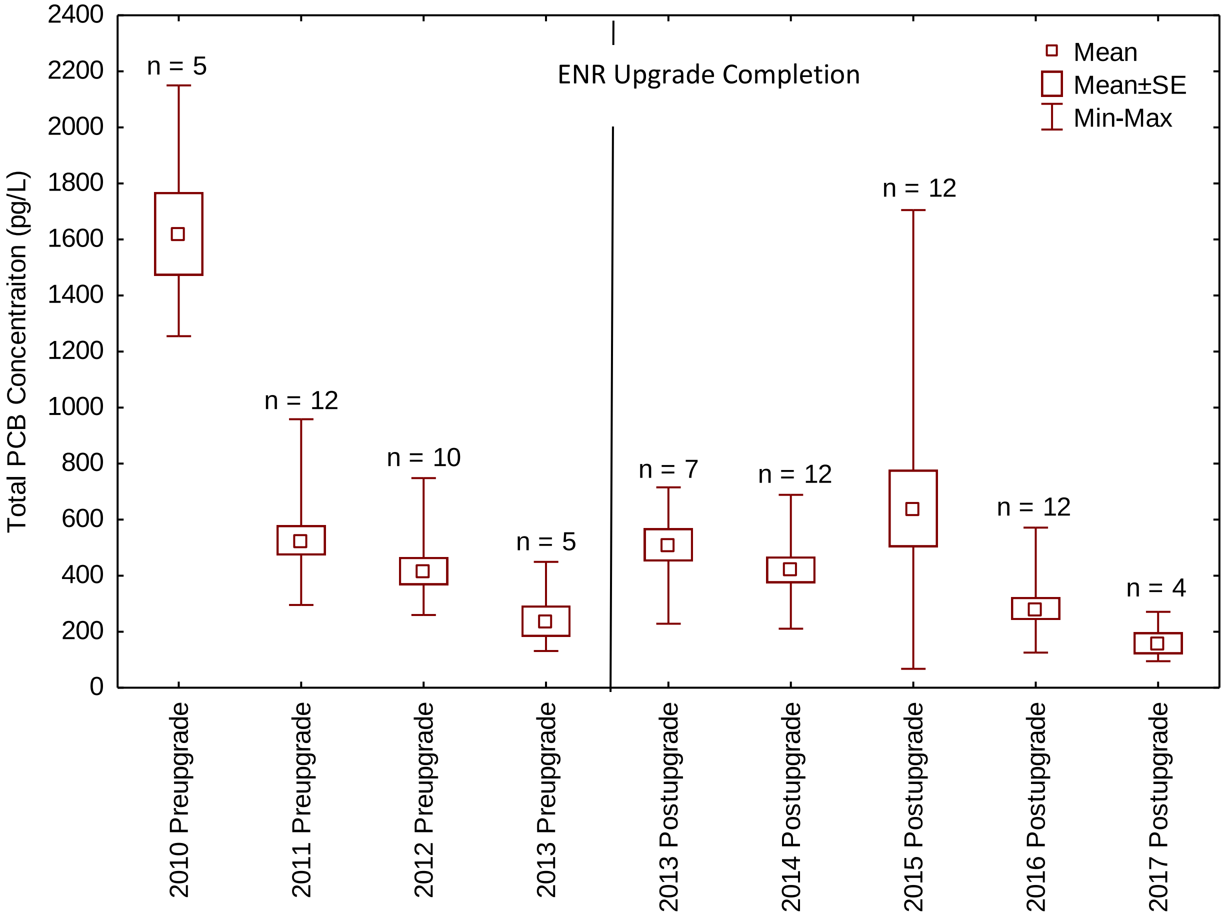

Figure 3-2. Total PCB concentrations in the Piscataway Creek WWTP effluent before and after the completion of upgrades for nutrient reduction (May 2013). Box mid-point is the mean concentration, Box is mean plus standard error, and Whisker is min/max concentration.

USEPA ECHO and PCS/ICIS – Naval Support Facility – Indian Head

The Naval Support Facility – Indian Head (NSFIH) WWTP upgrades included combined renovation and new construction to the sewage treatment plant including an equalization tank, a chemical feed system for phosphorus removal, a methanol feed system, an oxidation ditch system, constructed wetlands, secondary clarifiers, and a sand filtration system. Although less than 3% of the influent to the facility is from industrial facilities, the WWTP uses settling, filtration, and activated carbon to remove explosives, nitrate esters, and other contaminants as part of its initial treatment of wastewater before it enters the sanitary sewer system. Secondary treatment includes the use of sequencing batch reactors. The secondary effluent then receives tertiary treatment including the use of sand filtration, denitrification filters (that also remove phosphorus), and aeration. Finally, the facility uses UV for disinfection. After preliminary thickening, the sludge is aerobically digested to Class B standards, then dewatered somewhat in on-site reed dewatering beds. The resulting sludge (3% solids) is transported via 2,000-gallon tanker trucks to the nearby Mattawoman WWTP for further treatment (Barry, 2013).

Total PCB data for the NSFIH WWTP were available from EPA's ECHO and PCS/ICIS databases. The ECHO data for this facility span from 2008 to 2017 and include measurements for PCB load per year and average daily load. Pollutant load per year ranged from $2.8*10^{-5}$ to 0.039 kg/yr and showed an increase over 2015 to 2017, after a three-year decreasing trend from 2012 through 2014. Average daily load ranged from 8.1 * 10^{-7} to 0.0001 and like PCB load per year had a decreasing trend from 2012 through 2014, but increased over the last three years, 2015 through 2017. Both PCB load per year and average daily load indicate significant decreases after the nutrient reduction upgrades were completed in 2008 (Figure 3-3).

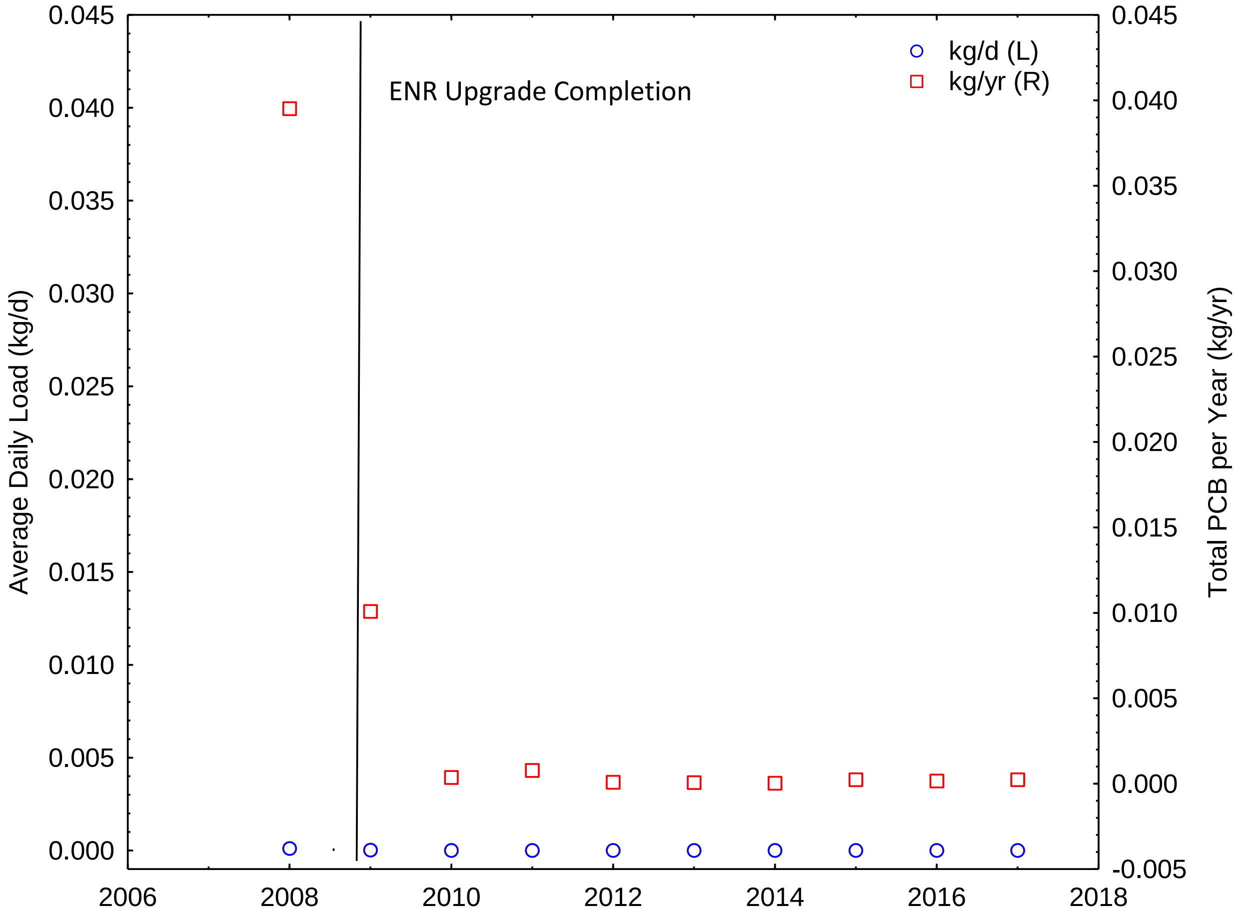

Figure 3-3. Total PCBs average daily load and load per year at the NSFIH WWTP from 2008 through 2017. ENR upgrade completion was December 2008.

DMR data for the NSFIH WWTP effluent were also available through PCS/ICIS in a variety of forms, including grams per quarter (g/qtr), g/yr, pounds per quarter (lb/qtr), lb/yr, µg/L, and pg/L. Measurements reported as g/yr were available for 2009, and the years 2014 through 2017. The 2009 reported value was 0.19 g/yr, while the other 8 reported values (2014 – 2017) ranged from 0.042 (3/2016) to 0.261 (6/2015) without showing any obvious trends. In lb/yr, 28 measurements were reported between 2008 and 2015, with the majority between 2008 and 2010, that range from 0.0001 (1/2010) to 0.372 (12/2015) and show an apparent decreasing trend from 2008 to 2010 but a spike in 2015. Almost quarterly measures of total PCBs as pg/L (1 measure – March 2014 appears to have been inadvertently entered as µg/L) were reported in pg/L from 2014 through 2017, ranging from 184 (12/2014) to 437 (3/2017) pg/L and indicate the possibility of a increasing trend. Analysis of Total PCB effluent concentration is restricted to the eleven 24-hour composite data points reported as pg/L which are all post-upgrade samples.

Based on annual average samples from 2008 through 2013 and quarterly samples from 2014 through 2017 extracted from PCS/ICIS, the NSFIH WWTP effluent concentration of total PCBs indicates that prior to the nutrient reduction upgrade, the 2008 and 2009 effluent concentrations were 81,110 and 19,895 pg/L and beginning in 2010 the effluent concentration decreased to less than 715, ranging from 166 in 2013 to 715 in 9/2015 (Figure 3-4). The reduction of total PCB in the NSFIH effluent appears correlated with the completion of nutrient reduction upgrades in December 2008.

The NSFIH WWTP ECHO data received a grade of 5 under the proposed data qualification criteria. The site is located within the Chesapeake Bay watershed (3), with infrequent/irregular composite or grab sampling (1), and the data being unpublished (e.g., DMR data) (1). The ICIS data received a grade of 7 because the site is in the Chesapeake Bay Watershed (3), there were frequent, flow-paced composites or representative grab samples (3), and the data are unpublished (e.g., DMR data) (1).

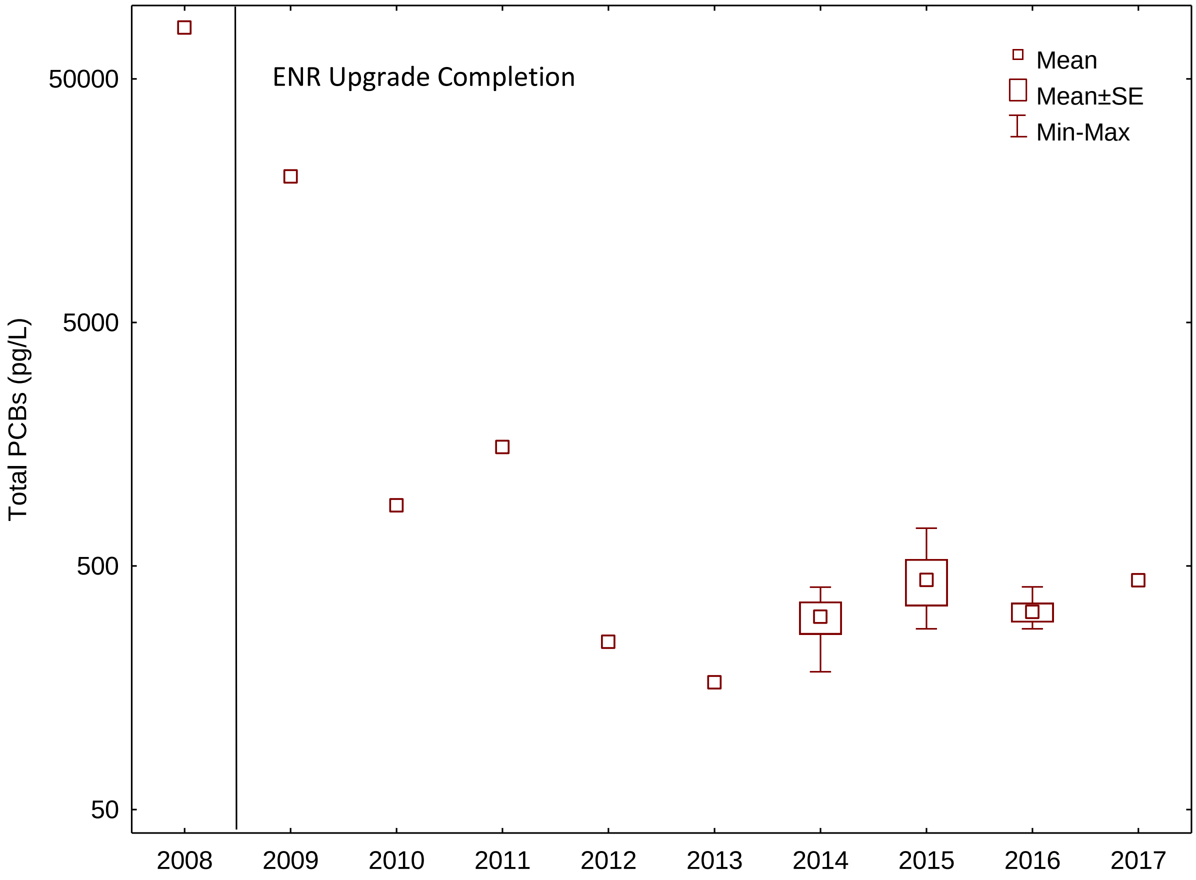

Figure 3-4. Total PCBs from 2008 - 2017 in the Naval Support Center - Indian Head effluent. NSC-IH ENR completion was 12/30/2008. Box mid-point is the mean concentration, Box is mean plus standard error, and Whisker is min/max concentration.

Back River WWTP TMDL

A total maximum daily load (TMDL) was established for the Back River Oligohaline Tidal Chesapeake Bay segment in 2012 (MDE 2011). The baseline load for total PCBs, TMDL allocations, load reductions, and maximum daily loads in the Back River embayment are summarized in Table 3-5. Approximately 62.5 percent of the baseline load consists of point sources/waste load allocations (WLAs). Current point sources of PCBs to the Back River include the Back River WWTP and NPDES regulated stormwater discharges from Baltimore City and Baltimore County. The average PCB concentration for the Back River WWTP discharger was reported as 906 pg/L, with an average baseline load of 0.365 g/day and 133.2 g/year (MDE 2011; Table 5). Sampling for PCB analysis occurred in May of 2006. The baseline total PCB loading was calculated based on the average discharge flow for the period between March 2010 and February 2011 and the average total PCB effluent concentration. MDE (2011) only reports the average concentration and the calculated loading and does not include individual measurements used to determine the average, and thus no trends can be discerned from the reported data.

The Back River WWTP data received a grade of 7 under the proposed data qualification criteria. The site is located within the Chesapeake Bay watershed (3). The sampling was composed of infrequent/irregular composite or grab samples (1), and the data are peer reviewed and published (3).

Table 3-5. Summary of Baseline total PCB Loads, TMDL Allocations, Load Reductions, and Maximum Daily Loads (MDL) in the Back River Embayment (MDE 2012).

Source	**Baseline Load (g/year)**	**Percent of Total Baseline Load (%)**	**TMDL (g/year)**	**Load Reduction (%)**	**MDL (g/day)**
Direct Atmospheric Deposition	267.8	29.0	160.0	40.3	1.09
Non-regulated Watershed	65.7	7.1	31.2	52.5	0.21
Contaminated Sites	12.8	1.4	12.8	0.0	0.09
Nonpoint Sources/LAs	**346.3**	**37.5**	**204.0**	**41.1**	**1.39**
WWTP	133.2	14.4	48.5	63.6	0.41
NPDES Regulated Stormwater[1]					
Baltimore County	273.7	29.7	127.6	53.4	0.87
Baltimore City	169.9	18.4	82.3	51.6	0.56
Point Sources/WLAs	**576.8**	**62.5**	**258.4**	**55.2**	**1.84**
MOS (5%)	**-**	**-**	**24.3**	**-**	**0.17**
Total	**923.1**	**100.0**	**486.7**	**47.3**	**3.40**

[1] – Load per jurisdiction applies to all NPDES stormwater dischargers within the jurisdiction's portion of the watershed draining to the Back River embayment. These dischargers are identified in MDE (2012) Appendix J.

South River WWTP TMDL

A TMDL was established for the South River Mesohaline Tidal Chesapeake Bay segment in 2014 (MDE 2014). The baseline load for total PCBs, TMDL allocations, load reductions, and maximum daily loads in the South River are summarized in Table 3-6. Approximately 0.2 percent of the baseline load consists of point sources/WLAs. Current point sources of PCBs to the South River include the Summer Hill Mobile Home WWTP and several NPDES regulated stormwater discharges. Because no PCB data are available for the WWTP, the concentrations were estimated based on the median total PCB effluent concentration from 13 WWTPs monitored by MDE in the Chesapeake Bay Watershed. The average concentration for total PCBs was reported as 910 pg/L with a baseline load of 0.024 g/year. No trend could be observed because only the average and baseline load values were reported and not the raw data used to calculate the values.

The South River TMDL did not receive a grade under the proposed study prioritization criteria because the data for the Summer Hill Mobile WWTP are estimations based on the median total PCB effluent concentration from 13 different facilities.

Table 3-6. Summary of Baseline total PCB Loads, TMDL Allocations, Load Reductions, and Maximum Daily Loads (MDL) in the South River (MDE 2014).

Source	**Baseline Load (g/year)**	**Percent of Total Baseline Load (%)**	**TMDL (g/year)**	**Load Reduction (%)**	**MDL (g/day)**
Chesapeake Bay Mainstem Influence	2,227.0	97.8	1,124.0	49.5	4.62
Direct Atmospheric Deposition (to the Surface of the Embayment)	38.4	1.7	38.4	0.0	0.16
Watershed Nonpoint Sources	8.2	0.4	8.2	0.0	0.03
Nonpoint Sources	**2,273.6**	**99.8**	**1,171**	**48.5**	**4.81**
WWTP	0.024	0.001	0.024	0.0	0.00
NPDES Regulated Stormwater	3.9	0.2	3.9	0.0	0.02
Point Sources	**3.92**	**0.2**	**3.92**	**0.0**	**0.02**
MOS (5%)	**-**	**-**	**62**	**-**	**0.25**
Total	**2,278**	**100**	**1,237**	**45.7**	**5.08**

Virginia

Virginia Department of Environmental Quality (VaDEQ) provided a compiled list of WWTP that have undergone nutrient reduction upgrades on their website[2]. The compiled list consists of 64 facilities and of those 64, sixteen facilities were identified by VaDEQ as having PCB data. Summarized in Table 3-7 were those that were identified by VaDEQ as having collected PCB data either pre-upgrade or post-upgrade for the reduction of nutrients. The sixteen identified facilities had a variety of treatment processes and were all upgraded or are in the process of completing an upgrade for enhanced nutrient removal (ENR) including in most instances some form of biological nutrient removal (BNR). For some facilities the upgrade consisted of moving to state of the art nutrient removal which in the example of Dale City Service #1 WWTF included upgrading the sequencing biological reactors (SBRs), rehabilitating the two existing tertiary clarifiers and installing a new one, upgrading the aerobic digester blowers and recycle pump station, and installing a supplemental carbon storage and feed system and static mixtures for aluminum salt feed on the tertiary clarifiers.

VaDEQ identified sixteen facilities that had collected PCB data on their effluent discharge. For nine of these facilities, these data were collected before the completion of the upgrade for the reduction of nutrients and for seven of these facilities it was after the upgrade (Table 3-7). The measured total PCB concentration, as well as the congener group concentration (i.e., mono, di, tri, etc homologs), for each

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[2] http://www.deq.virginia.gov/Programs/Water/CleanWaterFinancingAssistance/WaterQualityImprovementFund/WaterQualityImprovementFundList.aspx

Table 3-7. Summary of WWTP in Virginia that have completed or are completing an upgrade aimed at the reduction of nutrients from their discharge but also have records for PCB concentration in their influent, effluent, and/or sludge.

Facility	**Details of Treatment Process and Upgrade**	**Expected Nutrient Load Reduction (lbs/year)**		**PCB Data? What type (i.e. effluent, influent, sludge) and When (pre-, post-upgrade)**
		Nitrogen	**Phosphorous**	
Hampton Roads Sanitation District (HRSD) – Army Base	The Army Base Treatment Plant provides primary and secondary treatment, effluent disinfection and dechlorination, and combined primary and waste activated solids thickening, dewatering, and incineration. A new preliminary treatment facility was constructed to provide raw wastewater influent screening, pumping, grit removal, and residuals handling. The secondary treatment process has been upgraded to an **enhanced nutrient removal system consisting of a 5-stage activated sludge, biological nutrient removal process** that includes new aeration tanks, modifications to existing aeration tanks, modifications to existing secondary clarifiers, and a Nitrification Enhancement Facility. HRSD – Army Base upgrade with ENR technology was completed in March 2015.	1,074,474	26,134	• Effluent PCB Data • Pre-Upgrade Completion • Wet/Dry Weather PCB Data • July and October 2011 • Total PCBs and Homolog data
HRSD – James River WWTP	The James River WWTP treatment process includes screening, grit collection, pre-aeration, and primary clarification followed by aeration tanks, secondary clarification, and chlorine contact tanks. **Nutrient reduction upgrades include augmenting the secondary treatment process with an integrated fixed film activated sludge (IFAS) system** and upgrades related to the secondary treatment process include screening improvements, modification of the biological reactors to an MLE configuration with IFAS in the aerobic sections, blower upgrades, electrical upgrades, and replacement of the polymer system and digester heating boiler.	407,909	NA	• Effluent PCB Data • Post-Upgrade Completion • Wet/Dry Weather PCB Data • July and August 2011 • Total PCBs and Homolog data
HRSD – Nansemond WWTP	The Nansemond Wastewater Treatment Plant consists of preliminary treatment (grit and screening), primary treatment, secondary treatment (3-stage BNR activated sludge system), effluent disinfection and dechlorination. Upgrades to the secondary treatment process include new aeration tanks to upgrade to **5-stage BNR treatment**, modifications to existing aeration and anaerobic/anoxic tanks, a new supplemental carbon feed facility, replacement of secondary clarifier sludge collection mechanisms, electrical systems and instrumentation and control upgrades, and new blowers, standby power and switchgear.	566,500	NA	• Effluent PCB Data • Post-Upgrade Completion • Wet/Dry Weather PCB Data • June, July and October 2011 • Total PCBs and Homolog data

Table 3-7. Continued.

Facility	**Details of Treatment Process and Upgrade**	**Expected Nutrient Load Reduction (lbs/year)**		**PCB Data? What type (i.e. effluent, influent, sludge) and When (pre-, post-upgrade)**
		Nitrogen	**Phosphorous**	
HRSD – Virginia Initiative Plant	The Virginia Initiative Plant (VIP) provides secondary treatment (activated sludge) with biological nutrient removal, biological phosphorus removal and seasonal nitrification and denitrification. Treatment processes at the plant include influent screening and pumping, vortex grit collection, primary clarification, secondary treatment with 3-stage nutrient removal, and chemical disinfection. **Enhanced nutrient removal include upgrading the 3-stage nutrient removal process to a 5-stage process by adding additional biological reactor volume and secondary clarification capacity.** Two operating modes will be supported under this design; a normal flow mode providing 5-stage biological nutrient removal and a wet weather mode comprised of a 3-stage process in parallel with an activated sludge treatment process.	450,527	121,764	• Effluent PCB Data • Post-Upgrade Completion • Wet/Dry Weather PCB Data • May, July and October 2011 • Total PCBs and Homolog data
Alexandria Advanced WTF	The Alexandria Advanced WTF utilizes a biological nutrient removal (BNR) process that can use either the Modified Ludzack Ettinger (MLE) process or a step feed nitrogen removal mode of operation. The facility was upgraded to achieve **Enhanced Nutrient Removal (ENR) by improving its biological reactor basins, secondary settling tanks, and dewatering concentrate system and the primary scum system.** In addition to the liquid process upgrades, the capacity of some of the solids handling process will be increased to continue to produce Class A biosolids.	2,580,800	NA	• Effluent PCB Data • Pre-Upgrade Completion • Wet/Dry Weather PCB Data • June 2011 • Total PCBs and Homolog data
Arlington County Water Pollution Control Plant (ACWPCP)	Upgrades for the ACWPCP consisted of 2 design packages. Improvements under Design Package 1 provided equalization to minimize wet weather bypasses, provided chemical storage and feed for phosphorus removal, and minimized odors from the preliminary side of the plant, as well as provided treated effluent water for on-site use and prepared for the implementation of Design Package 2. Design Package 2 upgraded all associated electrical equipment and provided for effluent filtration.	609,112	NA	• Effluent PCB Data • Pre-Upgrade Completion • Wet/Dry Weather PCB Data • June 2011 • Total PCBs and Homolog data
City of Richmond WWTP	The City of Richmond WWTP's liquid processes include preliminary treatment, primary clarification, biological activated sludge process, secondary clarification, deep bed/gravity effluent filtration, disinfection and dechlorination. **Nutrient Reduction Technology improvements were implemented in five construction contracts and included new chemical storage and feed pumps, methanol feed and storage upgrades, filter upgrades, UV disinfection, electrical switchgear upgrades, scum control upgrades, aeration upgrades, upgrades to Return Activated Sludge (RAS) Capacity, bioaugmentation upgrades, new sedimentation tanks, and fermentation.**	829,150	6,850	• Effluent PCB Data • Pre-Upgrade Completion • Wet/Dry Weather PCB Data • January and February 2011 • Total PCBs and Homolog data

Table 3-7. Continued.

Facility	Details of Treatment Process and Upgrade	Expected Nutrient Load Reduction (lbs/year)		PCB Data? What type (i.e. effluent, influent, sludge) and When (pre-, post-upgrade)
		Nitrogen	Phosphorous	
Dale City Service #1 WWTF	The Dale Service Corporation Section 1 WWTF consisted of influent screening and grit removal, an equalization basin for surge capacity, biological nutrient removal by SBRs that discharge to a surge pond, tertiary clarification and tertiary filtration for solids polishing, and UV disinfection. **The WWTF was upgraded for State of the Art nutrient removal by upgrading the SBRs, rehabilitating the two existing tertiary clarifiers and installing a new one, upgrading the aerobic digester blowers and recycle pump station, and installing a supplemental carbon storage and feed system and static mixtures for aluminum salt feed on the tertiary clarifiers.**	28,019	NA	• Effluent PCB Data • Pre-Upgrade Completion • Wet/Dry Weather PCB Data • December 2011 • Total PCBs and Homolog data
Dale City Service #8 WWTF	The Dale Service Corporation Section 8 WWTF consisted of influent screening and grit removal, equalization basin for surge capacity, biological nutrient removal by SBRs that discharge to a surge pond, tertiary clarification and tertiary filtration for solids polishing, followed by ultraviolet (UV) disinfection. **The WWTF was upgraded for State of the Art nutrient removal technology by upgrading the SBRs, rehabilitating the two existing tertiary clarifiers and installing a new one, upgrading the aerobic digester blowers and recycle pump station, and installing a supplemental carbon storage and feed system and static mixtures for aluminum salt feed on the tertiary clarifiers.** The grit removal unit and surge pond were also upgraded.	28,019	NA	• Effluent PCB Data • Pre-Upgrade Completion • Wet/Dry Weather PCB Data • December 2011 • Total PCBs and Homolog data
Falling Creek WWTP	Chesterfield County's Falling Creek WWTP consists of screening, grit removal, communition, flow equalization, primary sedimentation, activated sludge with seasonal denitrification, secondary clarification, chemical coagulation and sedimentation, chlorination, post-aeration, and dechlorination. **The secondary treatment process was upgraded to an Enhanced Nutrient Removal including headworks and primary treatment areas were upgraded with fine screens, secondary treatment was upgraded to a 4-stage activated sludge, BNR process, and chemical feed systems and process piping were improved.**	470,600	NA	• Effluent PCB Data • Pre-Upgrade Completion • Wet/Dry Weather PCB Data • February and March 2011 • Total PCBs and Homolog data
Henrico County Water Reclamation Facility (WRF)	The Henrico County WRF is capable of BNR with a liquid treatment process consisting of screening, grit removal, primary clarification, activated sludge BNR, secondary clarification, filtration, and chlorination/dechlorination. **ENR upgrades include upgraded BNR tanks capable of a 5-stage or 3-stage process, reactor modifications including a secondary anoxic zone and a re-aeration zone, and modifications to the nitrate recycle pump station**. A carbon source was added in the secondary anoxic zones of the BNR basins and caustic was added to the treatment process.	685,250	NA	• Effluent PCB Data • Pre-Upgrade Completion • Wet/Dry Weather PCB Data • January and March 2011 • Total PCBs and Homolog data

Table 3-7. Continued.

Facility	**Details of Treatment Process and Upgrade**	**Expected Nutrient Load Reduction (lbs/year)**		**PCB Data? What type (i.e. effluent, influent, sludge) and When (pre-, post-upgrade)**
		Nitrogen	**Phosphorous**	
Hopewell Regional Wastewater Treatment Facility (WTF)	The Hopewell Regional WTF is a secondary wastewater treatment plant that was retrofitted with BNR-equivalent technology. Nitrogen reduction improvements were implemented to achieve partial segregation of domestic and industrial flows in the initial treatment stages and reduce effluent ammonia concentrations. **Upgrades included new pump stations, primary clarifier modifications, a new screening facility, new moving bed bioreactor (MBBR) tanks, a blower building, a dissolved air flotation building, new aeration tanks, an additional secondary clarifier, effluent re-aeration and solids handling improvements.**	4,096,141	NA	• Effluent PCB Data • Post-Upgrade Completion • Wet/Dry Weather PCB Data • March and June 2011 • Total PCBs and Homolog data
Fairfax County Normal Cole Jr. Pollution Control Plant (PCP)	Fairfax County's Noman M. Cole Jr PCP is capable of BNR with a treatment system that includes equalization storage, primary clarification, step-feed activated sludge treatment with anoxic zones, secondary clarification, chemical phosphorus removal, tertiary clarification, final effluent filtration, and chlorination/dechlorination. **The plant was upgraded to ENR capability by the construction of activated sludge tank methanol facilities. Additionally, it was upgraded to State of the Art nitrogen removal using Moving Bed Biofilm Reactors.**	1,480,000	NA	• Effluent PCB Data • Post-Upgrade Completion • Wet/Dry Weather PCB Data • June 2011 • Total PCBs and Homolog data
Chesterfield County Proctor's Creek WWTP	Chesterfield County's Proctors Creek WWTP provides tertiary treatment and BNR and consists of screening, grit removal, communition, flow equalization, primary sedimentation, activated sludge with BNR mode up to 21.5 MGD (nitrification with seasonal denitrification only at flows from 21.5 - 27 MGD), backup chemical phosphorus removal, effluent filtration, chlorination, dechlorination, and post-aeration**. The secondary treatment/BNR process was upgraded to an ENR system** to achieve a 5.0 mg/L annual average nitrogen concentration.	1,126,00	NA	• Effluent PCB Data • Pre-Upgrade Completion • Wet/Dry Weather PCB Data • February and March 2011 • Total PCBs and Homolog data
Stafford County Little Falls Run WTF	Stafford County's Little Falls Run WTF is capable of BNR. The facility also includes headworks, an alum feed system and chemical mix tank for total phosphorous (TP) removal, two secondary clarifiers, a secondary effluent screw lift pump station, a tertiary filtration system, ultraviolet disinfection, a sludge holding tank, four aerated sludge storage silos, and a centrifuge sludge dewatering system**. The plant was upgraded from BNR to ENR capable of attaining annual average effluent TN of 5.0 mg/L and TP of 0.30 mg/L. Upgrades included changing the Schreiber trains to work in parallel with the addition of cyclical aeration controls to improve the nitrification/denitrification process.**	250,339	31,064	• Effluent PCB Data • Pre-Upgrade Completion • Wet/Dry Weather PCB Data • October 2011 • Total PCBs

Table 3-7. Continued.

Facility	**Details of Treatment Process and Upgrade**	**Expected Nutrient Load Reduction (lbs/year)**		**PCB Data? What type (i.e. effluent, influent, sludge) and When (pre-, post-upgrade)**
		Nitrogen	**Phosphorous**	
Stafford County Aquia WTF	Stafford County's Aquia WTF has been upgraded to achieve State of the Art treatment with annual average nutrient concentrations of 3.0 mg/L total nitrogen and 0.18 mg/L total phosphorus. **Major components of the upgrade project included headworks upgrades, a new biological tank, upgrades to the existing biological tanks, the addition of secondary anoxic tanks and a third secondary clarifier, chemical feed facilities, waste activated sludge, return activated sludge, and nitrified recycle pumping, a new secondary anoxic influent pump station, a filter pump station, outfall modifications, and generators and electrical upgrades**.	67,002	NA	• Effluent PCB Data • Post-Upgrade Completion • Wet/Dry Weather PCB Data • October 2011 • Total PCBs

Table 3-8. Summary of Virginia facilities post and pre-upgrade effluent total PCB and PCB Homolog data from 2011.

Post-Upgrade Facility	SampleDate	Units	Total PCB	mono	di	tri	tetra	penta	hexa	hepta	octa	nona	deca
Dale Service Section 8	12/29/2011	pg/L	415.8	11.0	65.7	86.9	91.8	94.5	45.8	15.0	3.2	0.0	1.9
Dale Service Section 1	12/29/2011	pg/L	422.0	11.5	72.0	113.9	100.9	76.8	36.5	10.4	0.0	0.0	0.0
Falling Creek WWTP	2/9/2011	pg/L	1467.4	21.6	179.7	265.7	348.6	406.3	189.9	44.0	10.3	0.0	1.1
Falling Creek WWTP	2/23/2011	pg/L	943.7	17.6	135.7	159.1	199.0	267.1	126.2	28.4	7.2	2.0	1.4
Falling Creek WWTP	3/2/2011	pg/L	1363.2	22.6	140.4	179.3	303.3	428.9	204.0	66.5	14.7	2.2	1.3
Falling Creek WWTP	3/8/2011	pg/L	954.9	29.0	121.1	143.8	194.7	267.6	145.2	43.0	9.4	0.0	1.2
Arlington STP - WPCB	6/2/2011	pg/L	532.9	65.5	88.3	118.8	118.8	89.4	38.5	9.2	2.9	0.0	1.5
Arlington STP - WPCB	6/18/2011	pg/L	447.9	21.3	56.4	99.8	84.5	95.3	66.0	22.6	2.0	0.0	0.0
Alexandria Sanitation Authority	6/2/2011	pg/L	631.2	22.2	121.5	132.9	148.4	128.2	55.2	18.5	4.2	0.0	0.0
Alexandria Sanitation Authority	6/18/2011	pg/L	498.1	20.6	102.7	120.7	116.8	89.4	36.8	9.7	1.5	0.0	0.0
Proctors Creek WWTP	2/9/2011	pg/L	587.1	19.2	142.8	167.2	104.7	101.3	40.5	10.3	0.0	0.0	1.1
Proctors Creek WWTP	2/23/2011	pg/L	496.7	12.6	96.6	146.1	99.3	84.8	44.6	11.3	1.4	0.0	0.0
Proctors Creek WWTP	3/2/2011	pg/L	555.0	8.4	116.0	162.0	112.2	92.4	48.9	13.6	0.9	0.0	0.8
Proctors Creek WWTP	3/8/2011	pg/L	519.1	17.3	104.7	135.7	107.2	85.4	49.3	15.4	3.2	0.0	0.8
City of Richmond WWTP	1/27/2011	pg/L	3292.3	64.8	716.0	667.4	671.5	602.8	372.5	137.5	46.6	10.4	2.9
City of Richmond WWTP	2/3/2011	pg/L	2848.3	67.7	800.2	612.7	504.1	468.6	268.5	93.8	25.8	4.9	2.1
Henrico County WRF	1/27/2011	pg/L	515.8	21.1	108.9	79.8	104.3	126.4	56.7	14.4	4.1	0.0	0.0
Henrico County WRF	3/8/2011	pg/L	623.0	9.5	143.6	140.1	116.5	117.4	67.9	22.5	4.2	0.0	1.3
Stafford County - Little Falls Run	10/14/2011	pg/L	924.0										
Stafford County - Little Falls Run	10/14/2011	pg/L	371.3										

Pre-Upgrade Facility	SampleDate	Units	Total PCB	mono	di	tri	tetra	penta	hexa	hepta	octa	nona	deca
Hopewell RWTF	3/11/2011	pg/L	908.0	2.7	54.5	85.5	163.6	284.1	218.9	76.3	18.8	2.2	1.4
Hopewell RWTF	6/30/2011	pg/L	845.1	22.7	78.6	121.8	163.4	224.0	158.3	61.0	12.3	0.0	3.2
Army Base STP	7/13/2011	pg/L	1389.3	11.1	149.8	237.3	324.6	426.6	184.8	42.9	7.9	0.0	4.4
Army Base STP	10/20/2011	pg/L	1378.9	19.9	120.0	188.1	331.0	407.8	241.4	53.9	13.3	2.4	1.2
James River STP	7/6/2011	pg/L	1341.6	19.3	150.6	218.8	304.0	338.1	206.8	80.6	20.5	1.8	1.2
James River STP	7/13/2011	pg/L	755.0	12.5	116.7	152.9	185.5	190.3	78.8	15.9	2.3	0.0	0.0
James River STP	7/26/2011	pg/L	810.4	10.0	130.4	142.4	169.2	212.4	110.9	28.8	6.4	0.0	0.0
James River STP	8/11/2011	pg/L	1311.2	16.2	181.6	202.3	247.1	363.7	222.1	57.1	17.8	1.9	1.4
Virginia Initiative STP	5/24/2011	pg/L	1069.9	26.4	89.4	181.1	245.5	323.6	154.4	39.7	9.8	0.0	0.0
Virginia Initiative STP	7/8/2011	pg/L	1766.3	14.8	130.1	236.0	394.0	506.5	322.1	124.8	31.5	4.9	1.5
Virginia Initiative STP	7/13/2011	pg/L	1501.2	13.4	108.7	231.1	355.6	431.3	241.3	93.2	23.4	3.3	0.0
Virginia Initiative STP	9/17/2011	pg/L	1438.9	11.4	95.7	175.7	294.7	441.7	287.8	103.6	23.8	3.2	1.3
Nansemond STP	6/24/2011	pg/L	800.3	26.1	96.5	133.5	174.5	220.4	115.2	27.8	5.3	0.0	1.0
Nansemond STP	7/13/2011	pg/L	690.1	27.2	101.6	123.7	160.2	174.5	82.1	18.8	2.0	0.0	0.0
Nansemond STP	10/20/2011	pg/L	814.6	20.2	67.0	107.0	178.9	222.5	162.3	43.8	10.6	1.2	1.2
Noman M. Cole PCP	6/1/2011	pg/L	679.1	54.7	169.8	155.0	136.0	106.7	40.2	10.0	5.8	0.0	1.0
Noman M. Cole PCP	6/17/2011	pg/L	638.9	41.8	118.4	153.1	145.5	113.7	45.9	10.7	0.0	0.0	9.7
Aquia WWTF	10/14/2011	pg/L	924.5										

facility and sample are provided in Table 3-8. The bulk of the PCB concentration consisted of the di (average 15.1%), tri (average 19.2%), tetra (average 21.4%), and penta-chlorinated congeners (average 23.8%. Overall di, tri, tetra, and penta-chlorinated congeners account for an average of 79.5% of the total PCB congeners. Although there was an approximately 13% reduction in total PCB concentrations between facilities that were upgraded and those that were not it was not significant (t-test p=0.05) (Figure 3-5). The bulk of the reduction was in the tetra-chlorinated and higher PCBs (Figure 3-6). Mono-, di-, tri-chlorinated congeners indicated an increase in effluent concentration after upgrade (Figure 3-6).

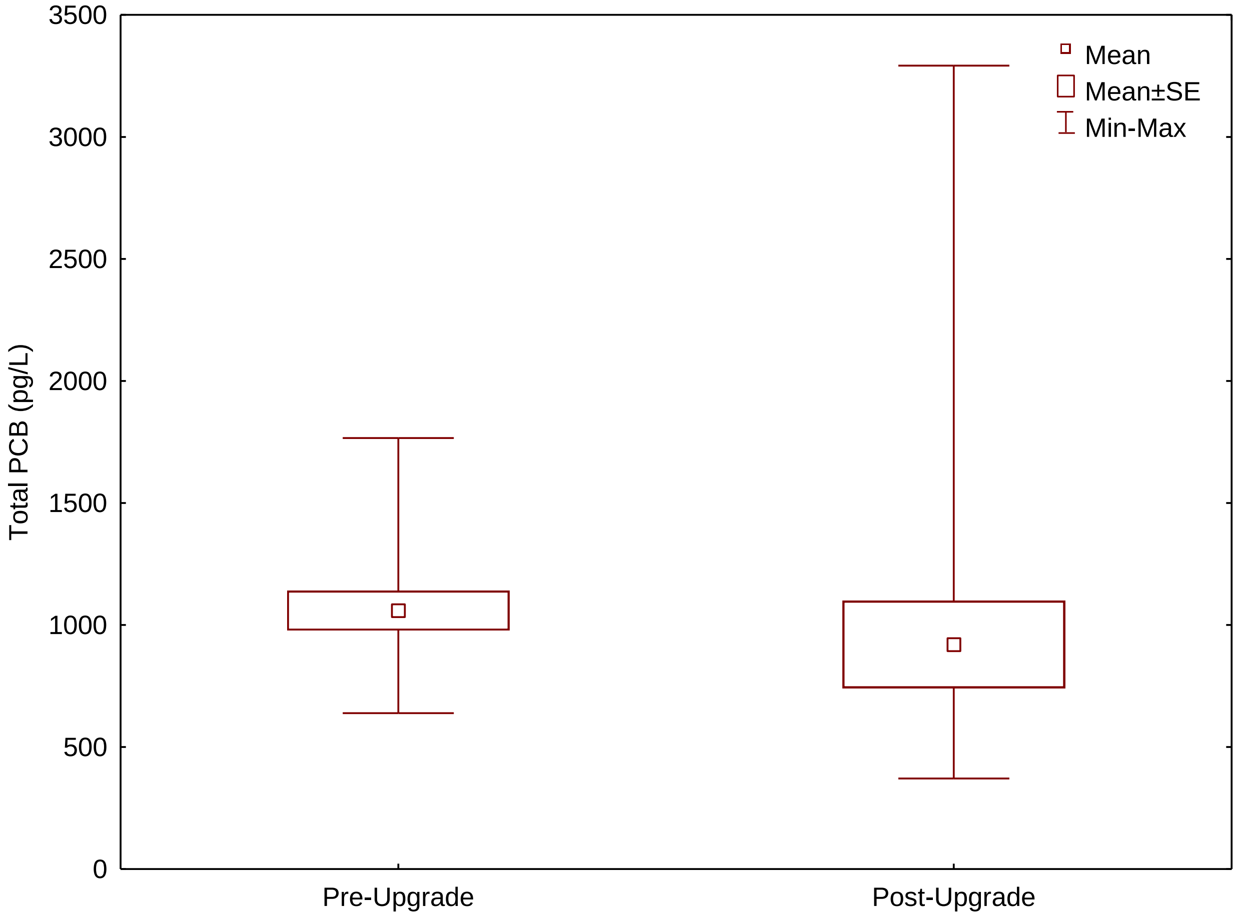

Figure 3-5. Total PCBs from 2011 in pre- and post-upgrade Virginia wastewater treatment plants. Box mid-point is the mean concentration, Box is mean plus standard error, and Whisker is min/max concentration.

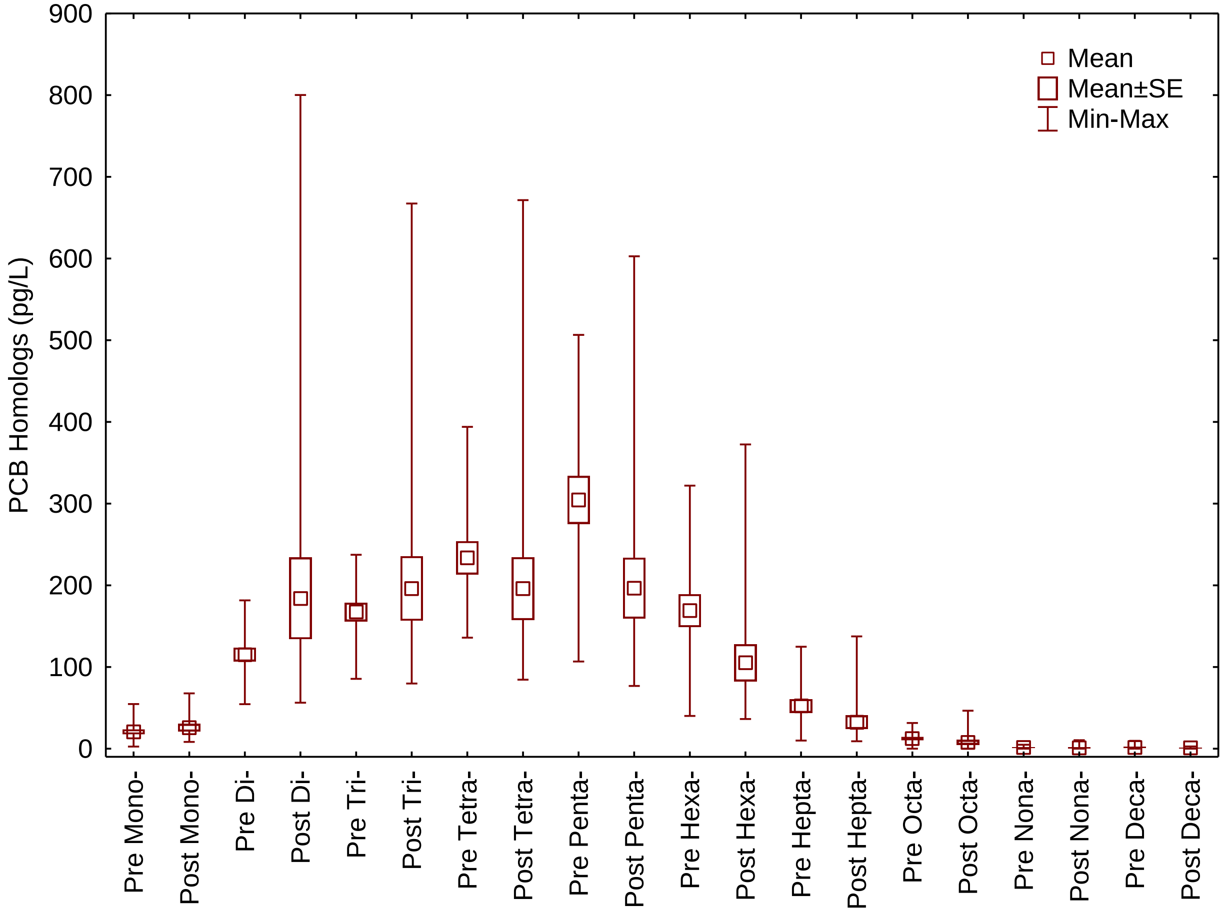

Figure 3-6. PCB homolog concentration in 2011 from pre-upgrade and post-upgrade nutrient reduction wastewater treatment plants. Box mid-point is the mean concentration, Box is mean plus standard error, and Whisker is min/max concentration.

West Virginia, New York, and Pennsylvania

No relevant PCB data from facilities that have had nutrient reduction upgrades could be located from West Virginia, New York, or Pennsylvania.

3.1.4. Other US Watersheds

Delaware River – City of Wilmington, Delaware

The City of Wilmington owns an 8.5-square-mile service area consisting of two sewer districts with three pump stations and a WWTP that serves 18,898 households. The plant provides primary and secondary treatment, solids handling, and has a surface water discharge that flows into the mouth of Shellpot Creek at the Delaware River in the Piedmont Watershed (#2). The plant's secondary treatment current design flow is 105 MGD, and the average daily dry-weather flow is 75 MGD, including contract user flows, or about 71 percent of design flow. The plant also has two holding tanks with 3MG of capacity, which are used to provide the equivalent of primary treatment for peak flows of up to 340 MGD during wet weather. The collection system is a combined sewer system. The collection system captures 90 percent of wet-weather flows though real-time control and there are no plans to separate the system. Personal communication with Rick Greene, of Delaware Department of Natural Resources and

Environmental Conservation (DNREC), provided a spreadsheet of the effluent concentration and load of PCBs being discharged by the City of Wilmington (Figure 3-7). As per Rick Greene, the reductions are "attributed to several actions: interceptor cleanouts; sewershed trackback sampling; industrial pretreatment actions; waste site cleanups; and separating storm sewers from sewage." The City of Wilmington has not undergone an upgrade for the reduction of nutrients.

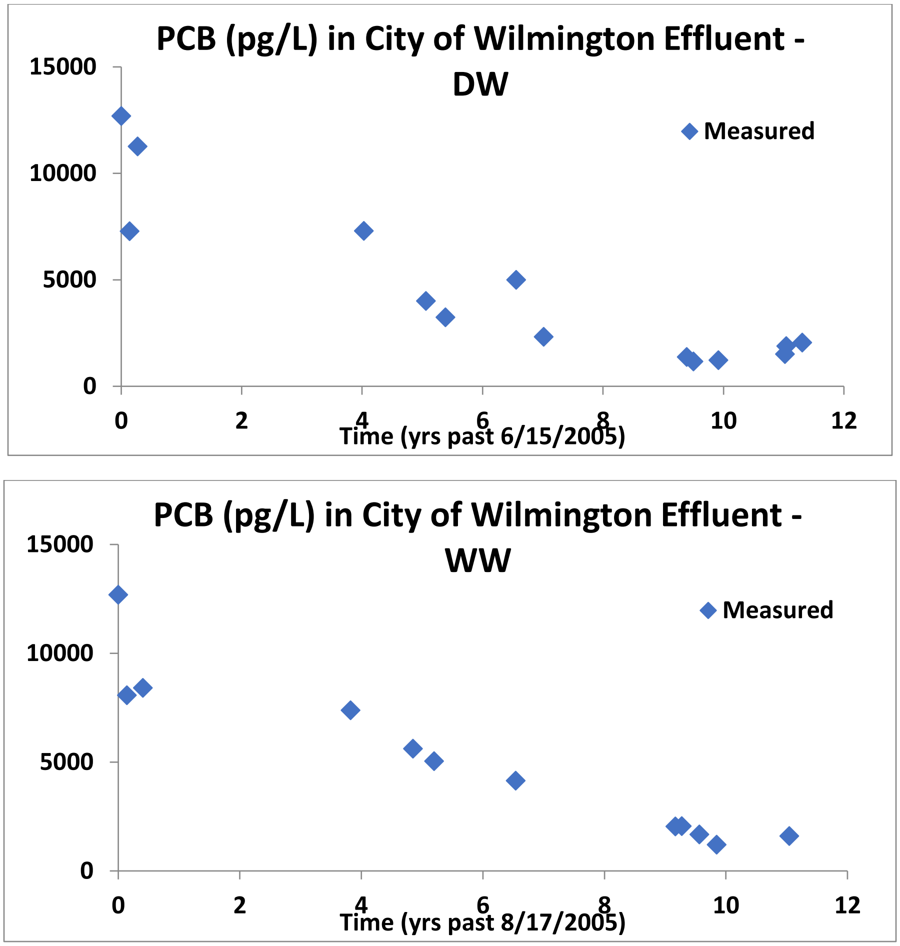

Figure 3-7. Summary of measured PCB (pg/L) concentrations in the City of Wilmington effluent during both dry weather (DW) and wet weather (WW) sampling (personal communication – Rick Greene, Delaware DNREC, 2017).

The City of Wilmington WWTP data received a grade of 4 under the proposed data qualification criteria. The site is not located within the Chesapeake Bay watershed but is in the mid-Atlantic (2), with infrequent/irregular composite or grab sampling (1), and the data being unpublished (e.g., DMR data) (1).

Saginaw River - City of Bay City, Michigan

The City of Bay City WWTP was initially built in 1952 with major modifications and additions constructed in 1969, 1977, 2003, and 2014[3]. The current City of Bay City WWTP using primary, secondary, and tertiary treatment as well as activated carbon treatment to treat 6.9 million gallons per day of

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[3] https://www.baycitymi.org/151/Departments

wastewater. The primary treatment includes raking and screening as well as grit removal. Secondary treatment includes the use of primary clarifiers, biological treatment (i.e., trickling filters), and chemical treatment for phosphorous removal using ferric chloride. Tertiary treatment includes the use of activate carbon for removal of organics (i.e., PCBs) and solids and UV disinfection. The ICIS data obtained indicated total PCBs were measured in 2007, 2011, and 2015 during the permit renewal process. The trend indicates that effluent total PCBs have decreased by 3 orders of magnitude (Figure 3-8). This may be due to the upgrade of the facility to remove PCBs or due to the decrease in PCB concentration in the influent.

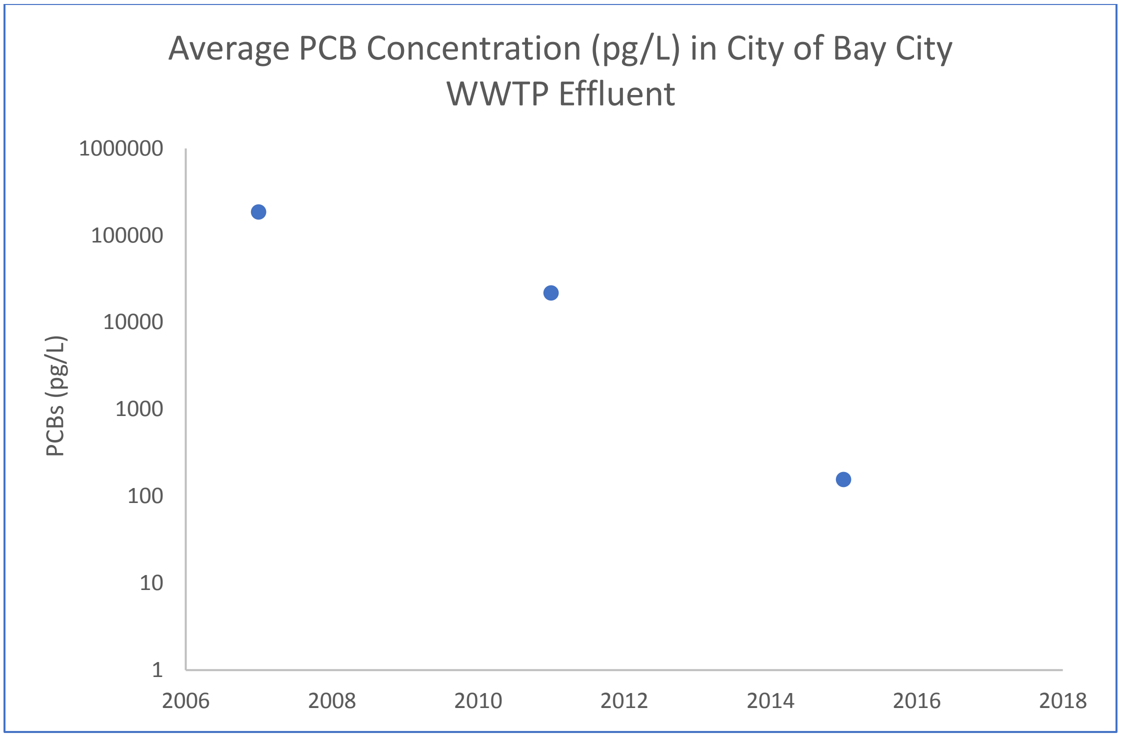

Figure 3-8. Summary of measured PCB (pg/L) concentrations in the City of Bay City WWTP effluent from 2007 - 2017. Only 2007, 2011, and 2015 had reported PCB concentrations.

The City of Bay City WWTP ICIS data received a grade of 3 because the site is not in the Chesapeake Bay Watershed or in the Eastern US (1), there were infrequent, samples (1), and the data are unpublished (e.g., DMR data) (1).

Detroit and Rouge River - City of Detroit, Michigan

The Detroit Water and Sewerage Department (DWSD) operates a wastewater treatment plant that serves the City of Detroit and 76 other communities. The facility treats on average 650 million gallons a day. The City of Detroit WWTP uses primary, secondary, and tertiary treatment of its wastewater with primary treatment consisting of 12 rectangular and 6 circular clarifiers and the use of ferric chloride for phosphorous removal. Secondary treatment is accomplished by 4 high-purity oxygen-activated sludge tanks and 25 secondary final clarifiers. Finally, chlorination and dechlorination of the final effluent before discharge to the Detroit and Rouge Rivers. The ICIS data obtained indicated total PCBs were measured in 2009, 2010, and 2015. The trend indicates that effluent total PCBs have decreased by an order of magnitude from 2009 but are about the same in 2015 as they were in 2010 (Figure 3-9).

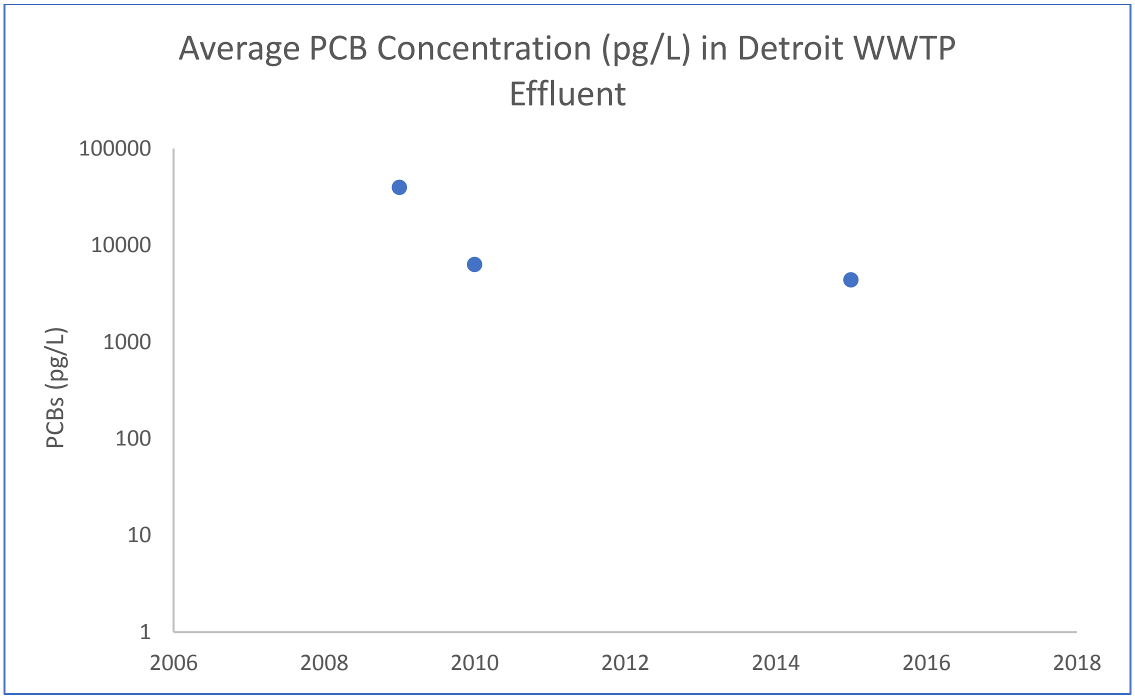

Figure 3-9. Summary of measured PCB (pg/L) concentrations in the City Detroit WWTP effluent from 2007 - 2017. Only 2009, 2010, and 2015 had reported PCB concentrations.

The City of Detroit WWTP ICIS data received a grade of 3 because the site is not in the Chesapeake Bay Watershed or in the Eastern US (1), there were infrequent, samples (1), and the data are unpublished (e.g., DMR data) (1).

Lake Erie - City of Monroe, Michigan

The City of Monroe WWTP went on line in 1935 and has had numerous treatment additions and expansions[4]. The facility is a publicly owned treatment works dedicated to providing the efficient transportation and treatment of wastewater from the metropolitan area. The City of Monroe WWTP uses a multi-stage process to treat wastewater by removing or reducing organic matter, solids, nutrients, disease-causing organisms, and other pollutants from the wastewater, or sewage, discharged from residences, businesses, and industries in our community.

The City of Monroe WWTP effluent is discharged into Lake Erie. The ICIS data obtained indicated total PCBs were measured in 2013, 2015, and 2017. The trend indicates that effluent total PCBs have decreased by an order of magnitude from 2015 to 2017 but had increased from 2013 to 2015 (Figure 3-10).

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[4] http://monroe.hosted.civiclive.com/cms/One.aspx?portalId=10126595&pageId=10355259

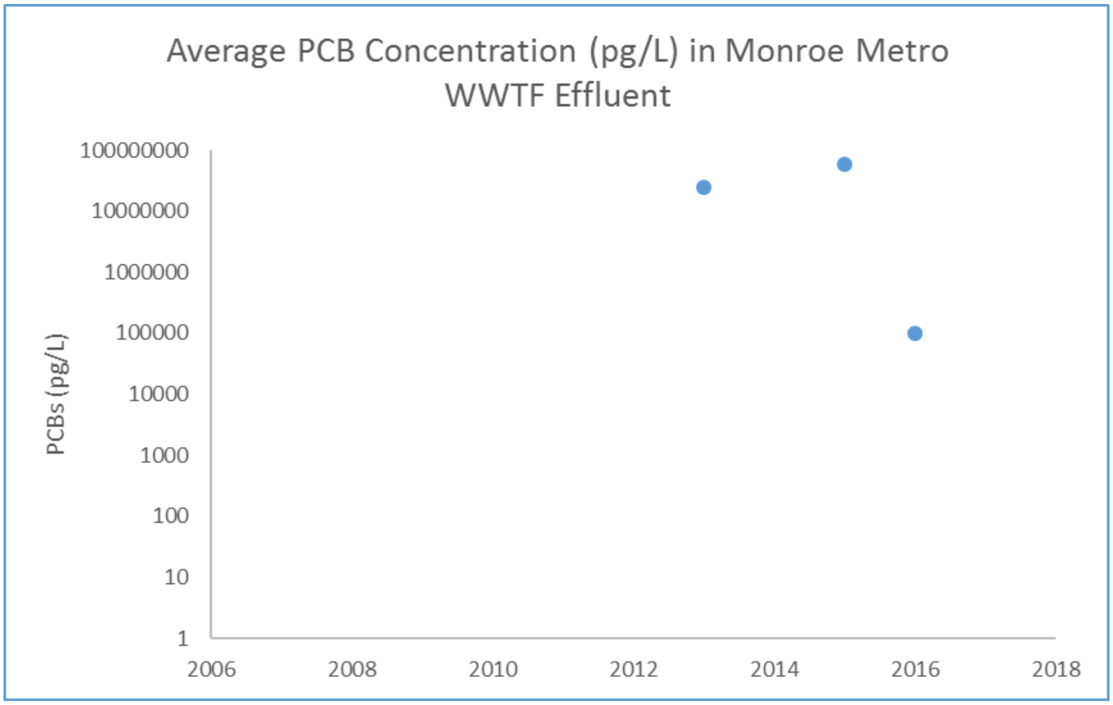

Figure 3-10. Summary of measured PCB (pg/L) concentrations in the City of Monroe Metro WWTP effluent from 2007 - 2017. Only 2013, 2015, and 2016 had reported PCB concentrations.

The City of Monroe WWTP ICIS data received a grade of 3 because the site is not in the Chesapeake Bay Watershed or in the Eastern US (1), there were infrequent, samples (1), and the data are unpublished (e.g., DMR data) (1).

Housatonic River – General Electric, Massachusetts

General Electric operates a groundwater treatment facility (GWTF) in Pittsfield, MA that treats an average of 150 gallons per minute (gpm) of groundwater associated with recovery wells/caissons; collected leachate; and miscellaneous other sources of water that are transported by truck to the GWTF. The GWTF treatment process includes a pH adjustment and chemical precipitation; clarification; sand filtration; and granular-activated carbon (GAC) (Arcadis 2011). The GE GWTF effluent is discharged into the Housatonic River. The ICIS data obtained indicated total PCBs were measured quarterly from 2010 through 2017. The trend indicates that effluent total PCBs have decreased by an order of magnitude from 2010 to 2017 (Figure 3-11).

The General Electric ICIS data received a grade of 6 because the site is not in the Chesapeake Bay Watershed but is in the Eastern US (2), there were frequent, flow-paced composites or representative grab samples (3), and the data are unpublished (e.g., DMR data) (1).

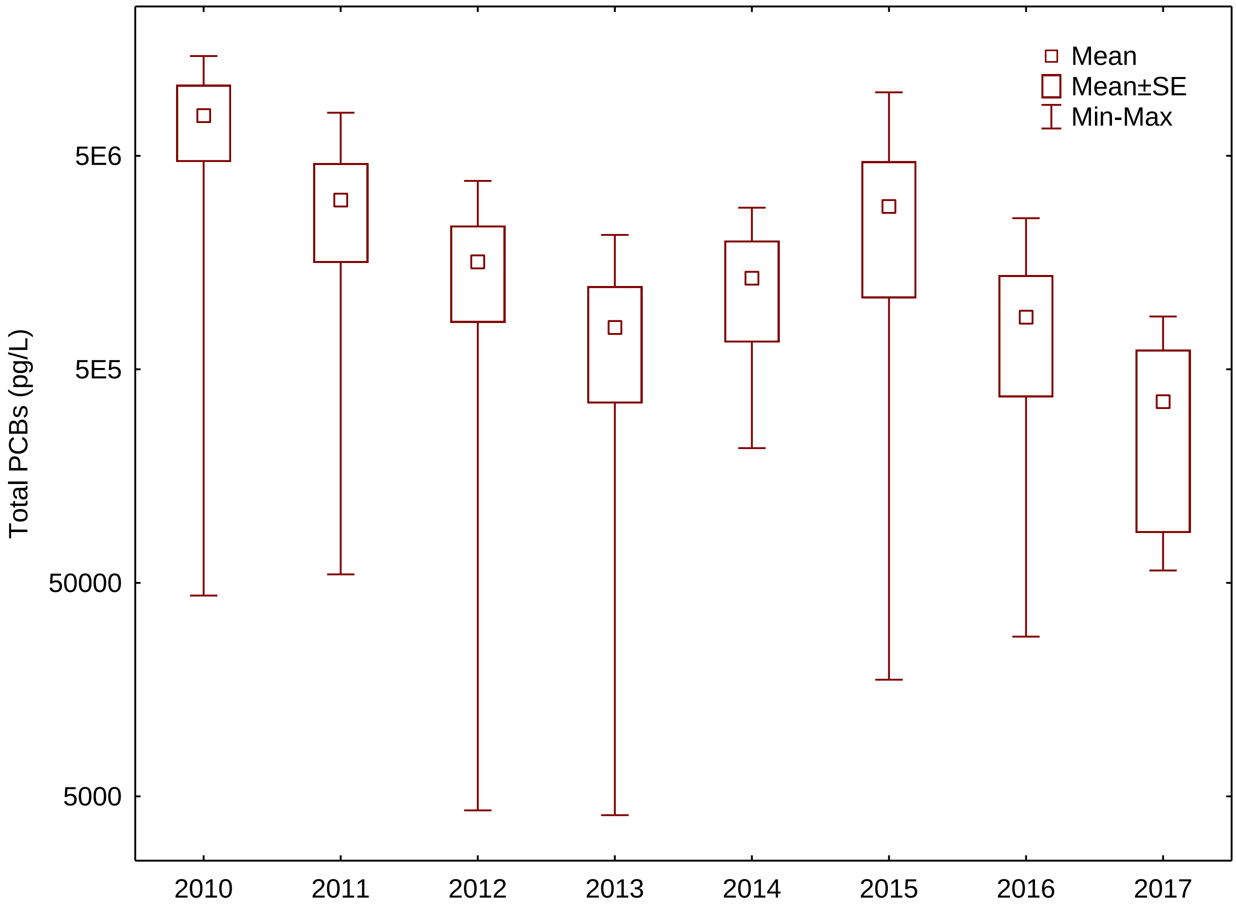

Figure 3-11. Summary of measured PCB (pg/L) concentrations in the General Electric Groundwater pump and treat effluent from 2010 - 2017. Quarterly measures were reported for each year. Box mid-point is the mean concentration, Box is mean plus standard error, and Whisker is min/max concentration.

St. Lawrence River – General Motors Massena Plant, New York

The General Motors Massena WWTP uses preliminary, secondary, and tertiary treatment to treat a maximum of 0.65 mgd. The preliminary treatment uses bar screens and pumping to remove grit and other solids; while the secondary treatment is accomplished by activated sludge. Tertiary treatment consists of an intermittent sand filter and activated carbon columns or beds. Disinfection is through chlorination.

The GM Massena WWTP effluent is discharged into the Saint Lawrence River. The ICIS data obtained indicated total PCBs were measured in 2009 through 2013. The trend indicates that effluent total PCBs have decreased by an order of magnitude from 2009 to 2015 (Figure 3-11).

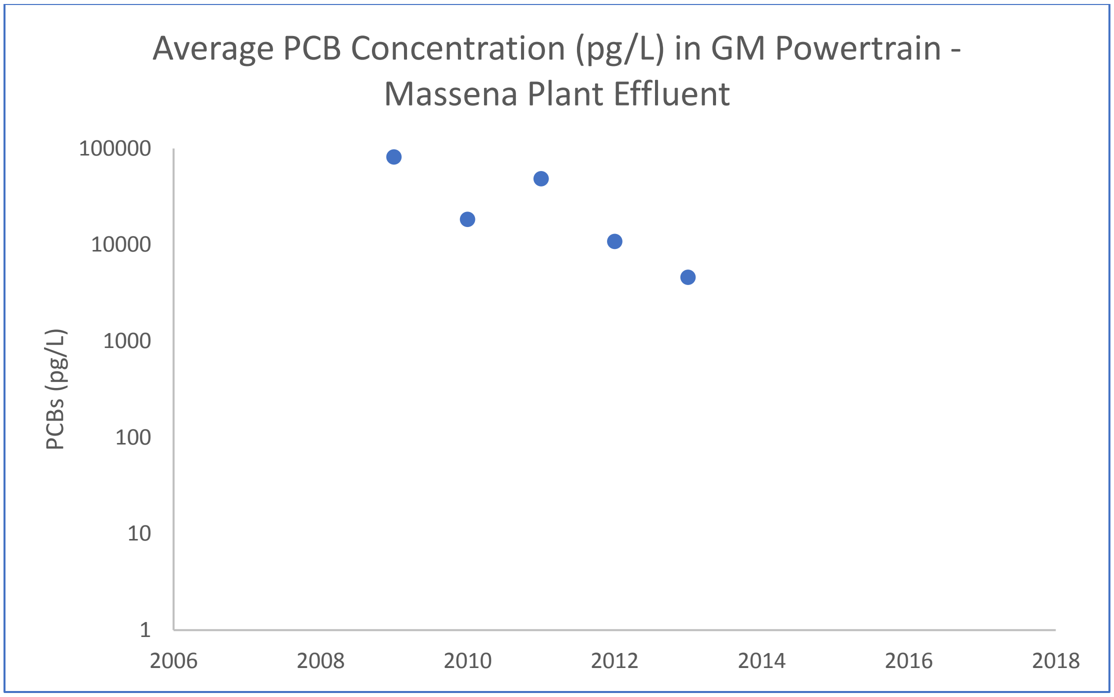

Figure 3-12. Summary of measured PCB (pg/L) concentrations in the GM Powertrain – Massena Plan effluent from 2007 - 2017. Only 2009, 2010, 2011, 2012, and 2013 had reported PCB concentrations.

The General Motors – Massena Plant ICIS data received a grade of 4 because the site is not in the Chesapeake Bay Watershed but is in the Easter US (2), there were infrequent, flow-paced composites or representative grab samples (1), and the data are unpublished (e.g., DMR data) (1).

3.2. Peer-Reviewed Literature Survey

Relevant literature sources that were identified, collected, and reviewed are summarized in the output from the bibliographic database created for this project in Attachment B. The most useful data sources appear to be those taken from the standard peer-reviewed literature (i.e., technical journals as opposed to reports published by research foundations or government entities), in that some directly address comparisons between different, actual WWTPs. That said, a variety of government or non-governmental (e.g., research foundation) sources of data were also collected and reviewed; only those that were deemed relevant are presented in Attachment B. In general, these sources tended to be useful for broader information on the state of knowledge about the fate of PCBs and other toxics in WWTPs.

Although performing a metanalysis of the data from the published literature would have increased the statistical confidence in the findings, most of the data that has been published on this topic varies widely in terms of both technical details (e.g., type of facility, sampling locations, sampling type, analytes/PCB congeners) and reporting format (units, presentation of raw data versus summary statistics), greatly complicating the ability to analyze the data in composite. Therefore, a detailed bibliography of the reviewed literature is provided below, organized by topical area for research published in technical journals, and then by study for major watershed-scale efforts that were referenced.

3.2.1. Conventional Activated Sludge Treatment

Available literature suggests that the reduction of toxic compounds (especially polychlorinated biphenyls, or PCBs) in WWTPs is somewhat variable. In 2006, Bergqvist, Augulyte, and Jurjoniene studied the removal efficiencies of two conventional activated sludge treatment plants in Sweden and Lithuania. Twenty-four individual polycyclic aromatic hydrocarbons (PAHs) and ten PCB congeners were quantified and evaluated using semipermeable membrane devices (SPMDs) to sequester organic pollutants from wastewater samples. Removal efficiencies of PAHs appeared to depend on the molecular weight of the compound. Low molecular weight (LMW) PAHs at the Swedish and Lithuanian plants totaled 380 and 280 ng/L respectively, while removal efficiencies of these compounds ranged from 84% to virtually 100% and from 33-95% (average of 76%), respectively. At both plants, methylated LMW PAHs were the most abundant compounds found, which are indicative of petroleum product contamination. There was no significant removal of high molecular weight (HMW) PAHs at either plant, and in most cases HMW PAHs actually increased in concentration during treatment processes. Similarly, the total concentration of all ten PCBs analyzed also increased from 0.3-1 ng/L and from 9-34 ng/L in the Swedish and Lithuanian plants respectively. Similarly, analysis of a conventional activated sludge plant in Beijing, China showed that dissolved concentrations of most PAHs, PCBs, substituted benzenes, and other target contaminants were higher in the effluent than in the influent (Wang, et al., 2003). This study deployed triolein-containing SPMDs at various locations along the treatment train for four weeks to sample and concentrate the dissolved portion of hydrophobic organic pollutants.

In 2004, Katsoyiannis and Samara studied the occurrence and removal of various persistent organic pollutants (POPs) in a sewage treatment plant in Thessaloniki, Northern Greece. Nineteen organochlorine compounds (OCs) and 7 PCBs were analyzed, and total removal of all individual POPs ranged from 65-91%. Primary removal of PCBs and OCs varied between 42-62% and 47-86%, respectively, while secondary POP removal was found to be lower at an overall average of 38%. Primary removal of PCBs exhibited a fairly strong correlation with log K_{ow} (an indication of the solid-liquid partitioning of hydrophobic contaminants), suggesting that these pollutants are substantially removed by sorption on sludge particles. Correlation coefficients (R-values) describing the strength of the relationship between percent removal and log K_{ow} ranged from 0.40 during secondary treatment to 0.70 during primary treatment. On the other hand, OCs exhibited a lower correlation with log K_{ow} (r of 0.21 for primary treatment and 0.30 for secondary treatment), showing that OC removal cannot be attributed only to sorption, but to other mechanisms as well.

Katsoyiannis and Samara went on to investigate POP fate in the same treatment plant, creating a mass balance at six different points across the treatment system and assessing the distribution of POPs between the dissolved and the adsorbed phases of wastewater and sludge (2005). For raw wastewater, a good linear relationship was observed between the distribution coefficients and the octanol-water partition coefficients. However, the findings suggested that other factors affect the phase distribution of organic compounds in treated wastewater. For all POPs, a significant increase in partitioning with a decreasing solids concentration was observed, revealing an effect from non-settling microparticles remaining in the “dissolved” phase during the separation procedure. Furthermore, the results indicated that the dissolved organic carbon content of wastewater contributes to the advective transport of POPs in the dissolved phase. The fate of the compounds was highly variable, with almost 60% of alpha-HCH remaining in the treated effluent but 98% of p-p’-DDE being accumulated in the waste sludge.

An analysis of wastewaters and sewage sludges from the Seine Aval treatment plant and associated sewerage systems found removal efficiencies of 76% and 98% for PCBs and PAHs respectively, with 50% of these pollutants being retained in the primary clarifier. For PCBs, removal efficiencies varied from 53-80% with increasing chlorination level. About 50% of total PCBs were found to be in the dissolved phase, and PCBs with a lower degree of chlorination were found to be more prevalent in the dissolved phase compared to more chlorinated congeners. In addition, PCB wastewater and dehydrated sludge concentrations were found to be significantly correlated (Blanchard, et al., 2004).

Badawy and Ali (2010) surveyed the occurrence, fate and removal of persistent organic pollutants, including 12 PCB congeners, at the 10th of Ramadan City WWTP in Egypt, which treats combined industrial and domestic wastewater, with the industrial fraction reportedly as high as 70-80 percent of the total flow. They report PCB removal rates of 11 to 53 percent through primary settling, and 33-74 percent through secondary treatment (an aerated oxidation pond and secondary clarification). These results suggest that although primary setting reduces PCBs in WWTP effluent, biological treatment significantly improves PCB removal.

HDR (2013) prepared an assessment of wastewater treatment technologies for several business and local government associations in Washington State in response to proposed human health based effluent discharge standards for four constituents of concern including PCBs. Their report cites data presented by Bolzonella el al. (2010) that found a correlation between dissolved PCB removal and solids retention time (SRT) and mixed liquor suspended solids (MLSS) concentration in a pilot-scale membrane bioreactor (MBR), which is basically an activated sludge process with high-efficiency secondary solids removal. Based on the literature review, HDR (2013) suggested that enhanced activated sludge treatment (with a relatively long SRT of 8 days or more) would be a worthwhile treatment technology for PCBs and other toxics. They speculate that the greater amount of biomass, coupled with a more diverse microbial community (especially nitrifiers), enhances both sorption and degradation processes. The report summarizes PCB removals of approximately 80 percent for “short SRT” (less than 8 days) activated sludge, and greater than 90 percent for long SRT activated sludge with membrane filtration.

Although dated, USEPA’s 1977 report on PCB removal in publicly-owned treatment works (USEPA 1977) presents some useful information, including data from the City of Baltimore’s WWTP. They report approximately 89 percent PCB reduction through activated sludge and approximately 83 percent PCB reduction through trickling filter treatment, both of which were, at the time, employed at the Baltimore WWTP. Both reductions were slightly lower than reductions of biochemical oxygen demand (BOD) and total suspended solids (TSS) through the treatment processes. In terms of reduction pathways, volatilization of PCBs was discounted as a significant removal mechanism with most of the reductions attributable to solids removal and biodegradation. The data show a clear reduction in biodegradation rate with increasing numbers of chlorine substitution (i.e., more highly chlorinated PCB congeners were less readily biodegraded).

Anderson (2005), in a technical briefing on endocrine disrupting compounds (EDCs), emphasizes the importance of a combination of treatment processes and redox conditions, noting that secondary biological treatment that includes nitrification (oxic), nutrient removal (anoxic, anaerobic) and disinfection may remove over 90 percent of certain steroids and over 95 percent of certain alkyl phenols. It is further noted that basic secondary treatment (i.e., without nutrient removal) may decrease removals by more than 15 percent. Important biological treatment processes include sorption onto biosolids, biodegradation (e.g., reductive dechlorination) and volatilization.

Needham and Ghosh (2018) studied the fate of PCBs in two WWTPs in the Chesapeake Bay Watershed: the Back River WWTP (BRWWTP) in Baltimore City and the Little Patuxent Water Reclamation Plant (which was used as a reference for biosolids PCB concentrations. Total PCBs in the influent of the

BRWWTP averaged 170 g/d, biosolids uptake accounted for 100 g/d, PCBs in the effluent averaged 5.2 g/d and 68 g/d were lost to volatilization and degradation. They also noted apparent biological degradation during anaerobic digestion of biosolids but suggest amending the wastewater treatment process with black carbon which would both reduce dissolved PCBs in the effluent and immobilize and reduce the bioavailability of PCBs during land application of biosolids.

Ohlinger, et al. (2013) studied the reactivity of twelve (12) trace organic compounds to conventional and advanced wastewater treatment processes in a pilot plant. The processes included BNR activated sludge, membrane filtration, granular media filtration and a biologically active filter along with three disinfection processes (chlorination, ozone and ultraviolet irradiation). Results were compared with trace organics removal through a full-scale high purity oxygen activated sludge (HPOAS) plant. Reductions through the BNR process were greater than through HPOAS, which the investigators attributed to a longer SRT and MLSS concentration in the BNR process. Atenolol, DEET, gemfibrozil, ibuprofen, sucralose, sulfamethoxazole, and triclosan concentrations were reduced across the BNR process, while iopamidol, meprobamate, carbamazepine and TCPP were not.

3.2.2. Physio-Chemical Treatment Processes

Pham and Proulx (1997) studied PCBs and PAHs in the Montreal Urban Community (MUC) WWTP in Quebec, Canada. The MUC WWTP serves a population of around 1.4 million, treats approximately 1.3 million cubic meters per day (mcmd) with a corresponding average effluent flow of about 19.8 cubic meters per second (cms), and includes approximately 8,000 commercial and industrial connections that contribute about 15% of total flow. The plant employs a physico-chemical treatment process that includes the addition of ferric chloride as a coagulant and an anionic polymer as a coagulant aid to increase sedimentation of suspended particles. Settled sludge is then removed and incinerated and the resulting ash is disposed of in a landfill. A total of ten influent and 6 effluent samples were taken to assess the presence and removal of 13 PCB congeners and 21 PAH congeners. Influent PCB concentrations ranged from below the detectable limit to 1.2 ng/L, while influent PAH concentrations ranged from 6-333 ng/L, with average influent totals of 4.3 ng/L and 1.5 µg/L respectively. Average effluent concentrations were 1.4 ng/L and 0.4 µg/L for PCBs and PAHs respectively. PCB and PAH removal efficiencies varied from 33-100% and 40-100% respectively with average removal efficiencies of 67% and 73% respectively. It was determined that removal rates increased with decreasing compound solubility, indicating that sorptive behavior was partially responsible for removal efficiencies. Therefore, certain compounds that were more soluble, such as less-chlorinated PCBs and LMW PAHs, increased in proportion in the effluent.

3.2.3. Multiple/Unknown Treatment Processes

A survey of digested sludge from 14 U.K. WWTPs sought to characterize the array of toxic compounds that are sorbed to sludge particles and subsequently removed during solids wasting processes (Stevens, et al., 2003). The study found concentrations of PAHs and PCBs ranging from 46-370 mg/kg dry weight (DW) and 110-440 µg/kg DW respectively. Additionally, polychlorinated naphthalene (PCN), synthetic musk, and short- and medium-chained polychlorinated alkanes varied from 50-190 µg/kg DW, 2.1-86 mg/kg DW, 7-200 mg/kg DW, and 30-9,700 mg/kg DW respectively.

Durell and Lizotte (1998) studied PCB levels at 26 New York City and New Jersey water pollution control plants (WPCPs), but the resulting article did not contain information on plant type. Average normal flow and high flow influent concentrations ranged from 31-625 ng/L and 53-408 ng/L respectively, with average normal and high flow influent concentrations for all plants of 110 and 160 ng/L respectively. Average effluent concentrations among WPCPs ranged from 10-55 ng/L with an overall average of 25 ng/L. Removal efficiencies ranged from 20-91% depending on plant while the average removal across all plants was found to be 64%.

In 2006, Vogelsang et al. described the occurrence and removal of selected organic micropollutants at mechanical, chemical, and advanced WWTPs in Norway. The results indicated that greater than 90% removal could be achieved for nonylphenols, PBDEs, and the more hydrophobic 4-6 ring PAHs by chemical precipitation, but that biological treatment appeared to be necessary for efficient removal of the less lipophilic 2 and 3 ring PAHs, the medium- to short-chained nonylphenol ethoxylates, and diethyl phthalate. For the 7 PCB congeners assessed, removal was found to be over 90% by combined biological and chemical treatment, however, removal by chemical treatment alone was not possible to estimate due to low influent concentrations. The mechanical WWTP exhibited low or insignificant removal efficiencies for PAHs, phthalates, and nonylphenols with their ethoxylates.

A study of the removal of various organic micropollutants such as pharmaceuticals, personal care products, endocrine disrupting compounds, and steroid- and xeno-estrogens in conventional treatment plants (CTPs) and MBRs found no significant difference in removal capacity between the two types of systems (Cirja, et al., 2008). Instead, removal rates were found to depend more on the following physico-chemical characteristics:

- Hydrophobicity – hydrophobic compounds are more readily removed via adsorption
- Chemical structure – complex structures and toxic groups show higher resistance to biodegradation processes
- pKa – controlling protonation state of some compounds could increase removal via adsorption to sludge
- SRT – high SRT (>8 days) enhances biodegradation processes
- Temperature – seasonal and geographical temperature variations seem to play an important role in removing micropollutants, with warmer temperatures being beneficial

Balasubramani, Howell, and Rifai (2014) quantified all 209 PCB congeners in industrial and municipal wastewater effluents from 16 plants in the Houston, TX area and found treatment efficiencies were highly variable among treatment plants but did not assess results on the basis of plant type. A partitioning investigation revealed that total PCB concentrations in the suspended medium was on average four times higher than the total concentrations obtained in the dissolved medium. Lighter PCB congeners exhibited highest concentrations in the dissolved phase whereas heavier PCBs exhibited the highest concentrations in the suspended phase. In addition to K_{ow}, the results suggested that other parameters such as TSS, total organic carbon (TOC), dissolved organic carbon (DOC), and particulate organic carbon (POC) played an important role in PCB partitioning. Additionally, the results showed higher relative concentrations of Dichlorobiphenyl compared to previous studies, which could be attributed to accumulation due to treatment processes that cause dechlorination of heavier PCBs into lighter ones.

Pilot testing was performed to determine the effectiveness of conventional activated sludge and a membrane bioreactor to remove PCBs (Bolzonella, Fatone, Pavan, & Cecchi 2010). EPA Method 1668 was used for the PCB analysis (detection limit of 0.01 ng/L per congener). Influent to the pilot system was a combination of municipal and industrial effluent. The detailed analysis was for several individual congeners. Limited testing using the Aroclor method (total PCBs) was used to compare the individual congeners and the total concentration of PCBs. Both conventional activated sludge (CAS) and membrane bioreactor (MBR) systems removed PCBs. The effluent MBR concentrations ranged from <0.01 ng/L to 0.04 ng/L compared to <0.01 ng/L to 0.88 ng/L for CAS. PCB concentrations in the sludge were consistent across all reactors and were found to increase with increasing chlorination. The pilot testing showed that increased SRT and higher mixed liquor suspended solids concentrations in the MBR system led to increased removal in the liquid stream. In particular, longer SRTs are helpful in the bioconversion of more hydrophobic PCBs. The results also suggested that increased removal performance was a result of the filtering capacity of the MBR system, with CAS removal rates being limited by the presence of suspended solids in the effluent.

Removal efficiencies of various emerging pollutants were analyzed in a primary settling and conventional activated sludge plant (PS+CAS) and in a plant that utilized physico-chemical lamellar settling and a biofiltration system (PCLS+BF) (Mailler, et al., 2014). The coagulation and flocculation processes of PCLS seemed to offer a real gain in terms of micropollutant removal. Overall, the two secondary treatments were found to exhibit similar levels of micropollutant removal, but some tested compounds were slightly better removed by CAS, such as biodegradable compounds, alkylphenols, metals, some PAHs, 4-chloro-3methylphenol, and polybrominated diphenyl ethers (PBDEs).

A detailed literature review and bibliography on removing PCBs during liquid-phase treatment is presented by Expertise Limited, an international water, environmental and chemical process engineering consultant (http://expertise-limited.co.uk/PolyCHlorinatedBiphenylsWaterTreatment.htm). Although the majority of the literature review is more relevant to industrial process wastewater treatment and the remediation sector, reductive dechlorination treatment pathways are discussed under the “Ex Situ Treatment” heading. Multiple citations are listed to substantiate the well-established process of reductive dechlorination under anaerobic conditions. Such anaerobic processes progressively dechlorinate PCBs to lesser chlorinated congeners which are less toxic and more readily degradable. Accordingly, anaerobic-aerobic technologies (such as various BNR processes) are suggested for effective PCB degradation (Abraham et al. 2002, Evans et al. 1996, Tiedje et al. 1993).

Kiedrzynska, et al. (2017) evaluated the efficacy of a “hybrid sequential biofiltration system” consisting of a geochemical filter and a constructed wetland operated in parallel for nutrient and PCB removal at a municipal WWTP. The highest PCB reductions (43 percent) resulted from the wetland treatment. They hypothesize that anaerobic conditions initially support dechlorination and the production of less chlorinated congeners which are more soluble and readily available for subsequent aerobic biodegradation driven by the input of oxygen by the macrophytes planted in the wetland cells. Their results further emphasize the importance of varying redox conditions on PCB degradation.

3.2.4. Advanced Treatment Processes

Source, distribution, and removal of PCBs was studied in a centralized Chinese WWTP that processes 90,000-120,000 cubic meters per day (cmd) of dyeing industrial and domestic wastewater, with 70% of that flow coming from industrial sources (Yao, et al., 2014). The plant’s main treatment train consists of primary sedimentation using polyaluminum chloride (PAC) as a chemical flocculant, followed by an anaerobic/aerobic biochemical process entailing anaerobic biofilter hydrolysis and aerobic bioprocessing by activated sludge. The plant also features secondary sedimentation and a high-density clarifier that employs ferrate oxidation. Liquid and solid samples were analyzed for PCB content at various stages throughout the treatment process. The study suggested that removal of hydrophobic PCBs is strongly dependent on the sorptive behavior of the compounds. Over the course of the study, the anaerobic hydrolysis stage often increased PCB concentrations compared to the preceding primary sedimentation tank. Furthermore, attributed to adsorption and sedimentation by PAC flocculants, PCBs in the suspended particulate matter of the primary sedimentation stage were nearly twice that in the suspended particulate matter of the raw wastewater. For less hydrophobic compounds, other mechanisms such as advection, volatilization, biotransformation, or oxidation and coagulation by ferrate may also be important mechanisms for removal. The total removal efficiency of all 209 PCBs analyzed was 23.2%, but mono-CBs, penta-CBs, hexa-CBs, and hepta-CBs were removed by over 80%.

3.2.5. Pre- and Post-Upgrade Studies

Although no PCBs were assessed, Quanrud and Snyder analyzed the impact of upgraded wastewater reclamation facilities on chemicals of emerging concern (CEC). With an admittedly limited dataset, the authors concluded that despite the substantial improvements in removal of BOD, TSS, nutrients, and other regulated water quality parameters, there seemed to be no significant increase in reduction of CEC concentrations as a result of facility upgrades (UA WRRC, 2016).

3.2.6. Modeling Efforts

In 2001, G. Byrns created a mathematical model to assess the effects of primary settling and secondary activated sludge biological treatment on the fate of xenobiotic organic compounds in WWTPs. The results of the model suggested that removal efficiencies and dominant mechanisms are a function of the solubility and sorption characteristics of the compound. Very soluble compounds appear to be removed as much by advective transport into the final effluent as by biodegradation, while strongly hydrophobic compounds are generally not significantly removed by biochemical reactions, but rather through sorption to sludge particles and transfer to the sludge processing systems. To a lesser, but sometimes still significant, extent, such hydrophobic compounds could also remain sorbed to suspended solids and discharged in the final effluent. For some larger PAHs, dioxins, and substituted phthalates, the model predicted an increase in the total final effluent concentration as the operating SRT increased above 3-5 days due to a higher fraction of these compounds being sorbed to suspended solids and transported into the final effluent. According to the model, the effects of biotransformation would eventually dominate, and the effluent concentration would begin to decline, but SRT values at which this might occur were not discussed.

3.2.7. Lab Scale Studies

Bench scale laboratory tests were undertaken to investigate the removal of several organic pollutants by activated sludge under aerobic conditions and anaerobic digestion of adsorbed species (Dionisi, et al., 2006). Under aerobic conditions, biodegradation only played a role in phenol removal, while adsorption was shown to be the removal mechanism for all other considered substances. As shown in other studies, phase partitioning was correlated to K_{ow}, suggesting that adsorption was more important for the more hydrophobic compounds. Under anaerobic sludge digestion, benzene was removed rapidly and completely, and a significant average depletion of chlorinated pollutants was observed under mesophilic conditions (24.6%). The process was shown to be stimulated by the addition of yeast extract, which caused the average depletion of chlorinated pollutants to increase to 49.7% along with the complete disinfection of the sludge.

Research on the effectiveness of UV light and peroxide on removing PCBs was tested in bench scale batch reactions (Yu, Macawile, Abella, & Gallardo 2011). The combination of UV and peroxide treatment achieved PCB removal greater than 89 percent, and in several cases exceeding 98 percent removal. The influent PCB concentration for the batch tests ranged from 50 to 100 micrograms per liter (µg/L). The final PCB concentration (for the one congener tested) was <10 µg/L (10,000 ng/L) for all tests and <5 µg/L (5,000 ng/L) for some tests. The lowest PCB concentrations in the effluent occurred at higher UV and peroxide doses.

Prior studies have shown that nearly complete biodegradation of less-chlorinated PCB congeners is possible in suspended-growth systems, but the extent of biodegradation decreases with increasing chlorination. Adsorption and precipitation then become the dominant removal mechanisms. Bench scale studies were completed to test the effectiveness of GAC and biological activated carbon (BAC) for removing PCBs (Ghosh, Weber, Jensen, & Smith 1999). The effluent from the GAC system was 800 ng/L. The biological film in the BAC system was presumed to support higher PCB removal with effluent concentrations of 200 ng/L. High suspended sediment in the GAC influent can affect performance. It is recommended that filtration be installed upstream of a GAC system to reduce solids and improve effectiveness.

In 2015, Dong, et al. performed lab scale tests of an anaerobic/aerobic moving-bed biofilm reactor with membrane filtration system (MBBR-MF) fed with simulated PCB-contaminated wastewater. The batch tests consisted of three day-long batches with a hydraulic retention time of eight hours each. PCB removal was 58% in the first batch, then 83 and 84 % in the second and third batches, respectively. The anaerobic degradation rate was 73% while the aerobic degradation rate was 83%, leading the authors to conclude that PCBs were primarily decomposed through aerobic bacteria oxidative destruction.

In a study of the fate of toxic chlorinated compounds during anaerobic biosolids digestion, dechlorination of PCBs was described by Ballapragada et al. (1998) with chlorine atom removal primarily at the *meta*- and *para*- substituted positions, and accumulations at the *ortho*- position. The result was a reduction of more chlorinated PCB congeners and accumulation of congeners with less chlorine atoms. In their laboratory digester experiments, the researchers showed no PCB degradation even after an 18-month acclimation period and speculated that PCB dechlorinating bacteria were not present in the biosolids used.

3.2.8. Chesapeake Stormwater Network

The Chesapeake Stormwater Network reports (*Potential Benefits of Nutrient and Sediment Practices to Reduce Toxic Contaminants in the Chesapeake Bay Watershed*) reflect the results of literature reviews focusing on the removal of toxic contaminants in urban stormwater systems (Part 1) and from the agricultural and wastewater sectors (Part 2). Part 1 highlights the strong similarities between PCBs (and other hydrophobic toxic contaminants) and suspended solids, a more easily measured water quality characteristic commonly monitored in both stormwater and wastewater treatment systems. Both the environmental behavior and the removal efficiencies of PCBs and suspended solids appear strongly correlated per the report.

Although Part 2 specifically addresses the wastewater sector, the level of detail is modest. The report states that there “is some evidence that BNR…may also be more effective in removing antibiotics from wastewater effluent”, although it notes that the environmental fate of antibiotics in biosolids after land application is uncertain. Similar findings and caveats are presented for biogenic hormones. The report states that “(w)hile conventional activated sludge and nitrifying activated sludge processes reduced estrogenicity by at least 80%, BNR was found to have the highest removal of all WWTP processes” (Ogunlaja et al., 2013). With regard to antibiotics, activated carbon treatment in WWTPs appears to be most effective with removals of up to 90% (Jelic et al., 2011).

3.2.9. Other Published Literature – Delaware River Basin Commission and other non-Chesapeake watersheds.

Multiple watershed-scale efforts to address PCBs were evaluated to determine their relevance to similar efforts in the Chesapeake Bay Watershed. As previously implied, most efforts to reduce PCBs in receiving waters and even in WWTP discharges has focused on source identification and reduction; case studies describing such efforts are common in the white and gray literature, although they provide little if any value to this study addressing the co-benefits of BNR upgrades vis-à-vis PCB and toxics reductions. Documents from the Delaware River Basin Commission, The Ohio River Valley Water Sanitation Commission, Texas Commission on Environmental Quality (for Lake Worth), and King County, WA (for Lake Washington) were collected and reviewed for relevant information.

Because it represents a large mid-Atlantic estuary adjacent to the Chesapeake Bay watershed, information from the Delaware River Estuary Toxics Management Program (part of the Delaware River Basin Commission, DRBC) was particularly mined for relevant information which might inform this study. The main DRBC reports related to PCBs and toxics (DRBC 1998, 2003) do not address reductions attributable to WWTP treatment explicitly, again focusing mainly on source control (including resolubilization from legacy sources, like contaminated sediments). Gregory Cavallo, the DRBC’s project manager for the collection, analysis and assessment of polychlorinated biphenyl’s (PCBs) monitoring data for water, fish tissue, sediment, air and point source samples in support of the PCB TMDL, was contacted to glean additional, unpublished information about the Delaware Bay Estuary PCB/toxics reduction program. Because PCB removal efficiencies (which are related to TSS removal efficiencies) are consistent for a given WWTP, source reduction can provide a greater return for investment than investing in in-plant efforts to enhance PCB removal. This includes removing solids from sewer collection systems (e.g., lift stations) which can store and resolubilize PCBs into WWTP influents. Nevertheless, anything (like low-level TP removal technology) that provides enhanced TSS reductions should have correspondingly improved PCB reductions (G. Cavallo, personal communication, May 25, 2018).

4. Discussion

4.1. Permitted Discharger Data

The permitted discharger data obtained for this project indicates that for many discharges an assessment of total PCBs is only completed for effluent. In some case, like the MDE PCB study, PCBs were evaluated in both influent and effluent from facilities before upgrades and from facilities after upgrades. Data for only one facility, Blue Plains, was located that include influent, effluent, and sludge concentrations of total PCBs. When evaluating whether upgrades for nutrient removal were effective in reducing total PCBs, having total PCB measures in influent, effluent, and sludge is critical. Some changes observed in the total PCBs in effluent may have been correlated to decreases in total PCBs in influent and not due to the upgrade. Other reductions in effluent total PCBs may have been attributable to an upgrade for nutrient removal and effluent concentrations were reduced after the upgrade. However, these are unable to be quantified and attributed to the source of the reduction due to the lack of quantified concentrations of influent, effluent, and sludge before and after the nutrient upgrade. Overall, it appears that nutrient upgrades have a reducing effect on the discharge of total PCBs and perhaps other toxics.

4.2. Published Literature

Much of the programmatic focus (e.g., of the Delaware River Basin Commission) vis-à-vis minimizing the discharge of PCBs from WWTPs has been on quantifying effluent loads, and in identifying and reducing sources of toxics in WWTP influents. There appears to be a perception (probably warranted) that there is not much that can be intentionally done within a WWTP (e.g., via operational modifications) to significantly improve PCB removal, particularly if the regulatory drivers are modest; source control gives a much larger “bang for the buck”.

Those operational efforts that can be undertaken within a WWTP generally revolve around enhancing sorption processes (e.g., via use of activated carbon) and improving solids removal processes (note that enhanced solids removal is often also a fundamental element of low-level Total Phosphorus reduction treatment strategies). Although biodegradation can be enhanced through operational controls, these involve tradeoffs and risks that often do not warrant implementation (e.g., increasing MLSS or SRT can decrease the effective hydraulic capacity of the WWTP, contributing to sludge bulking, and other issues that negatively impact WWTP performance). Nevertheless, it has been at least anecdotally established that ENR upgrades should result in greater reductions of PCBs and other similarly-behaved toxics, attributable to providing multiple biological degradation pathways (aerobic, anoxic and anaerobic) that combine reductive dechlorination under low DO conditions and robust aerobic biodegradation of lesser chlorinated PCB congeners. The relationship between other operating characteristics of BNR systems (e.g., longer SRTs as needed for nitrification) and enhanced PCB/toxics removal are well established in the literature.

Despite shortcomings of the literature in directly comparing ENR systems versus conventional activated sludge treatment, several references did more generally address PCB removal within activated sludge systems and correlations between PCB congener reductions and various WWTP operating parameters have been established. Such correlations suggest that upgrading to ENR is highly likely to improve the reduction of toxics. However, it is very difficult to quantitatively estimate these benefits based on the published literature alone.

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 and resulting implications

The latter point is of significant interest, since PCBs in biosolids are often (inadvertently) recycled back into the environment via sediment erosion, sediment resuspension, and volatilization or combustion followed by atmospheric deposition and stormwater runoff.

Although PCBs are readily sorbed to solids (which can subsequently be removed) in WWTPs, there is also ample evidence of significant biodegradation of PCBs, with lesser-chlorinated PCB congeners being more readily degraded. Operating parameters associated with BNR are likely to increase removals of PCBs by solid-phase sequestration and biodegradation, as both are positively correlated with:

a. Longer sludge retention times (SRTs), as needed for nitrification
b. Higher mixed liquor suspended solids (MLSS) concentrations
c. Combination of anaerobic, anoxic and oxic operating conditions (as needed for biological nitrogen and phosphorus removal)

No references directly addressing the impact of ENR upgrades on PCB or other toxic compound reductions in WWTP effluents were discovered, although several references did compare the toxics reduction between conventional activated sludge treatment and other treatment technologies (typically membrane bioreactors). Overall, it appears that the published data is limited use in terms of quantifying the PCB/toxics reduction benefits of ENR upgrades. On the other hand, the benefits can be described qualitatively with good confidence, since the operating factors discussed above (that is, varying redox conditions and increased contact with sorptive media) are key attributes of activated sludge systems that have been upgraded to BNR.

4.3. Potential Ways to Estimate PCB Reduction Due to Nutrient Control Upgrades

The consensus in the literature (e.g., USEPA, 1977; G. Cavallo, personal communication, May 25, 2018; Katsoyiannis and Samara, 2004) appears to be that PCB reductions are related to TSS reductions in WWTPs; therefore, developing a methodology that quantitatively estimates PCB reductions as a function of WWTP TSS reduction percentage may be warranted as a high level approximation of the PCB reductions that may be achieved. As also implied by the preceding discussion, the correlation relationship is likely to vary depending on specific WWTP characteristics including:

1. Use of aerobic, anoxic and anaerobic treatment, with higher overall removals associated with a greater proportion of anoxic and anaerobic conditions during treatment. This would suggest, for example, that a system featuring both enhanced biological nitrogen removal (which requires anoxic conditions) and enhanced biological phosphorus removal (which requires anaerobic conditions) would remove more PCBs than a system with only nitrogen removal or with neither.
2. SRTs in excess of 8 days result in improved PCB removal. Note that many BNR systems will have SRTs of 8 days or more to facilitate nitrification particularly during cooler times of the year.
3. Higher sludge yields, which should result in higher sludge wasting rates that incorporate greater amounts of sorbed PCBs. Note however, that sludge yield is inversely related to SRT – at higher SRTs, more endogenous respiration occurs, generally lowering the yield. Additionally, sludge yield is not a parameter that can be as readily controlled as other operating parameters.

4. Solids removal efficiency, which is implied in the suggestion of correlation; that is, the smaller the solids particles that are effectively removed during treatment, the greater than TSS reduction and accordingly, the greater the PCB reduction.
5. Influent characteristics, most notably the specific PCB congener ratio, are likely to be quite important; however, it is unlikely that many WWTPs collect this data. Additionally, the quantitative impacts of PCB congener ratios on removal estimates are particularly not well understood.

A crude (and best-case scenario) method for estimating PCB removal efficiency is to assume that it has the same removal efficiency as does TSS through the WWTP. This best-case assumption would be applicable to WWTPs that exhibit very favorable PCB removal characteristics; that is, an SRT of 8 days or more, and combined biological nitrogen and phosphorus removal. Under such a quantitative estimation framework, WWTPs with less than an 8-day SRT or with only biological nitrogen or phosphorus removal, but not both, could be assigned lower PCB removal efficiencies. Table 4-1 provides a rough framework for estimating both absolute PCB reductions for WWTP with different characteristics as a function of TSS removal percentage, along with a rough estimate of the fate of the PCBs (i.e., sorbed versus degraded).

Table 4-1. Summary of effluent reduction percentage and PCBs in sludge under a 0-8 day or a >8 day solids retention time (SRT) by different types of treatment processes.

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

The estimates presented in Table 4-1 are based on the literature in the following ways:

- The maximum estimate of PCB reduction is equivalent to the percent TSS reduction through the system (USEPA, 1977; HDR, 2013);
- The maximum estimated PCB reduction is associated with SRTs of 8 days or greater (HDR, 2013); and
- The amount of partitioning to sludge is inversely related to the variety of redox conditions within the wastewater treatment process (Abraham et al. 2002, Evans et al. 1996, Tiedje et al. 1993), with processes featuring a greater range of redox conditions (i.e., biological N and P removal which includes oxic, anoxic and anaerobic stages) removing more PCB through biochemical pathways (e.g., reductive dechlorination) rather than sorption to biosolids.

These estimates also come with several embedded assumptions, including the following:

- Performance within the two SRT ranges chosen (based on the literature) does not vary;
- Variation in performance and solids partitioning between the various treatment process types are based on best professional judgement

Further refinement of the estimates does not appear possible currently considering limitations in the underlying data.

4.4. Identification of Data Gaps

Data gaps exist in both the compiled discharger data and in the published literature. These gaps could be filled by a well-designed study of facilities that are slated to be upgraded for the reduction of nutrients but would take many years to compile the amount of data needed.

Discharger Compiled Data – To assess the potential reduction of non-target contaminants, particularly PCBs, from WWTP that had been upgraded for the reduction of nutrients (i.e., nitrogen and phosphorous) had many data gaps including the lack of measured PCBs in effluent; only effluent is measured for contaminants; and many facilities either did not measure or it was not able to be located, total PCBs prior to or after their upgrade for nutrient reduction. For some facilities that may have been upgraded for the reduction of nutrients, total PCBs is not routinely measured or has not been measured at all in the facility effluent. For other facilities, only effluent PCBs have been measured so conclusions on what may have caused the change in effluent PCB concentration cannot be determined due to the lack of influent or solids PCB concentrations. The change in effluent concentration may have been attributed to the nutrient reduction upgrade or may have been due to a change in influent or partitioning to sludge. Another data gap that was recognized during the compilation of discharger data was whether the appropriate data were collected before and after the upgrade for nutrient reduction. The lack of reporting the analytical method used for PCB analysis also represents a data gap. There are multiple analysis methods and they all represent different levels of detection. Methods with lower detection levels may be necessary to determine actual PCB concentrations.

Compiled Published Literature - Quantifying PCB and other toxics reductions attributable to WWTP BNR upgrades is a severely data limited question. Available data in the literature provides qualitative information at a relatively high level of confidence; however, from a quantitative perspective, confidence is low. Controlled field studies are needed to more reliably quantify expected reductions (absolute and relative to a baseline condition; that is, conventional activated sludge with no BNR).

5. Conclusion and Recommendations

It is highly likely that nutrient removal upgrades aid in the reduction of toxic compounds, including PCBs, in WWTP effluents. However, quantitative evidence to support this conclusion is limited and thus overall confidence is low. Several important findings and qualifiers include the following:

- PCB reductions should be differentiated from that of other toxics. Toxics with chemical properties like PCBs can be expected to behave similarly; however, many toxics possess characteristics quite dissimilar to those exhibited by PCBs.
- 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. Because PCBs are strongly hydrophobic, processes that reduce suspended solids in WWTP effluents (such as advanced filtration for low level total phosphorus treatment) will reduce PCBs in wastewater effluents. The bioavailability of sorbed toxics associated with WWTP discharges as well as the disposition of WWTP residuals containing sorbed toxics may be important considerations in evaluating the watershed-scale implications of toxics sorption processes during wastewater treatment and the potential for PCB cycling rather than effective removal of reactive toxics.
- Lighter, lesser chlorinated PCB congeners are more biologically degradable than heavier, more chlorinated congeners. All else being equal, other halogenated compounds will exhibit similar treatability characteristics; in other words, toxics with greater numbers of halogen (fluorine, chlorine, bromine, iodine, and astatine) substitution on carbon atoms will be more difficult to biologically treat than those with lesser halogen substitutions. Nevertheless, reductive dehalogenation (typically under highly anaerobic conditions) is a well-established pathway for transforming PCBs and other toxics and is, in fact, commonly implemented as an *in situ* treatment process for contaminated sediments, soils and groundwaters. It is theoretically well-grounded, and at least partially established scientifically that providing a mix of anaerobic, anoxic and oxic/aerobic conditions – which are fundamental aspects of BNR – will reduce PCBs and other toxics to a greater extent than will exclusively aerobic treatment (e.g., before upgrading to BNR).

Other operational characteristics of nutrient reduction processes as compared to conventional activated sludge system suggest that at least modest improvements in toxics reductions should be affected by nutrient removal upgrades. Anything that increases the volume of solid residuals generated and removed should further reduce hydrophobic toxics like PCBs following well-established sorption isotherm relationships. Additionally, processes which increase the contact time between biologically active solids and toxics should affect higher levels of biodegradation. For example, nitrification (required as a first step in biological nitrogen reduction) requires longer hydraulic and solids retention times than conventional activated sludge treatment, and even biological nitrogen and phosphorus removal adds a modest amount of overall biological treatment time. Anaerobic (for biological phosphorus removal) and anoxic (for biological nitrogen removal) treatment supports more diverse microbial populations and biodegradation pathways that enhance overall reductions of PCBs and other toxics. This is an area, however, that would benefit from additional controlled studies to quantify such reductions.

The literature relating to PCB and toxic reductions resulting from upgrading WWTPs to BNR is limited and currently only allows for broad conclusions to be made. Accordingly, it is recommended that the CBT and its partners make efforts to better quantify such reductions by (in order of difficulty/resource demand):

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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Appendix A: Quality Assurance Project Plan

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Appendix B: Compiled Published Literature

Table B-1. Summary of Peer-reviewed literature compiled and scored based on QAPP (Appendix A).

CBT Toxics Literature Review	Relevance			Toxic Compound Information	WWTP Information		Are scientific and technical procedures sound? (Examples include using analytical methods approved under 40 CFR 136, following EPA- or state-issued guidance, and using sound statistical procedures)		Are data clearly and completely documented? (This includes descriptions of assumptions, methods, QA, sponsoring organizations [for journal articles], and analyses)		Information Source Type		Has the document been reviewed by internal or external reviewers? (before you saw it)		Has variability and uncertainty been characterized? (This could be quantitative or qualitative evaluations of the procedures, measures, methods, or models evaluated and characterized)			Study Prioritization			
Citation, URL, and/or File Name	**Select from pulldown: Yes or Maybe**	**If it's applicable, did you save copy on network?**	**Notes (for relevance)**	**Compound type, group, or name**	**WWTP Type(s)**	**Location**	**Select from pulldown: Yes; No; Partially; or N/A (Source did not provide this level of detail)**	**If No or Partially, explain why**	**Select from pulldown: Yes; No; or Partially**	**If this is Partially, briefly explain why**	**Select from pulldown: 1 = Peer-reviewed journal article; 2 = Federal or state source, or 3 = Other**	**If "Other" source, please describe (e.g., trade journal, concerned citizen's group website, graduate student thesis)**	**Yes**	**Notes**	**Select from pulldown: Yes, No, or Partially**	**If this is Partially, briefly explain why**	**Notes**	**Type of WWTP**	**Constituents Measured**	**Media Sampled**	**Total Score**
Anderson, P.D. (2005) Technical Brief: Endocrine Disrupting Compounds and Implications for Wastewater Treatment. Prepared for Water Environment Research Foundation (WERF), Alexandria, VA. Project 04-WEM-6.	Yes	Yes	Discusses removal of EDCs through WWTPs	EDCs	Various	Various	Yes	Literature review	Partially	Depends on source data	3 = Other	Research Foundation.	Yes	Peer reviewed report	Partially	Literature review so depends on source data		1	1	1	3
*Balasubramani, A.; Howell, N. L.; and Rifai, H. S. (2014). Polychlorinated Biphenyls (PCBs) in Industrial and Municipal Effluents: Concentrations, Congener Profiles, and Partitioning onto Particulates and Organic Carbon. Science of the Total Environment. 473-474, 702-713. *O:\Projects\Chesapeake Bay Trust\2017 Scope 8 - Assessing WWTP Toxics\Source\Obtained By RTP\Jesse lit\Balasubramanietal.2014finishedpapereffluents	Maybe	Yes	Effluent from 16 plants analyzed, but treatment type not discussed.	PCBs	Municipal and industrial wastewater treatment plants and petrochemical industrial outfalls (16 total). Treatment type not discussed.	Houston, TX area	Yes	Could be more robust - only one outfall sample taken from most facilities (two outfall samples were taken at one of the municipal plants). No influent samples.	Yes		1 = Peer-reviewed journal article		Yes	Peer-reviewed journal article	Yes		Compared results with other similar studies.	1	2	1	4

Ballapragada, B., H.D. Stensel, J.F. Ferguson, V.S. Magar, J.A. Puhakka (1998) Toxic Chlorinated Compounds: Fate and Biodegradation in Anaerobic Digestion. Prepared for WERF. Project No. 91-TFT-3.	Yes	Yes		PCBs and others toxic chlorinated compounds	Anaerobic digestion of biosolids	N/A	Yes		Yes		3 = Other	Research Foundation	Yes		Yes			1	3	1	5
*Bergqvist, P.A., Augulyte, L., and Jurjoniene, V. (2006). PAH and PCB Removal Efficiencies in Umea (Sweden) and Siauliai (Lithuania) Municipal Wastewater Treatment Plants. Water, Air, and Soil Pollution. 175:291. doi:10.1007/s11270-006-9139-5. *O:\Projects\Chesapeake Bay Trust\2017 Scope 8 - Assessing WWTP Toxics\Source\Obtained By RTP\Jesse lit\Bergqvist_2004_PAH and PCB removal in Sweden and Lithuania	Yes	Yes	Could help provide baseline of removal by CAS plants	PAHs and PCBs	Conventional AS	Sweden and Lithuania	Yes		Partially	No information on sponsoring organizations	1 = Peer-reviewed journal article		Yes	Peer-reviewed journal article	Yes			1	3	2	6
*Blanchard, M.; Teil, M.; Ollivon, D.; Legenti, L.; and Chevreuil, M. (2004). Polycyclic Aromatic Hydrocarbons and Polychlorobiphenyls in Wastewaters and Sewage Sludges from the Paris Area (France). Environmental Research. 95 (2), 184-197. *O:\Projects\Chesapeake Bay Trust\2017 Scope 8 - Assessing WWTP Toxics\Source\Obtained By RTP\Jesse lit\Blanchard et al. 2004	Yes	Yes	Liquid and solid phases analyzed at various locations along the treatment train	PAHs and PCBs	Conventional AS	Paris, France	Yes		Yes		1 = Peer-reviewed journal article		Yes	Peer-reviewed journal article	Yes			1	3	3	7
*Bolzonella, D., Fatone, F., Pavan, P., & Cecchi, F. (2010). Poly-chlorinated Dibenzo-p-dioxins, Dibenzo-furans and Dioxin-like Poly-chlorinated Biphenyls Occurrence and Removal In Conventional and Membrane Activated Sludge Processes. Bioresource technology, 101(24), 9445-9454. *O:\Projects\Chesapeake Bay Trust\2017 Scope 8 - Assessing WWTP Toxics\Source\Obtained By RTP\Jesse lit\Bolzonella et al. 2010	Yes	Yes	Side-by-side pilot scale comparison of a non-BNR reactor and a BNR reactor	Dioxins, furans, and PCBs	Pilot scale conventional activated sludge and membrane bioreactor	Italy - wastewater from an urban and industrial area of northeast Italy	Yes		Yes		1 = Peer-reviewed journal article		Yes	Peer-reviewed journal article	Yes			3	3	3	9
*Byrns, G. (2001). The Fate of Xenobiotic Organic Compounds in Wastewater Treatment Plants. Water Research. 35(10), 2523-2533. *O:\Projects\Chesapeake Bay Trust\2017 Scope 8 - Assessing WWTP Toxics\Source\Obtained By RTP\Jesse lit\Byrns_2001_The Fate of Xenobiotic Organic Compounds in WWTPs	Maybe	Yes	Could help determine likely removal mechanisms, and thus potential upgrade benefits. No PCBs in study	Xenobiotics, including Benzene, Acenapthylene, Pyrene, Dichloromethane, Chlorobenzene, DDT, Dibutylphthalate, etc.	Model based on treatment train of a typical diffused air activated sludge system, including primary sedimentation	N/A (mathematical model). Author based in the UK	Yes	Apparently attempts to synthesize multiple peer review apporaches into a generalized fate model.	Partially	No QA or sponsorship information	1 = Peer-reviewed journal article		Yes	Peer-reviewed journal article	Yes			1	1	2	4
*Cirja, M.; Ivashechkin, P.; Schaffer, A.; and Corvini, P. F. X. (2008). Factors Affecting the Removal of Organic Micropollutants from Wastewater in Conventional Treatment Plants (CTP) and Membrane Bioreactors (MBR). Review in Environmental Science and Bio/Technology. 7 (1), 61-78. *O:\Projects\Chesapeake Bay Trust\2017 Scope 8 - Assessing WWTP Toxics\Source\Obtained By RTP\Jesse lit\Cirja_2008_Factors Affecting the Removal of Organic Micropollutants from Wastweater in CTP & MBR	Yes	Yes	Several toxic componds and multiple treatment types discussed. No explicit samples/data, but could be helpful in determining likely removal mechanisms and thus potential	Pharmaceuticals, personal care products, endocrine disrupting compounds	Comparison of conventional activated sludge (CAS) and membrane bioreactor (MBR) processes	N/A (synthesis and overview/disucssion of prior research). Authors based in Germany and Switzerland	Partially	Summary and synthesis of available body of research, no emphasis on assessing the scientific and technical soundness of said research. More	Partially	Again, assumptions and methods of prior research not discussed. This study funded under the AQUAbase Project by the European Commission	1 = Peer-reviewed journal article		Yes	Peer-reviewed journal article	No			3	1	3 (all media types sampled in vario	7

			upgrade benefits					qualitative and descriptive; quantitative results from other studies are presented but no quantitative results are produced in this study.												us literature discussed)	
*Dionisi, D.; Bertin, L.; Bornoroni, L.; Capodicasa, S.; Papini, M. P.; Fava, F. (2006). Removal of Organic Xenobiotics in Activated Sludges under Aerobic Conditions and Anaerobic Digestion of the Adsorbed Species. Chemical Technology and Biotechnology. 81 (9), 1496-1505. *O:\Projects\Chesapeake Bay Trust\2017 Scope 8 - Assessing WWTP Toxics\Source\Obtained By RTP\Jesse lit\Dionisi_et_al-2006-Removal of organic xenobiotics in activated sludges under aerobic conditions and anaerobic digestion of the adsorbed species	Yes	Yes	More concerned with removal of adsorbed toxics from waste sludge. Only one PCB congener assessed	PAHs, PCBs, surfactants, chlorinated and non-chlorinated benznes, and phenols	Bench scale CAS tests.	Italy - Sludge from Roma Nord WWTP	Yes		Partially	No funding information	1 = Peer-reviewed journal article		Yes	Peer-reviewed journal article	No			1	3	2	6
*Dong, B.; Chen, H.; Yang, Y.; He, Q.; and Dai, X. (2015). Biodegradation of Polychlorinated Biphenyls Using a Moving-Bed Biofilm Reactor. CLEAN – Soil, Air, Water. 43 (7), 1078-1083. *O:\Projects\Chesapeake Bay Trust\2017 Scope 8 - Assessing WWTP Toxics\Source\Obtained By RTP\Jesse lit\Dong_et_al-2015-Biodegradation of PCBs using a moving-bed biofilm reactor	Yes	Yes	Lab scale reactor	PCB	Lab scale moving bed bioreactor with membrane filtration (MBBR-MF)	China - Activated sludge from a municipal WWTP in Shanghai	Yes		Yes		1 = Peer-reviewed journal article		Yes	Peer-reviewed journal article	Yes			2	2	2	6
*Durell, G. and Lizotte, R. (1998) PCB Levels at 26 New York City and New Jersey WPCPs that Discharge to the New York/New Jersey Harbor Estuary. Environmental Science & Technology. 32 (8), 1022-1031. *O:\Projects\Chesapeake Bay Trust\2017 Scope 8 - Assessing WWTP Toxics\Source\Obtained By RTP\Jesse lit\Durell_1998_PCB levels at 26 New York City and New Jersey WPCPs	Maybe	Yes	No info on plant type other than to say that inconsistent results made it impossible to attribute specific congener removal to the treatment process.	PCBs	26 different plants analyzed, but plant type not disucces	New York City and New Jersey	Yes		Partially	No information on sponsoring organizations	1 = Peer-reviewed journal article		Yes	Peer-reviewed journal article	Yes			1	2	2	5
*Ghosh, U., Weber, A., Jensen, J., & Smith, J. (1999). Granular Activated Carbon and Biological Activated Carbon Treatment of Dissolved and Sorbed Polychlorinated Biphenyls. Water Environment Research, 71(2), 232-240. *O:\Projects\Chesapeake Bay Trust\2017 Scope 8 - Assessing WWTP Toxics\Source\Obtained By RTP\Jesse lit\Ghosh_1999_GAC and BAC Treatment of Dissolved and Sorbed Polychlorinated Biphenyls	Maybe	Yes	Bench scale study. Not sure if GAC/BAC is commonly used for nutrient removal.	PCBs	Bench scale GAC and BAC columns	Pennsylvania??	Yes		Yes		1 = Peer-reviewed journal article		Yes	Peer-reviewed journal article	Yes			1	2	3	6

*Katsoyiannis, A. and Samara, C. (2004). Persistent Organic Pollutants (POPs) in the Sewage Treatment Plant of Thessaloniki, Northern Greece: Occurrence and Removal. Water Research, 38 (11), 2685-2698. *O:\Projects\Chesapeake Bay Trust\2017 Scope 8 - Assessing WWTP Toxics\Source\Obtained By RTP\Jesse lit\Katsoyiannis_2004_Persistent Organic Pollutants POPs in the conventional activated sludge treatment process Occurrence and removal	Yes	Yes	CAS plant, but assessed at six different points across the treatment system.	Persistant organic pollutants, including 7 PCBs and 19 organochlorine pesticides	conventional activated sludge	Thessaloniki, Greece	Yes		Yes		1 = Peer-reviewed journal article		Yes	Peer-reviewed journal article	Yes			1	3	3	7
*Katsoyiannis, A. and Samara, C. (2005). Persistent Organic Pollutants (POPs) in the Conventional Activated Sludge Treatment Process: Fate and Mass Balance. Environmental Research. 97 (3), 245-257. *O:\Projects\Chesapeake Bay Trust\2017 Scope 8 - Assessing WWTP Toxics\Source\Obtained By RTP\Jesse lit\Katsoyiannis and Samara 2005	Yes	Yes	Extension of 2004 research to include fate and mass balance of POPs	Persistant organic pollutants, including 7 PCBs and 19 organochlorine pesticides	conventional activated sludge	Thessaloniki, Greece	Yes		Yes		1 = Peer-reviewed journal article		Yes	Peer-reviewed journal article	Yes			1	3	3	7
Kiedrzynska, E., M. Urbaniak, M. Kiedrzynski, A. Jozwik, A. Bednarek, I. Gagala, M. Zalewski. (2017) The Use of a Hybrid Sequential Biofiltration System for the Improvement of Nutrient Removal and PCB Control in Municipal Wastewater. Scientific Reports (Springer Nature) 7:5477.	Yes	Yes		PCBs and nutrients	Biofilter	Poland	Partially	Methods not well described	Partially	Methods not well described	1 = Peer reviewed journal		Yes		Yes			2	2	2	6
*Mailler, R., Gasperi, J., Rocher, V., Gilbert-Pawlik, S., Geara-Matta, D., Moilleron, R., Chebbo, G. (2014). Biofiltration vs Conventional Activated Sludge Plants: What About Priority and Emerging Pollutants Removal? Environmental Science and Pollution Research. 21 (8), 5379–5390. *O:\Projects\Chesapeake Bay Trust\2017 Scope 8 - Assessing WWTP Toxics\Source\Obtained By RTP\Jesse lit\Mailler et al_2014_Biofiltration vs CAS plants what about priority and emerging pollutants removal	Yes	Yes	Side-by-side comparison of two operational WWTPs. Primary (primary settling vs physico-chemical lamellar settling) and secondary (CAS vs biofiltration) treatment processes are compared, but seems to be no data on PCB removal by the secondary treatments	All priority substances listed in the European Water Framework Directive and additional compounds of interest including flame retardants, surfactants, pesticides, and personal care products. Includes 8 PCBs, but only provides data on 1	Conventional activated sludge and biofiltration	Paris, France	Yes		Yes		1 = Peer-reviewed journal article		Yes	Peer-reviewed journal article	Yes			3	3	2	8

Needham, T.P., U. Ghosh (2018) Four Decades Since the Ban, Old Urban Wastewater Treatment Plant Remains a Dominant Source of PCBs to the Environment. Environmental Pollution 246 (2019) 390-397.	Yes	Yes		PCBs	Activated sludge	Maryland	Yes		Yes		1 = Peer reviewed journal		Yes		Yes			2	2	3	7
Ohlinger, K., C. De Las Casas, R. Merlo, S. Snyder (2013) Holistic Assessment of Trace Organic Compounds in Wastewater Treatment. Prepared for WERF. Project No. U3R11.	Yes	Yes		Trace organics	Various in lab	Lab	Yes		Yes		3 = Other	Research Foundation	Yes		Yes			2	1	2	5
*Pham, T.T., & Proulx, S. (1997). PCBs and PAHs in the Montreal Urban Community (Quebec, Canada) wastewater treatment plant and in the effluent plume in the St Lawrence River. Water Research, 31, 1887–1896. *O:\Projects\Chesapeake Bay Trust\2017 Scope 8 - Assessing WWTP Toxics\Source\Obtained By RTP\Jesse lit\Pham & Proulx, 1997_PCBs_and_PAHs_in_the_Montreal_Urban_Comm	Maybe	Yes	Physico-chemical treatment only, consisting of addition of coagulant and coagulant aide, then sedimentation and solids removal. Could help determine dominant removal mechanisms	PCBs and PAHs	Physico-chemical	Montreal, Quebec, Canada	Yes		Partially	Some analyses contracted to outside lab, with no disucssion of the lab's QA measures	1 = Peer-reviewed journal article		Yes	Peer-reviewed journal article	No			1	3	2	6

*Stevens, J.L., Northcott, G.L., Stern, G.A., Tomy, G.T., & Jones, K.C. (2003). PAHs, PCBs, PCNs, organochlorine pesticides, synthetic musks and polychlorinated n-alkanes in UK sewage sludge: Survey results and implications. Environmental Science and Technology, 37, 462–467. *O:\Projects\Chesapeake Bay Trust\2017 Scope 8 - Assessing WWTP Toxics\Source\Obtained By RTP\Jesse lit\Stevens_et_al_2003_PAHs, PCBs, PCNs, organochlorine pesticides, synthetic musks, and polychlorinated n-alkanes in UK sewage sludge	Maybe	Yes	Digested sludge was the only media analyzed, but could help determine fate of PCBs and other toxics. No discussion of PCB concentrations by plant type.	PAHs, PCBs, PCNs, organochlorine pesticies, synthetic musks, and polychlorinated n-Alkanes	14 plants total, all activated sludge or percolating biofilter.	United Kingdom	Yes		Yes		1 = Peer-reviewed journal article		Yes	Peer-reviewed journal article	Partially	Measures to reduce interfering factors are disucssed, then reader is directed to referenced for further details on validated procedures		1	3	1	5
*University of Arizona (UA) Water Resources Research Center (WRRC). (2016). Water Resources Research Center Annual Technical Report, FY 2015. Retrieved from: https://water.usgs.gov/wrri/AnnualReports/2015/FY2015_AZ_Annual_Report.pdf *O:\Projects\Chesapeake Bay Trust\2017 Scope 8 - Assessing WWTP Toxics\Source\Obtained By RTP\Jesse lit\UA WRRC, 2016	Yes	Yes	No data on PCBs, but pre-and post-upgrade data for other toxics	Various contaminants of emerging concern, including pharmaceuticals, personal care products, flame retardants, and compounds used in industrial applications and consumer products	Plant 1 upgraded from primary clarifiers and biotowers to DAF clarification, 5-stage Bardenpho, and tertiary filtration. Plant 2 upgraded from pure oxygen AS to 5-stage Bardenpho.	Tucson, AZ	Yes		Yes		2 = Federal or State source		Unknown	Most likely reviewed. Result of a 104(b) research grant from the University of Arizona (UA) Water Resources Research Center (WRRC). Research then presented in the WRRC annual technical report	Yes		Analysis using published methods; laboratory QA/QC measures outlined; small sample size acknowledged and discussed	3	1	1	5
*Vogelsang, C.; Grung, M.; Jantsch, T. G.; Tollefsen, K. E.; and Liltved, H. (2006). Occurrence and Removal of Selected Organic Micropollutants at Mechanical, Chemical, and Advanced Wastewater Treatment Plants in Norway. Water Research. 40 (19), 3559-3570. *O:\Projects\Chesapeake Bay Trust\2017 Scope 8 - Assessing WWTP Toxics\Source\Obtained By RTP\Jesse lit\Vogelsang et al. 2006	Yes	Yes	Discusses removal of various toxics from WWTPs employing various levels of treatment	PAHs, nonylphenols, phthalates, PBDEs, and PCBs	*Plant A: biological treatment (anoxic and aerobic-activated sludge process) with simultaneous chemical precipitation *Plants B-D: chemical treatment *Plant E: mechanical treatment	Norway	Yes		Yes		1 = Peer-reviewed journal article		Yes	Peer-reviewed journal article	Yes			3	3	2	8

*Wang, C.X., Wang, Y., Kiefer, F., Yediler, A., Wang, Z.J., & Kettrup, A. (2003). Ecotoxicological and chemical characterization of selected treatment process effluents of municipal sewage treatment plant. Ecotoxicology and Environmental Safety, 56, 211–217. *O:\Projects\Chesapeake Bay Trust\2017 Scope 8 - Assessing WWTP Toxics\Source\Obtained By RTP\Jesse lit\Wang_2003_Ecotoxicological and chemical characterization of selected treatment process effluents of municipal sewage treatment plant	Yes		Dissolved fraction only, but could help determine removal mechanisms	PCBs, PAHs, organocholine pesticides, herbicides, substituted benzenes	Conventional activated sludge	Beijing, China	Yes		Yes		1 = Peer-reviewed journal article		Yes	Peer-reviewed journal article	Yes			1	3	2	6
*Yao, Min; Zhongjian Li; Xingwang Zhang; and Lecheng Lei. (2014). Polychlorinated Biphenyls in the Centralized Wastewater Treatment Plant in a Chemical Industry Zone: Source, Distribution, and Removal. Journal of Chemistry, Vol. 2014, Article ID 352675. doi:10.1155/2014/352675. *O:\Projects\Chesapeake Bay Trust\2017 Scope 8 - Assessing WWTP Toxics\Source\Obtained By RTP\Jesse lit\Yao, et al., 2014	Yes		PCBs at multiple locations along the treatment train of an advanced WWTP	PCBs	Advanced, including primary sedimentation w/ PAC, A/O biochemical treatment (anaerobic hydrolysis by anaerobic biofilter, then aerated activated sludge), secondary settling, and high-density clarification by ferrate oxidation	Zhejiang province, China	Yes		Yes		1 = Peer-reviewed journal article		Yes	Peer-reviewed journal article	Yes			2	2	3	7
*Yu, Dennis; Macawile, Maria; Abella, Leonila; & Gallardo, Susan. (2011). Degradation of Polychlorinated Biphenyls in Aqueous Solutions after UV-Peroxide Treatment: Focus on Toxicity of Effluent to Primary Producers. Ecotoxicology and Environmental Safety. 74. 1607-14. *O:\Projects\Chesapeake Bay Trust\2017 Scope 8 - Assessing WWTP Toxics\Source\Obtained By RTP\Jesse lit\Yu_et_al_2011_Degradation of PCBs in aqueous solutions after UV-peroxide treatment	Maybe		Only 1 PCB congener assessed, but could help determine alternative removal mechanisms.	PCB 153, which is a Hexa-CB.	Bench scale batch reactions	Manila, Philippines	Yes		Yes		1 = Peer-reviewed journal article		Yes	Peer-reviewed journal article	Yes			1	2	2	5
US EPA. (1977) PCBs Removal in Publicly-Owned Treatment Works. Final Report EPA 440/5-77-017. July 19, 1977.	Yes	Yes	Documents removals of PCBs through various unit processes, but not BNR	PCBs	Trickling filter, conventional activated sludge, polishing lagoon	Bloomington, IN and Baltimore, MD	Yes		Yes		2 = Federal or State source		Yes	EPA Report	Yes			1	2	3	6
HDR. (2013) Treatment Technology Review and Assessment. Association of Washington Business Association of Washington Cities; Washington State Association of Counties. December 4, 2013.	Yes	Yes	Pilot testing of MBR and CAS	PCBs, PAHs, Mercury, Arsenic	Membrane Bioreactor, Conventional Activated Sludge	Pilot reactor at WWTP in Washington state	Yes		Yes		3 = Other	Private sector report	Unknown	Presumably reviewed by client and internally	Partially	Provides ranges but not advanced statistics		1	3	2	6
GHC. (unknown) City of Rehoboth Beach Wastewater Treatment Plant Ocean Outfall Project Final Environmental Impact Statement.	Yes	Yes	Reports concentrations of total PCBs in Rehoboth and Delaware River Estuary effluents	Metals, Volatiles, Semi-Volatiles, Phenolics, PCBs	BNR	Delaware	N/A - Source did not provide this level of detail		Partially	No details are provided re: metholds	3 = Other	EIS	Unknown	Given that this is an EIS, it has been reviewed; however, it is unknown how much the toxics data may	No			2	3	1	6

														have been reviewed							
Expertise Limited. (2017) Polychlorinated Biphenyls (PCBs) Water Treatment.	Yes	Yes	Bibliography on treatability of PCBs	PCBs	Not specific. Addresses various processes.	N/A	N/A - Source did not provide this level of detail	Bibliography (annotated)	Partially	Clear, but given that this is a bibliography, methods, etc. are not necessarily detailed	3 = Other	Website/annotated bibliography	Unknown		Partially			2	2	3	7
Badawy, Ali. (2010) Removal of some of priority organic pollutants (POPs) in conventionally treated wastewater. Afinidad LXVII (547, May-June 2010)	Yes	Yes	Measured PCBs in invluent, across primary settling and in final effluent for conventional activated sludge plant	PCBs, organichlorine pesticides, PAGs	Conventional activated sludge	10th of Ramadan City, Egypt	Yes		Yes		1 = Peer-reviewed journal article	Appears to be a peer-reviewed journal	Unknown	Presumably	Yes			1	3	2	6
Delaware River Basin Commission. (1998) Study of the Loadings of Polychlorinated Biphenyls from Tributaries and Point Sources Discharging to the Tidal Delaware River. June 1998.	Yes	Yes	The data in the report is of marginal significance, but the program is potentially relevant and will be explored in more detail.	PCBs	Various	Delaware River Basin	Yes		Yes		2 = Federal or State source		Yes		Yes			1	2	2	5
Chesapeake Stormwater Network (2016) Potential Benefits of Nutrient and Sediment Practices to Reduce Toxic Contaminants in the Chesapeake Bay Watershed. March 15, 2016	Yes	Yes	Focus of report is relevant, but data is only marginally useful	Antibiotics, hormones, herbicides (wastewater) PCBs, PAHs, Petroleum Hydrocarbons, Mercury, Trace Metals, Pesticides, Plasticizers, Flame Retardants, Dioxins and Furans (Stormwater)	Various (this is a literature review)	Various	Partially	Lit review	Partially	Lit review	2 = Federal or State source		Unknown	Presumably	Partially	Lit review		2	1	2	5

WERF. (1998) Toxic Chlorinated Compounds: Fate and Biodegradation in Anaerobic Digstion. Project 91-TFT-3.	Maybe	Yes	Looks at treatabililty of various compounds in anaerobic sludge digestion	Chlorinated organic compounds, including PCBs	Anaerobic Sludge Digestion	Pilot	Yes		Yes		3 = Other	Research Foundation	Yes		Yes			1	3	1	5