Calgon Carbon
Pittsburgh, PA
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PFAS: Drinking Water Treatment

Thomas F. Speth, Rajiv Khera, Jonathan Pressman, Pat Ransom,
Craig Patterson, Matthew Magnuson

Advisory Limits

- PFOA and PFOS are not regulated by the USEPA. However, in 2016, USEPA established a Lifetime Drinking Water Health Advisory limit of 0.07 µg/L for PFOA + PFOS

United States Environmental Protection Agency | Office of Water Mail Code 4304T | EPA 822-R-16-005 May 2016

Drinking Water Health Advisory for Perfluorooctanoic Acid (PFOA)

United States Environmental Protection Agency | Office of Water Mail Code 4304T | EPA 822-R-16-004 May 2016

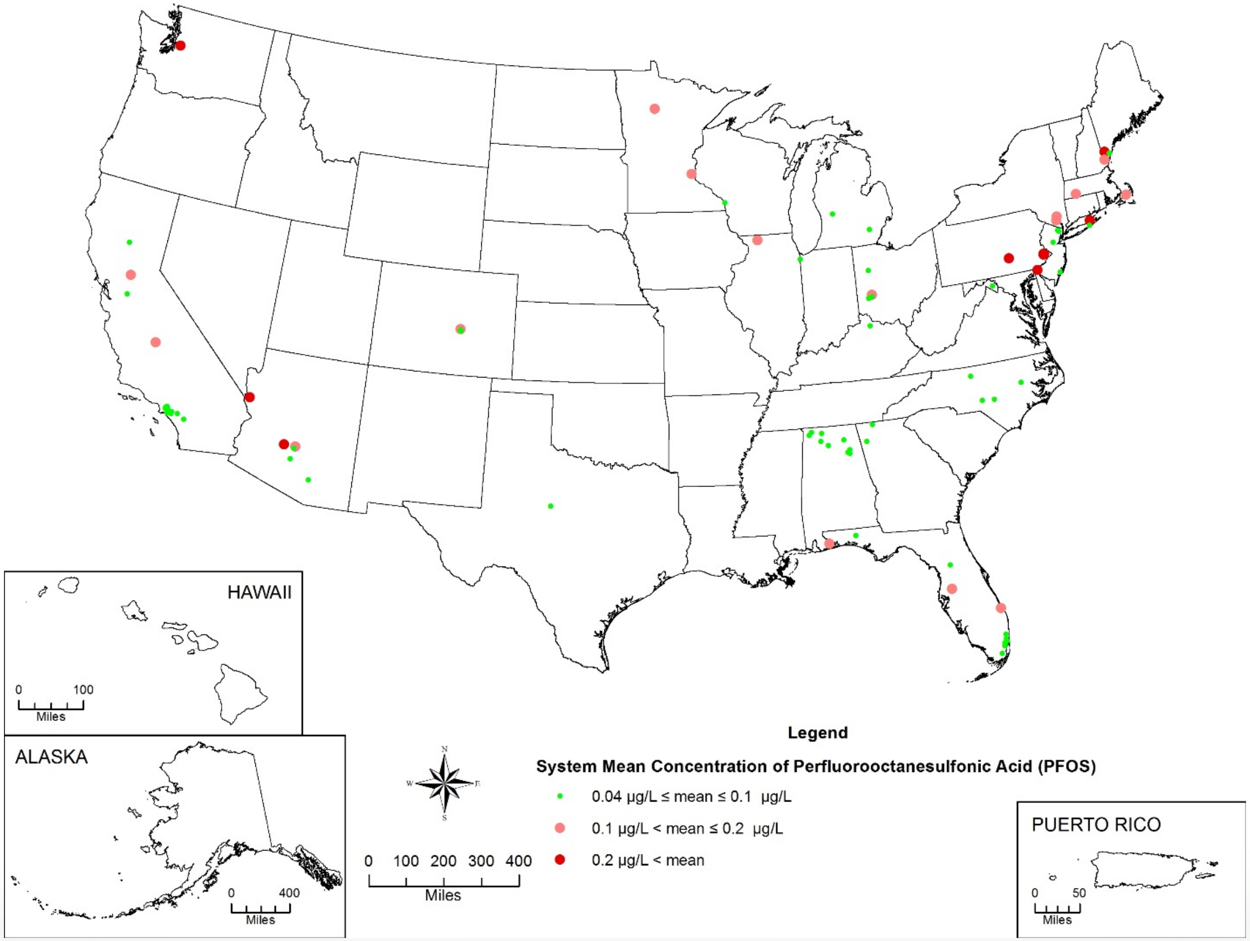
Drinking Water Health Advisory for Perfluorooctane Sulfonate (PFOS)

https://www.epa.gov/ground-water-and-drinking-water/drinking-water-health-advisories-pfoa-and-pfos

- PFOA and PFOS are on the draft CCL4

UCMR3 PFOA Results

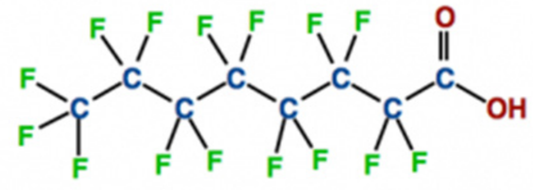
Mean Concentrations



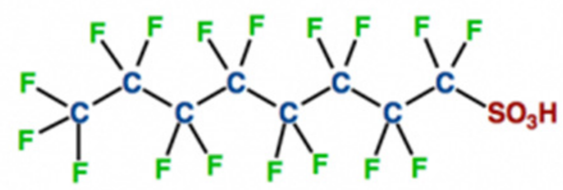
General Properties

Of note…

- Strong bonds - stable
- Negatively charged
- Low volatility
- High molecular weight
- Moderate solubility



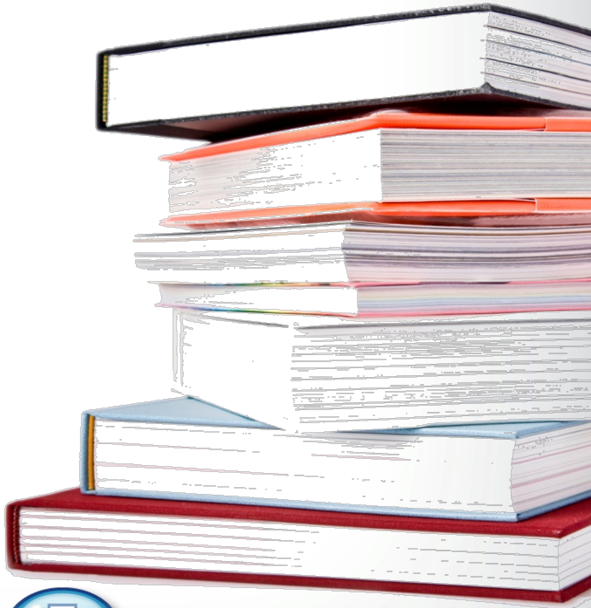
PFOA - perfluorooctanoic acid



PFOS - perfluorooctanesulfonic acid

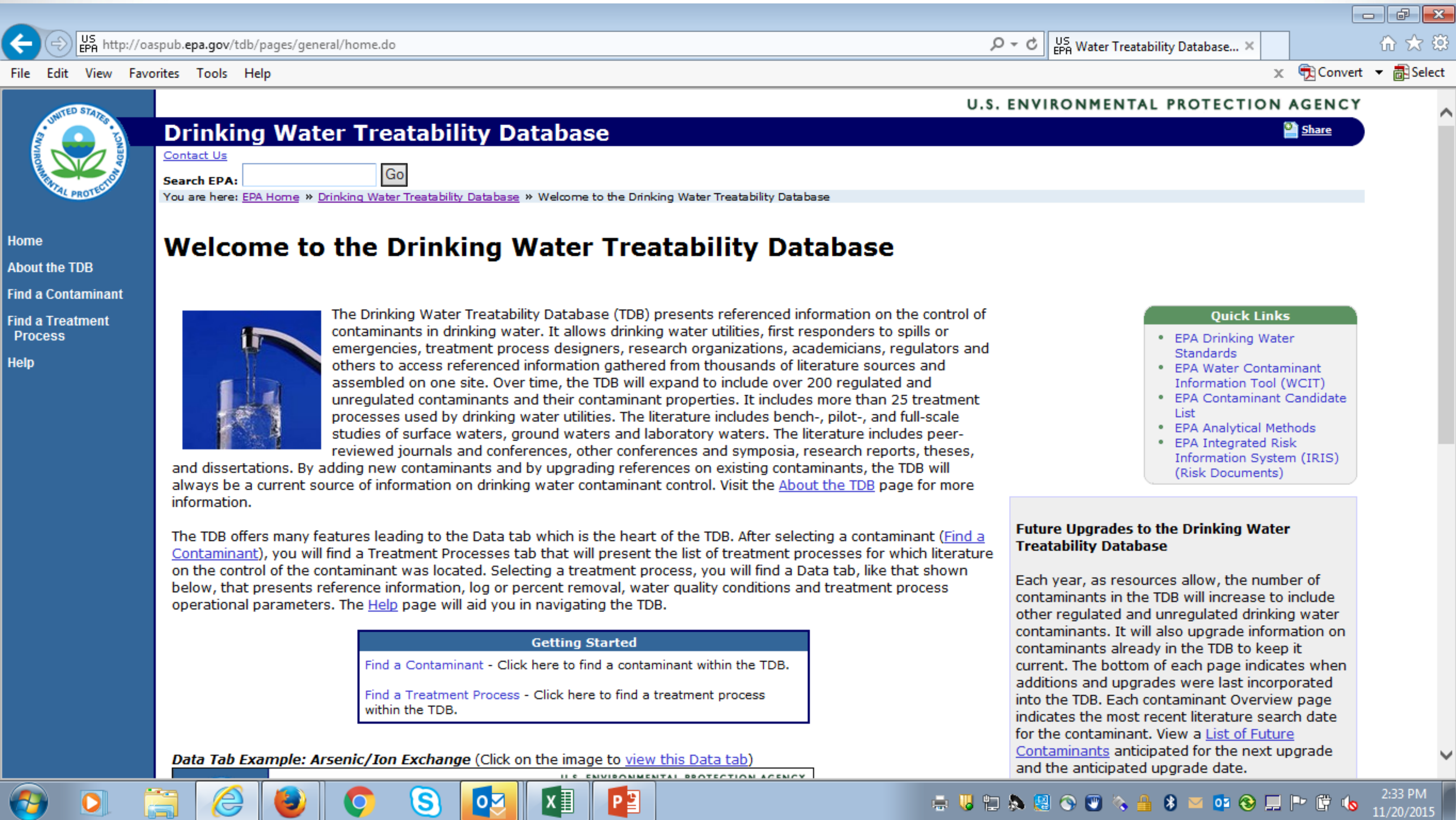
Publically Available Resource

- Interactive database that contains over 65 regulated and unregulated contaminants and covers 34 treatment processes commonly employed or known to be effective
- Referenced information gathered from thousands of literature sources assembled on one site
- Carbon tetrachloride, nitrate, **PFOA**, **PFOS**, strontium, 1,2,3-TCP, and cis 1,2-DCE added recently



http://iaspub.epa.gov/tdb/pages/general/home.do
Search: EPA TDB

Drinking Water Treatability Database



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Drinking Water Treatability Database

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- Home
- About the TDB
- Find a Contaminant
- Find a Treatment Process
- Help

Welcome to the Drinking Water Treatability Database

The Drinking Water Treatability Database (TDB) presents referenced information on the control of contaminants in drinking water. It allows drinking water utilities, first responders to spills or emergencies, treatment process designers, research organizations, academicians, regulators and others to access referenced information gathered from thousands of literature sources and assembled on one site. Over time, the TDB will expand to include over 200 regulated and unregulated contaminants and their contaminant properties. It includes more than 25 treatment processes used by drinking water utilities. The literature includes bench-, pilot-, and full-scale studies of surface waters, ground waters and laboratory waters. The literature includes peer-reviewed journals and conferences, other conferences and symposia, research reports, theses, and dissertations. By adding new contaminants and by upgrading references on existing contaminants, the TDB will always be a current source of information on drinking water contaminant control. Visit the About the TDB page for more information.

The TDB offers many features leading to the Data tab which is the heart of the TDB. After selecting a contaminant (Find a Contaminant), you will find a Treatment Processes tab that will present the list of treatment processes for which literature on the control of the contaminant was located. Selecting a treatment process, you will find a Data tab, like that shown below, that presents reference information, log or percent removal, water quality conditions and treatment process operational parameters. The Help page will aid you in navigating the TDB.

Getting Started

Find a Contaminant - Click here to find a contaminant within the TDB.

Find a Treatment Process - Click here to find a treatment process within the TDB.

Data Tab Example: Arsenic/Ion Exchange (Click on the image to view this Data tab)

Quick Links

- EPA Drinking Water Standards
- EPA Water Contaminant Information Tool (WCIT)
- EPA Contaminant Candidate List
- EPA Analytical Methods
- EPA Integrated Risk Information System (IRIS) (Risk Documents)

Future Upgrades to the Drinking Water Treatability Database

Each year, as resources allow, the number of contaminants in the TDB will increase to include other regulated and unregulated drinking water contaminants. It will also upgrade information on contaminants already in the TDB to keep it current. The bottom of each page indicates when additions and upgrades were last incorporated into the TDB. Each contaminant Overview page indicates the most recent literature search date for the contaminant. View a List of Future Contaminants anticipated for the next upgrade and the anticipated upgrade date.

Drinking Water Treatability Database

https://oaspub.epa.gov/tdb/pages/contaminant/treatmentSummary.do

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Perfluorooctanoic Acid

Overview | Treatment Processes | Properties | Fate and Transport | References

The following processes were found to be effective for the removal of perfluorooctanoic acid: GAC (up to 99 percent removal), membrane separation (up to > 98 percent), powdered activated carbon (88 percent), and ion exchange (73 to 95 percent). UV irradiation at wavelengths in the 185-220 nm range and/or at long irradiation times (up to 72 hours) could potentially be effective (62 to 90 percent). Membrane filtration varied in effectiveness (22 to 56 percent).

Based on the available literature, the following are not considered effective for the removal of perfluorooctanoic acid: conventional treatment (no removal) and UV at wavelengths outside of the 185-220 nm range (4 percent to 10 percent removal). UV/hydrogen peroxide treatment (35 percent removal) was less effective in comparison to UV alone (45 percent) after 24 hours of irradiation.

Studies were identified evaluating the following treatment technologies for the removal of perfluorooctanoic acid:

Conventional Treatment - Multiple full-scale studies reported insignificant removal of PFOA by conventional treatment. PFOA levels after conventional drinking water treatment were found to correlate to the PFOA levels detected in their surface waters sourc...

GAC Isotherm - Adsorption was observed for PFOA detected in a contaminated groundwater. It was found to be nonlinear.

Granular Activated Carbon - Removal of PFOA by GAC can be effective. Bench scale tests, including rapid small scale column tests, showed removals from less than zero to 95 percent, depending on carbon type and background TOC concentrations [1700, 2423, 2441]. At one full sca...

Ion Exchange - Removal of PFOA using anion exchange resins was found to be effective (73 to 95 percent removal) in a bench study [2427], and in a full scale application [2424; 2441] that used a resin designed for arsenic removal.

PFOS Treatment: Ineffective

Treatment	Percent Removal
Conventional Treatment	0
Low Pressure Membranes	0 to 23
Biological Treatment (inc. slow sand)	0 to 15
Disinfection - Chloramines	0
Oxidation	
Permanganate	1 to 53 * #
Hydrogen Peroxide	0 to 2 *
Ozone	0 to 7
Advanced oxidation	
UV – TiO_2	15
UV – Ozone	0 *
Ozone – Peroxide	9

** All bench-scale data*

 # Up to 18 days of exposure

PFOS Treatment: Effective

Treatment	Percent Removal
Anion Exchange Resin *	90 to 99 @
High Pressure Membranes	93 to 99
Powdered Activated Carbon (PAC)	10 to 97 ^
Granular Activated Carbon (GAC) *	
Extended Run Time #	0 to 26
Frequent GAC Replacement	> 89 to > 98

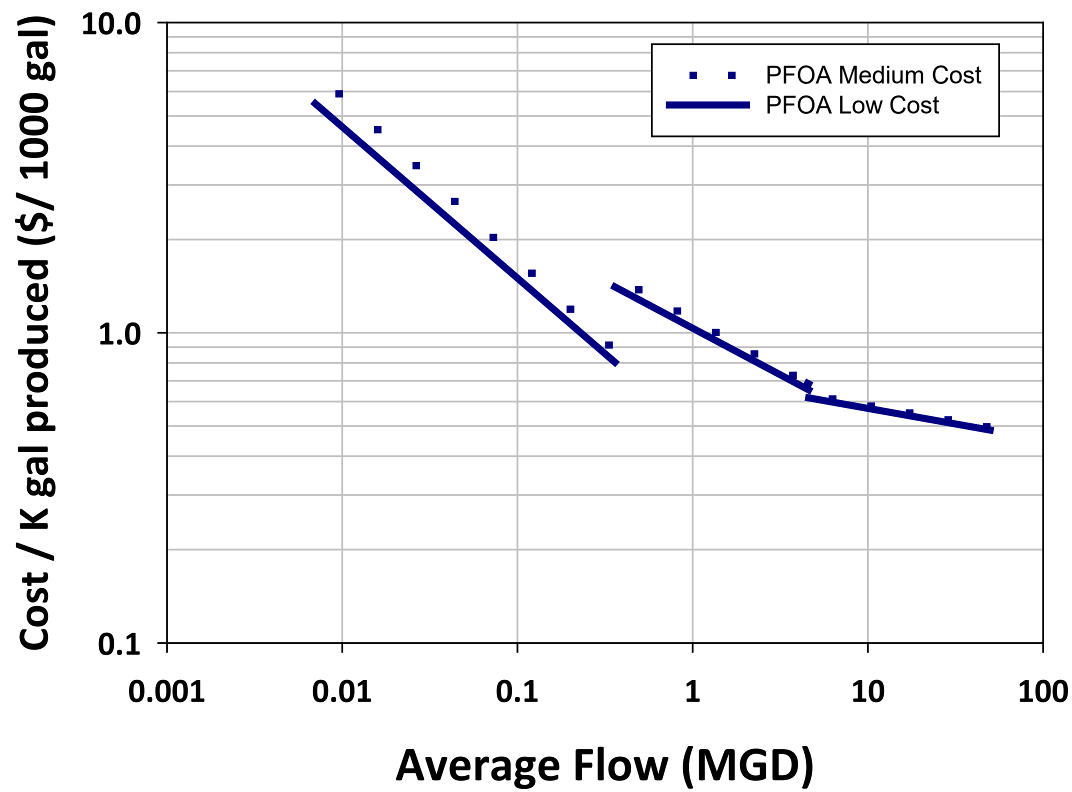
* Non-steady state process
@ No bed volume fed data for cost analysis
^ Dose, water, and carbon dependent
# Extended run time with no regeneration

PAC Dose to Achieve	
50% Removal	16 mg/l
90% Removal	>50 mg/L

Dudley et al., 2015

Cost /1000 gal: PFOA

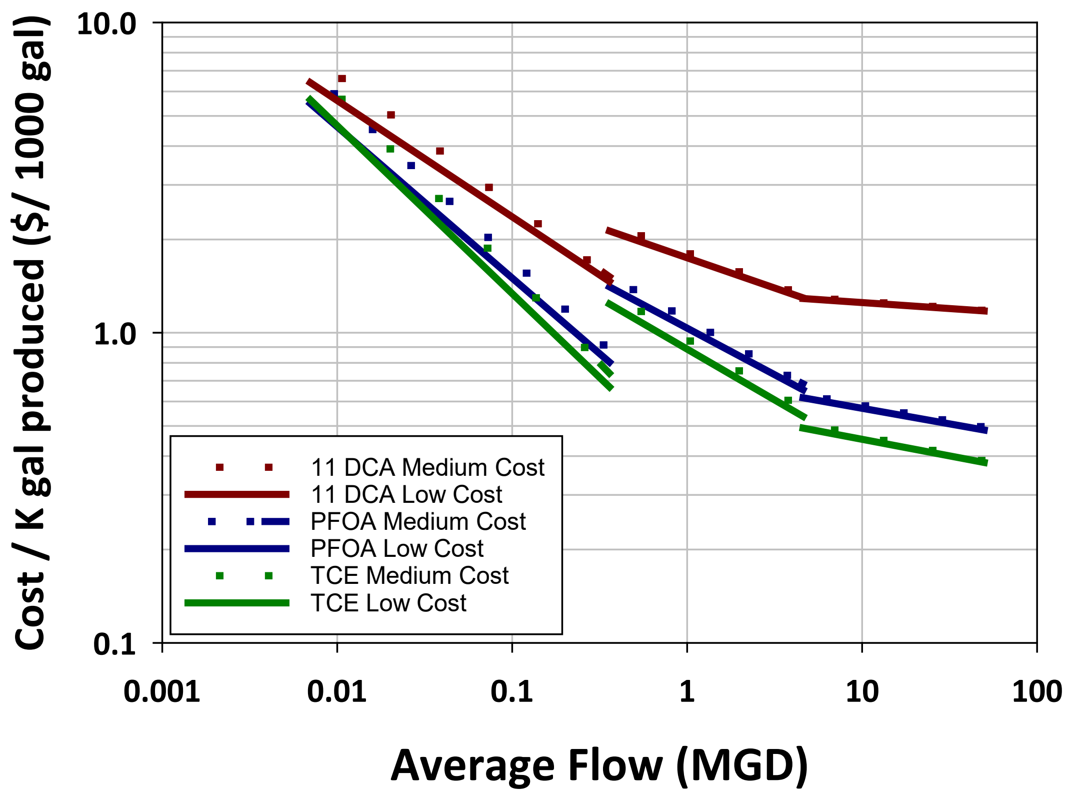
PFOA will break through before PFOS



- Full Scale
- 26 min EBCT
- Lead-Lag configuration
- F600 Calgon carbon
- 1.5 m^3/min flow
- Full automation
- POTW residual discharge
- Off site regeneration
- 70K bed volumes to breakthrough for PFOA

Cost / 1000 gal: PFOA, TCE, & 11 DCA

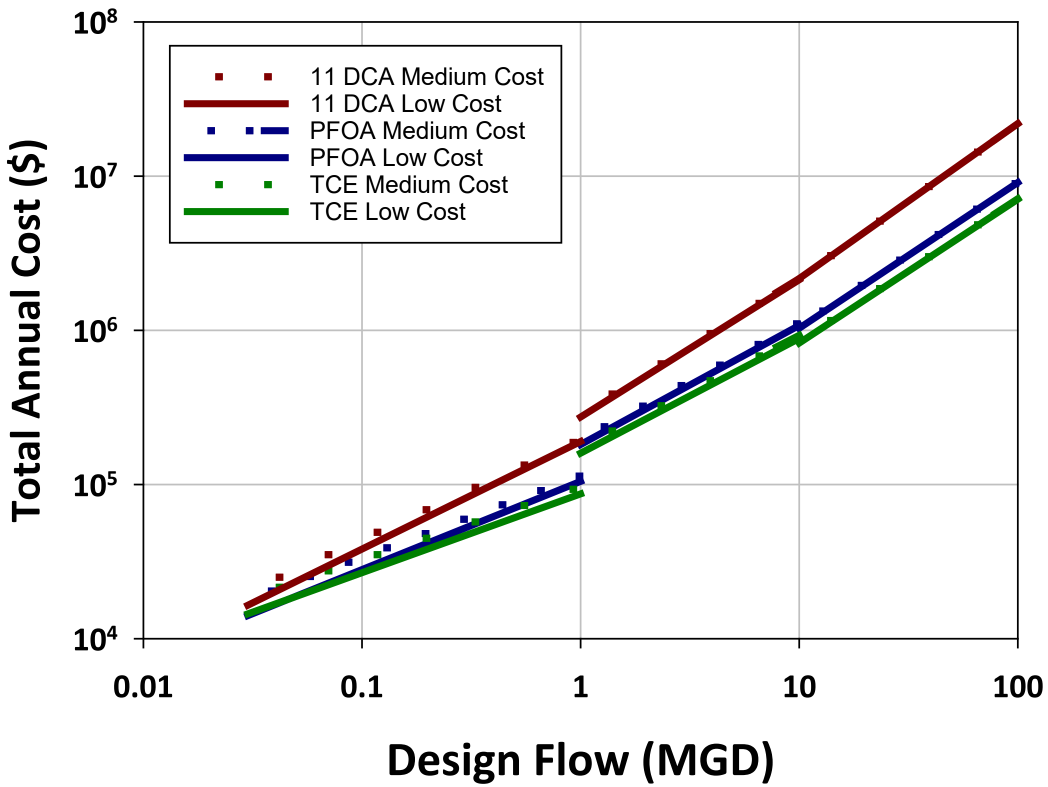
PFOA will break through before PFOS



- Full Scale
- 26 min EBCT
- Lead-Lag configuration
- F600 Calgon carbon
- 1.5 m^3/min flow
- Full automation
- POTW residual discharge
- Off site regeneration
- 135K, 70K, and 11K bed volumes to breakthrough for TCE, PFOA, and 11DCA, respectively.

GAC Total Cost: PFOA, TCE, and 11 DCA

PFOA will break through before PFOS



- Full Scale
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- 135K, 70K, and 11K bed volumes to breakthrough for TCE, PFOA, and 11DCA, respectively.

Cost Model Background

- 1996 SDWA Amendments
  - Thorough review of benefits and costs

- Past/Current Unit Cost Modeling Approach
  - Three cost models
    - WaterCost: 0.92 mgd-100 mgd
    - Water: 0.015-1.0 mgd
    - Very Small System (VSS): 015-0.1mgd

Cost Model Background

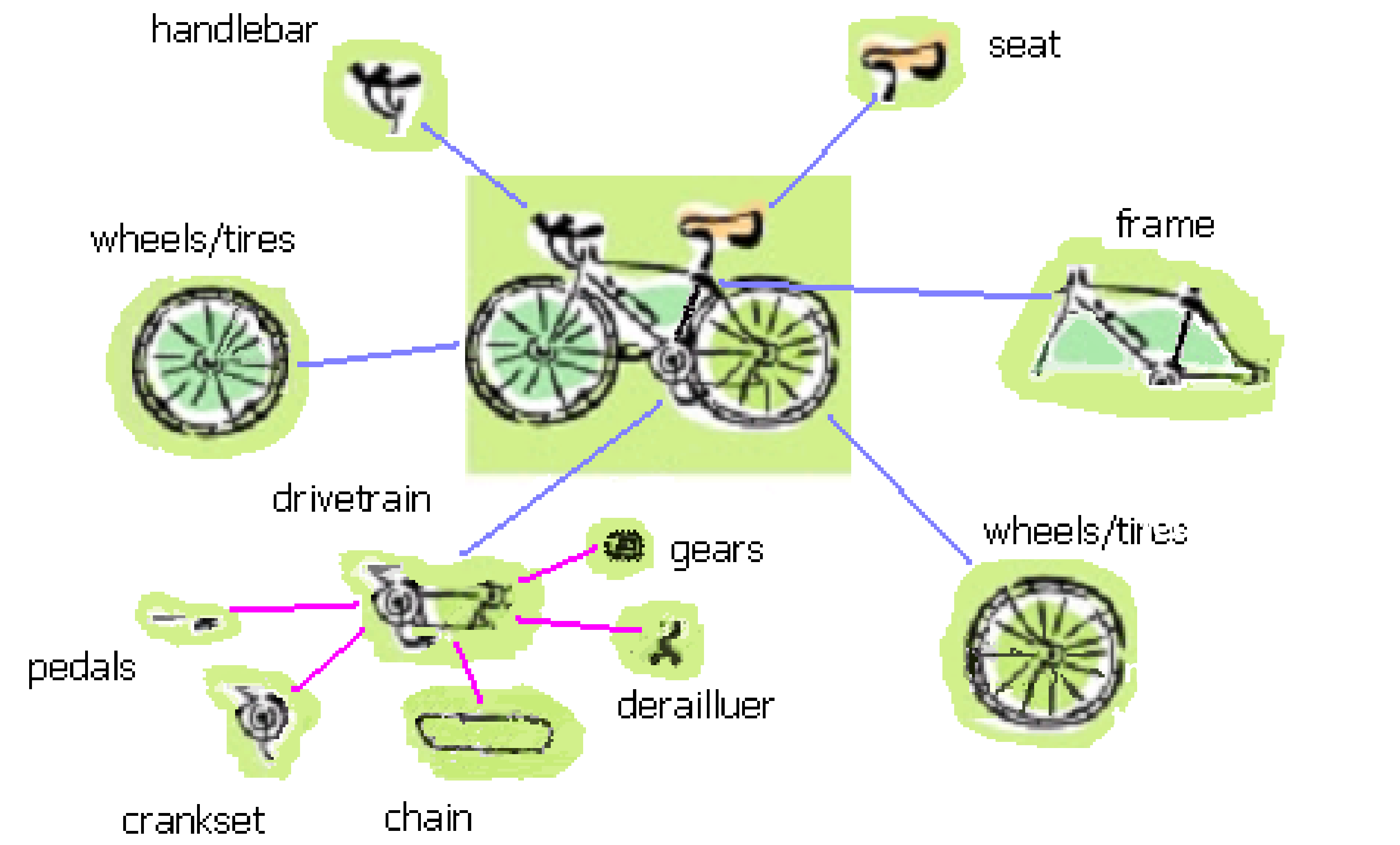
- Blue Ribbon Panel in 1996
  - revise 20-year amortization assumption
  - account for site-specific factors that affect cost
- EPA Technology Design Workshop in 1997
  - current models are inadequate
  - recommended Level 3/4 WBS for long-term approach
- National Drinking Water Advisory Council in 2001
  - detailed recommendations more readily implemented in WBS model than the existing parametric models

WBS Approach

- Description

  A treatment technology is broken down into discrete components that can be measured for the purpose of estimating costs. The components include specific equipment (e.g., tanks, vessels, pipes, and instruments) and other identifiable cost elements such as annual expenditures on labor, chemicals, and energy.

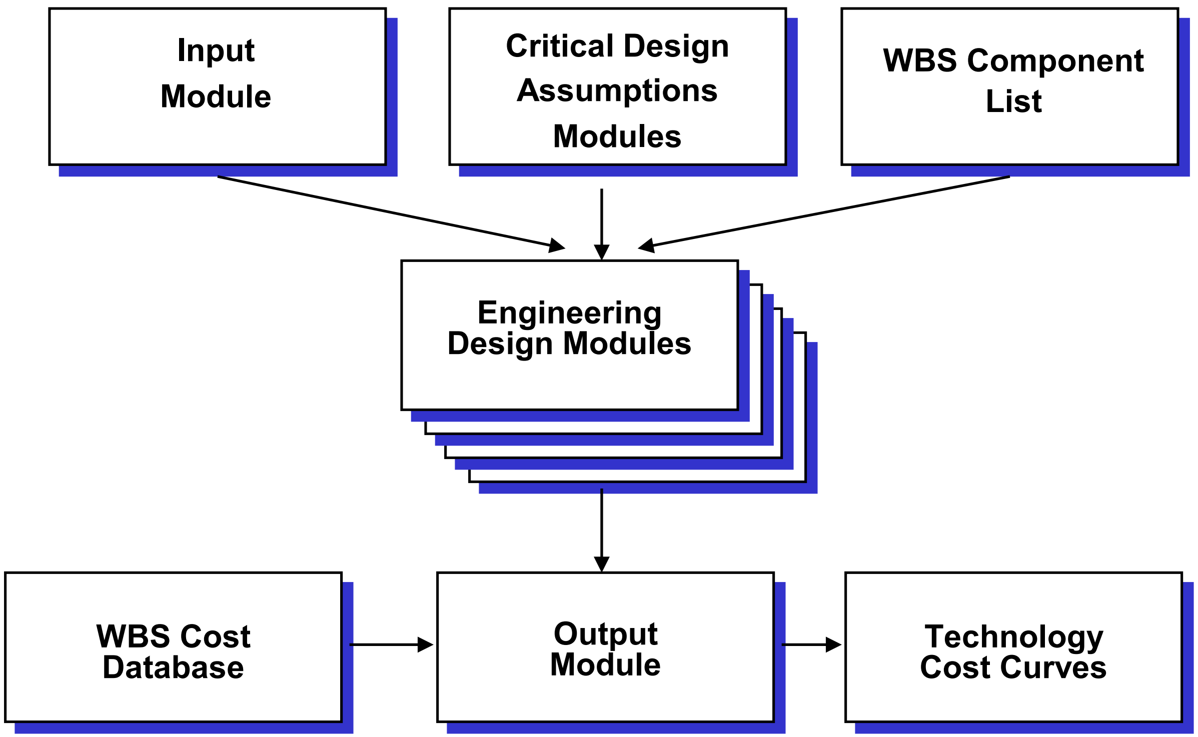
What is a Work Breakdown?



Key Features of the WBS Models

- Engineering
  - Transparent process design and cost analysis
  - Defensible design criteria and assumptions based on generally recommended engineering practices
- Structural
  - Spreadsheet-based to facilitate review/distribution and maintain transparency
  - Modular format to enhance flexibility
  - Individual technology-specific models constructed using a consistent process-based approach
  - Technology models linked to a central database to facilitate cost updates

WBS Portfolio Structure



WBS Approach

Final/Available to Public

- Granular Activated Carbon
- Packed Tower Aeration
- Multistage Bubble Aeration
- Anion Exchange
- Cation Exchange
- Biological Treatment
- POU / POE Treatment
- Nontreatment Solutions (New\ Wells/Interconnection)

Under Development

- Adsorptive Media (including activated alumina et al.)
- Greensand Filtration
- Microfiltration/Ultrafiltration

Under Development (continued)

- Reverse Osmosis/Nanofiltration
- Electrodialysis Reversal
- Conventional Filtration
- Lime Softening
- Biologically Active Filtration
- Chlorine Disinfection (including chlorine gas, hypochlorite et al.)
- Ozone Disinfection
- UV Disinfection
- UV Advanced Oxidation
- Diffuse Aeration
- Tray Aeration
- Spray Aeration
- Various Add-on Technologies (e.g., chemical addition)

EPA

PFAS: Drinking Water Treatability

What is known

- PAC can handle PFAS and PFOA removal to a certain extent
- GAC can handle PFAS and PFOA, but questions remain about shorter chains
- Ion Exchange has promise, but there are fundamental questions
- Reverse osmosis is the most robust process for PFASs but have serious cost, expertise, and residual issues
- Other technologies either do not work within the construct of drinking water, or are prohibitively expensive or energy intensive.

Technologies exist to treat for PFOA and PFOS, but there are many issues that need to be resolved for PFAS.

PFAS: Drinking Water Treatability

What is missing?

- Pilot- and full-scale treatment and cost data for shorter chain PFASs.
    - GAC
    - Ion exchange
- Treatment data and modeling at concentrations near the 2016 Health Advisory for various water qualities
- POU treatment and cost data (GAC, IEX, RO)
- Data for treating residual streams (ion exchange regenerant, membrane retentate, spent media, off gas streams, etc.)
- Impact of new treatment on other treatments and distribution system (e.g., disinfection and corrosion)
- Optimal combinations of technologies (primary and residual treatments)

Technologies exist to treat for PFOA and PFOS, but there are many issues that need to be resolved for PFAS.

PFAS: Drinking Water Conclusions

What will be done

- Upload TDB sheets for short chain PFASs and conduct costing analysis
- Develop cost models specifically for PFAS
- Conduct bench-, pilot-, and full-scale research for multiple technologies including investigating residual stream management and impacts of PFAS treatment on other treatment processes and distribution.

Technologies exist to treat for PFOA and PFOS, but there are many issues that need to be resolved for PFAS.

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Questions?