Water Science and Policy Brown Bag Seminar

# Water Science and Policy Implications of PFAS in Delaware Drinking Water Streams

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*Biden School of Public Policy & Administration*
*Interdisciplinary Graduate Program in Water Science and Policy*

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*Interdisciplinary Graduate Program in Water Science and Policy*

University of Delaware

September 17, 2025

INTERDISCIPLINARY DEGREES

# M.S. AND PH.D. in WATER SCIENCE AND POLICY

**Water is essential to all living things, vital to sustainable growth and fundamental to how the impacts of climate change will be felt across the globe.**

The University of Delaware's interdisciplinary program in Water Science and Policy prepares graduates to:

- understand water and its relationship to Earth's diverse systems
- better manage and protect our precious water resources

Building on the strengths of a diverse faculty across four colleges, the program offers three options for advanced study:

- a Ph.D. degree with a water science concentration
- a Ph.D. degree with a water policy concentration
- an M.S. degree with a thesis

All degree options require courses across five categories: physical science, chemical/biological science, policy, research methods, and statistics and analysis.

## EXCEPTIONAL LEARNING OPPORTUNITIES

- Delaware is within easy reach of government and nonprofit agencies that play critical roles in water research, management and conservation.
- The University of Delaware offers outstanding laboratory, informatics, library, environmental sensing, data science and shared core instrumentation facilities.
- To enrich the educational experience and provide professional development, students are connected with water professionals in research institutions, government agencies, environmental organizations and industries. Opportunities include work with Stroud Water Research Center, U.S. Geological Survey, U.S. Fish and Wildlife Service, Delaware Department of Natural Resources and Environmental Control, Chesapeake Bay Program and the World Health Organization.
- Graduates pursue water-related career opportunities in academia, national research laboratories, federal agencies, state agencies associated with environmental issues, private consulting companies, nongovernmental and nonprofit agencies, and international agencies.

Learn more at **udel.edu/grad**

## TO APPLY

Admission to graduate programs is competitive. Those who meet stated requirements are not guaranteed admission, nor are those who fail to meet all those requirements necessarily precluded from admission if they offer other appropriate strengths. To apply for admission, see **www.udel.edu/gradoffice/apply** for detailed instructions, web-based forms and contact information. To be admitted to this graduate program, applicants should meet the following requirements:

1. **A completed University of Delaware Graduate Studies application.** In the application, prospective students should indicate whether they are applying for the M.S. or the Ph.D. program.
2. **A personal statement** is required and should address the following questions:
   a. What are your specific research and educational goals?
   b. What are your long-term professional career objectives?
   c. How do you see this program assisting you with achieving your objectives?
   d. What is the name of the faculty member (affiliated with the program) who has agreed to be advisor?
3. **Graduate Record Examination (GRE)** is optional. Any scores submitted voluntarily by an applicant will be evaluated holistically but will not be used to determine admission or funding decisions.
4. **Official, up-to-date transcripts** of all undergraduate and graduate programs. A minimum of 3.0 on a 4.0 scale is required in the major.
5. **Three letters of recommendation** from individuals knowledgeable of the applicant's academic preparation and potential ability as a graduate student.
6. **International students must take the Test of English as a Foreign Language (TOEFL).** Minimum scores are 550 on the paper test, 213 for the computer test or 79 on the internet-based tests. TOEFL scores more than two years old cannot be considered official.

### PRIOR DEGREE REQUIREMENTS

Applicants for the Ph.D. program will typically have an M.S. degree in a related field. Direct admission to the Ph.D. program immediately after a B.S. degree will be considered for qualified candidates, as determined by the program committee. These candidates will be required to complete all the course requirements associated with the Water Science and Policy M.S. program prior to starting the Ph.D. curriculum. Prior graduate coursework (a maximum of 9 credit hours) will be considered toward Ph.D. course requirements, with the approval of the program committee.

## APPLICATION DEADLINE

**FALL**
**February 1:** To be considered for departmental funding
**July 1:** Final deadline to apply

**SPRING**
**December 1:** Final deadline to apply

## CONTACT

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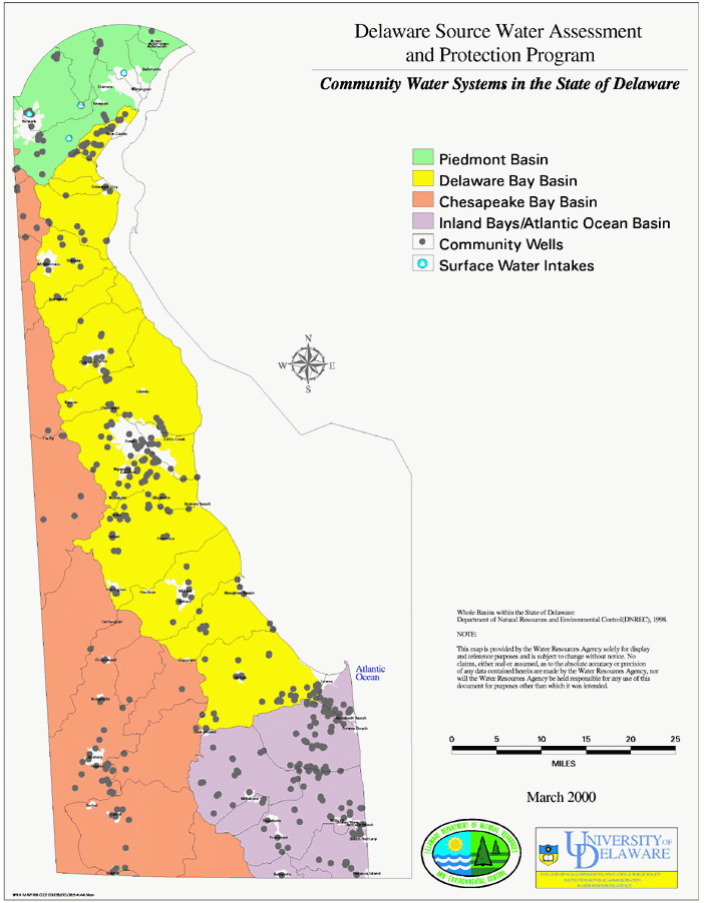
wfeller@udel.edu

**udel.edu/grad/water-science-policy**

Learn more at **udel.edu/grad**



UNIVERSITY OF DELAWARE
**GRADUATE COLLEGE**


Delaware Source Water Assessment
and Protection Program
Community Water Systems in the State of Delaware
Piedmont Basin
Delaware Bay Basin
Chesapeake Bay Basin
Inland Bays/Atlantic Ocean Basin
Community Wells
Surface Water Intakes
N
W
E
S
Atlantic Ocean
Whole Basins within the State of Delaware:
Department of Natural Resources and Environmental Control(DNREC), 1998.
NOTE:
This map is provided by the Water Resources Agency solely for display and reference purposes and is subject to change without notice. No claims, either real or assumed, as to the absolute accuracy or precision of any data contained herein are made by the Water Resources Agency, nor will the Water Resources Agency be held responsible for any use of this document for purposes other than which it was intended.
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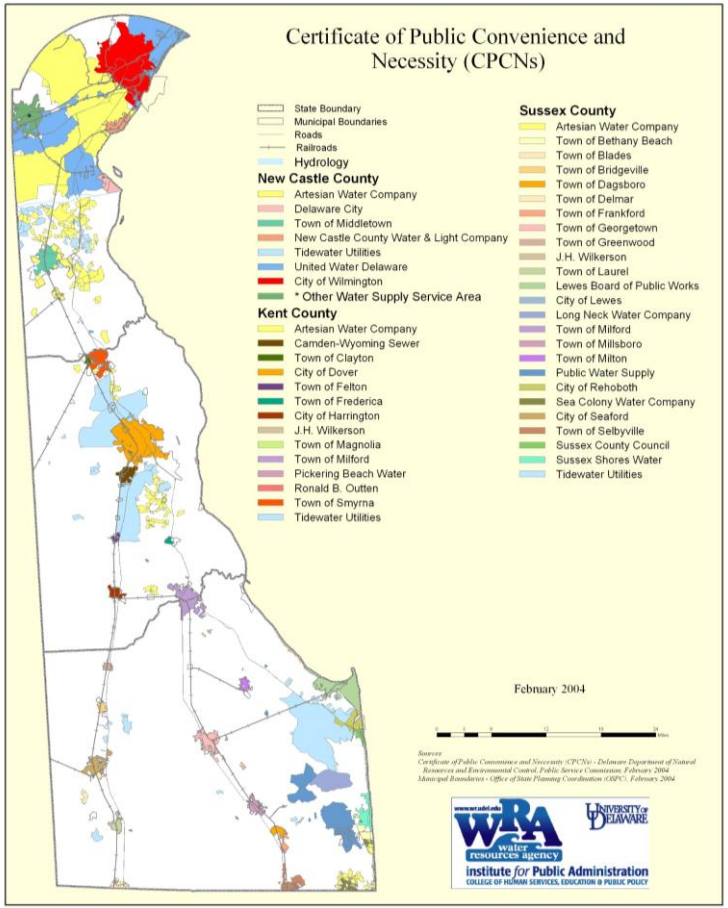
March 2000
UNIVERSITY OF DELAWARE


Certificate of Public Convenience and
Necessity (CPCNs)
State Boundary
Municipal Boundaries
Roads
Railroads
Hydrology
New Castle County
Artesian Water Company
Delaware City
Town of Middletown
New Castle County Water & Light Company
Tidewater Utilities
United Water Delaware
City of Wilmington
* Other Water Supply Service Area
Kent County
Artesian Water Company
Camden-Wyoming Sewer
Town of Clayton
City of Dover
Town of Felton
Town of Frederica
City of Harrington
J.H. Wilkerson
Town of Magnolia
Town of Milford
Pickering Beach Water
Ronald B. Outten
Town of Smyrna
Tidewater Utilities
Sussex County
Artesian Water Company
Town of Bethany Beach
Town of Blades
Town of Bridgeville
Town of Dagsboro
Town of Delmar
Town of Frankford
Town of Georgetown
Town of Greenwood
J.H. Wilkerson
Town of Laurel
Lewes Board of Public Works
City of Lewes
Long Neck Water Company
Town of Milford
Town of Millsboro
Town of Milton
Public Water Supply
City of Rehoboth
Sea Colony Water Company
City of Seaford
Town of Selbyville
Sussex County Council
Sussex Shores Water
Tidewater Utilities
February 2004
Sources:
Certificate of Public Convenience and Necessity (CPCNs) - Delaware Department of Natural Resources and Environmental Control, Public Service Commission, February 2004
Municipal Boundaries - Office of State Planning Coordination (OSPC), February 2004
WRA water resources agency
UNIVERSITY OF DELAWARE
institute for Public Administration
COLLEGE OF HUMAN SERVICES, EDUCATION & PUBLIC POLICY

# New Castle County

## Water Supplies

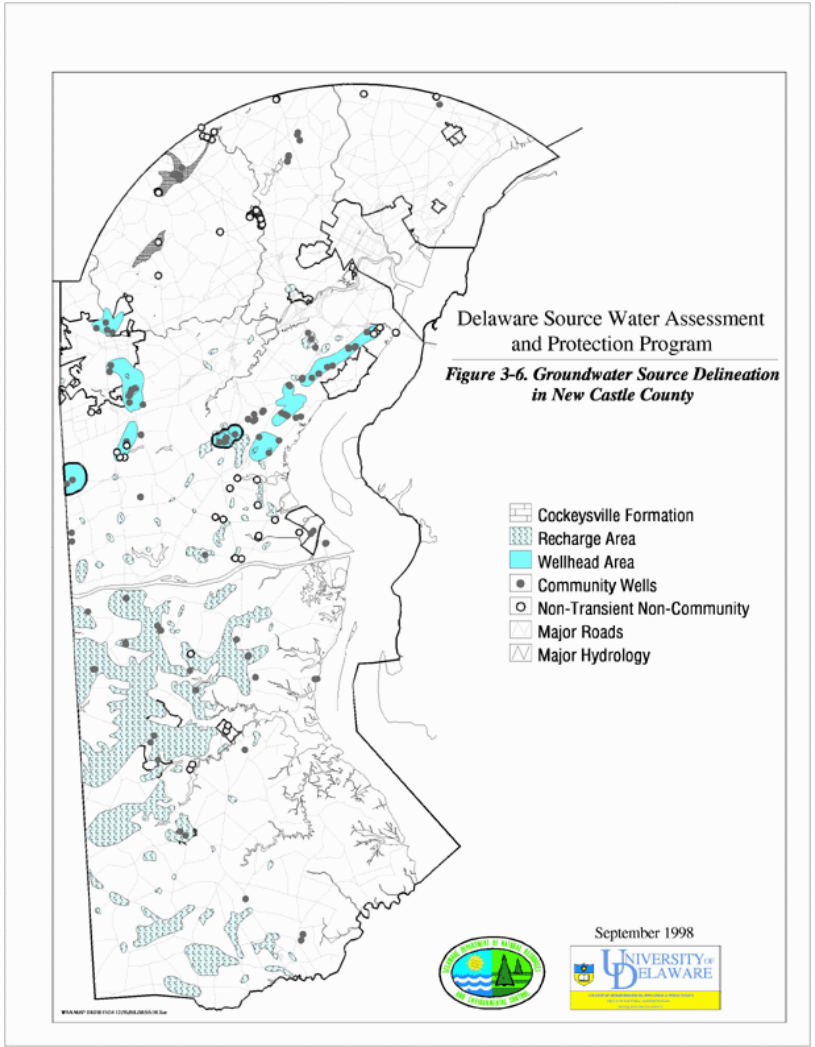
Streams - 75 %

Wells - 25 %

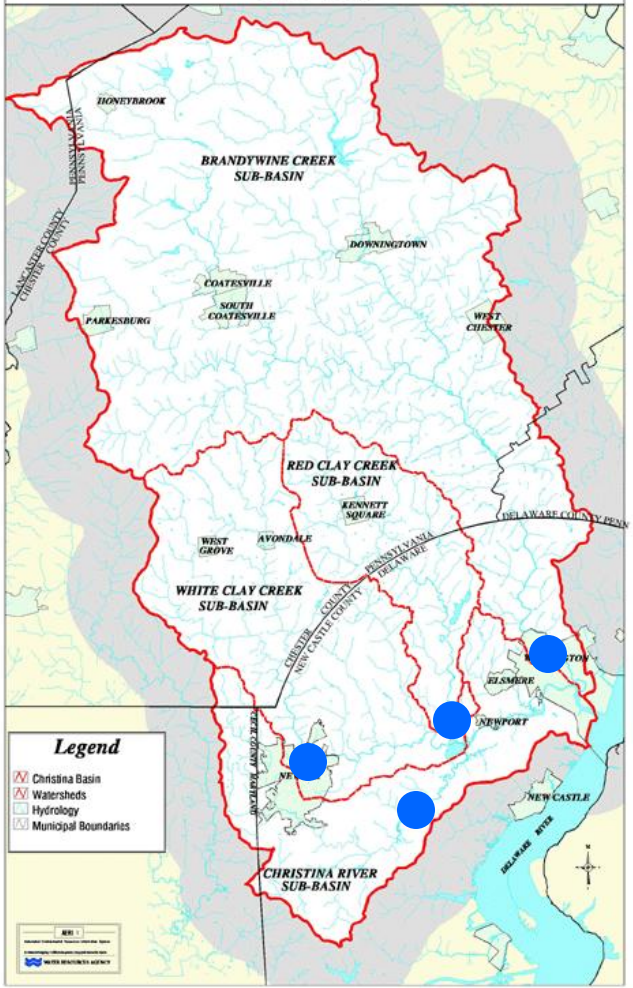
## Demands

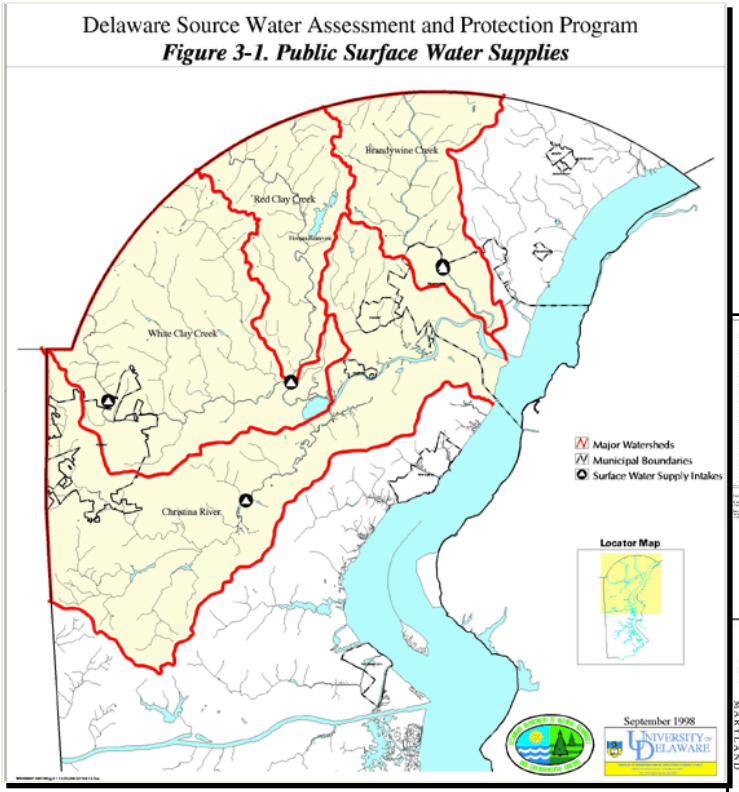
Normal - 60 mgd

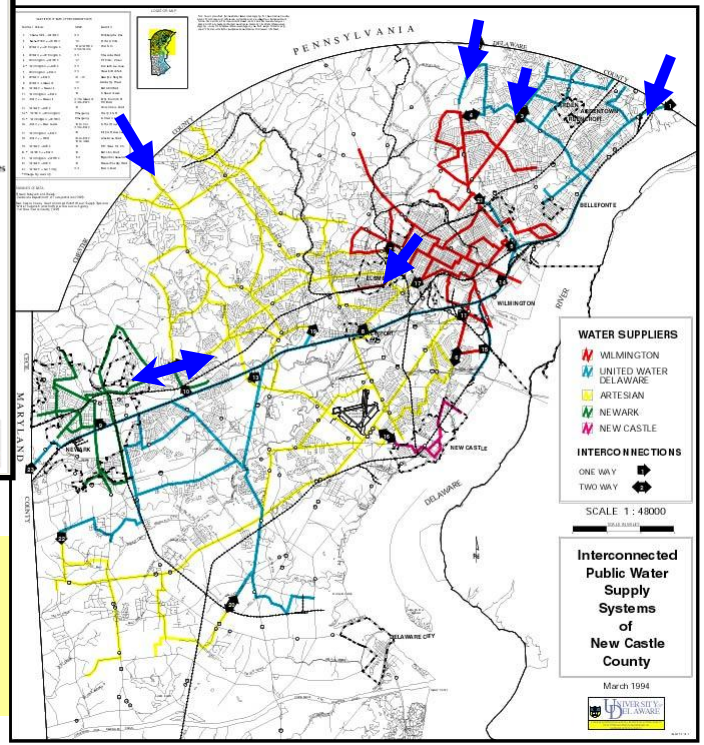
Peak - 75 mgd



# Christina Basin Water Quality Management Strategy
## *Base Map*






New Castle County

# Public Water Supply System Interconnections

# PFAS Research at the Delaware Water Resources Center

## The Science

1. Determine level of contamination in Delaware drinking water streams
2. Locate areas of contamination and research possible sources
3. Explain how other regions can sample their drinking water

## The Policy

1. Compare findings with state and federal goals and regulations
2. Highlight the implications for PFAS removal and mitigation in Delaware

# What are PFAS?

## Per- and polyfluoroalkyl substances

- Synthetic organic compounds with carbon-fluorine bond
  - Resistant to degradation, water, oil, and heat
  - “Forever Chemicals”
- Thousands of compounds
  - Over 2,000 different known uses
  - Produced since the 1940s
- Main Sources:
  - Fire foam, non-stick products, food packaging, household cleaning and beauty products, etc.

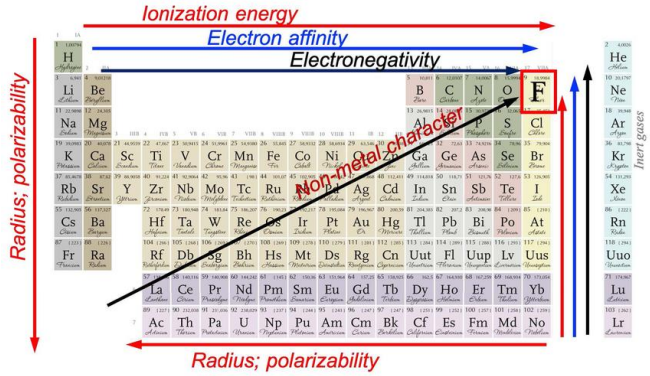



*Image from Creative Commons*


*Image created on Canva*

# Health Implications Relating to PFAS

- Route of Exposure
  - Mainly through ingestion of contaminated food and water
- Possible carcinogenic effects
  - Kidney, testicular, and hormonal cancers
- Possible non-carcinogenic effects
  - Child and fetal development
  - Immune, nervous, and reproductive system
  - Liver, thryoid and kidneys

Based on EPA Toxicology Reports for: PFOA, PFOS, HFPO-DA, PFBS, PFHxS, PFBA, and PFHxA

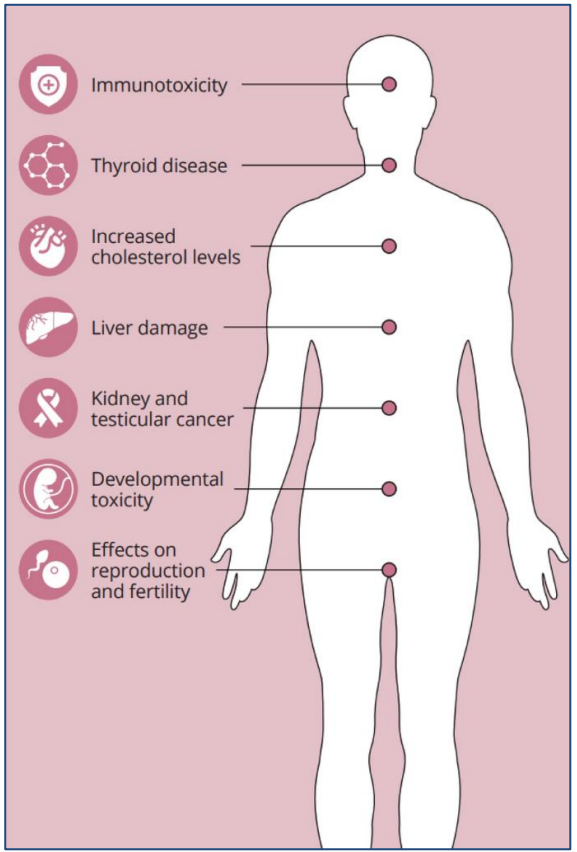


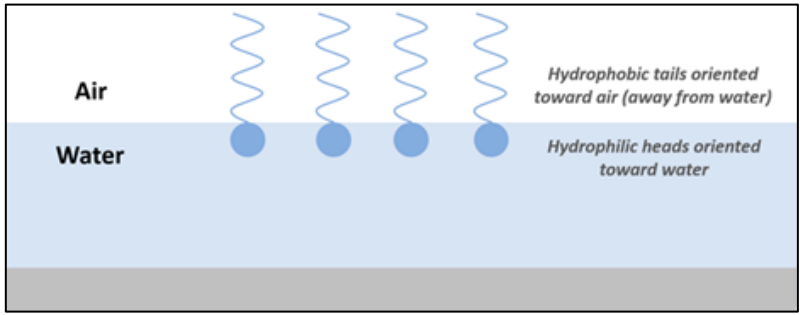

*Image from Environmental Sciences Europe*

# PFAS in the Environment

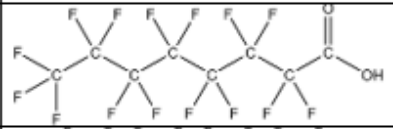
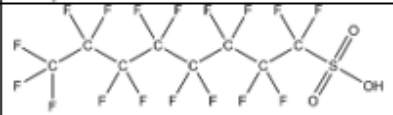
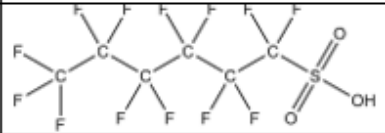
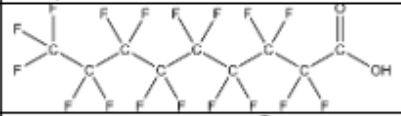
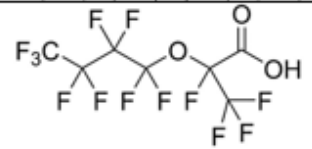
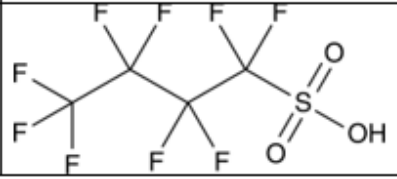
- Sources: industrial effluent, emergency aqueous fire foams, nonpoint sources

- Transport
  - Enters air, soil, groundwater, surface water via direct exposures and indirect exposures

- PFAS in the water column
  - Accumulates at the water's surface and sediment interfaces



# Compounds

| Chemical Name | Synonyms | Chemical Formula | Chemical Structure | Main Use(s) |
|---|---|---|---|---|
| Perfluorooctanoic acid | **PFOA, C8** | $C_8HF_{15}O_2$ |  | Processing aid in the production of fluoropolymers |
| Perfluorooctane sulfonate | **PFOS** | $C_8HF_{17}O_3S$ |  | Component of aqueous film-forming foams, surfactant in fluoropolymer manufacturing |
| Perfluorohexanesulfonic acid | **PFHxS** | $C_6HF_{13}O_3S$ |  | Surfactant in fluoropolymer manufacturing |
| 2,3,3,3-Tetrafluoro-2-(1,1,2,2,3,3,3-heptafluoropropoxy) propanoate | **PFNA, C9** | $C_9HF_{17}O_2$ |  | Processing aid in the production of fluoropolymers |
| Perfluorobutanesulfonic acid | **HFPO-DA, GenX** | $C_6HF_{11}O_3$ |  | Processing aid in the production of fluoropolymers |
| Perfluorobutanesulfonic acid | **PFBS** | $C_4HF_9O_3S$ |  | Treatment of fabric, carpet, and paper |

# Federal Drinking Water Standards

## Current Federal Regulations (2025)

| Compound | Standard (ppt) |
|---|---|
| PFOA | 4.0 |
| PFOS | 4.0 |

Compliance required by 2031

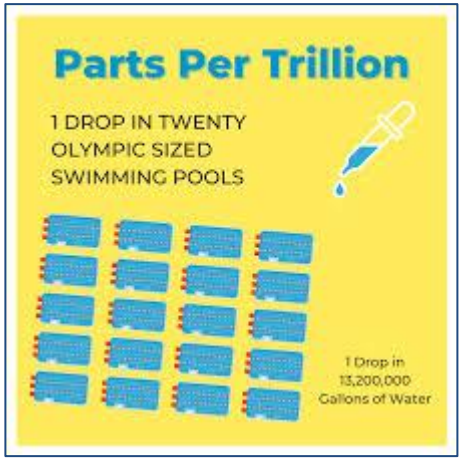



*Image from [Pennichuck Water]*

## Previous Regulations (2024)

| Contaminant | Maximum Contaminant Limit (ppt) |
|---|---|
| PFOA | 4.0 |
| PFOS | 4.0 |
| PFHxS | 10 |
| PFNA | 10 |
| HFPO-DA | 10 |
| Containing two or more of the following: PFHxS, PFNA, HFPO-DA, PFBS | 1 unitless (Hazard Index) |

ppt = parts per trillion = ng/L

## Health Advisories

| Year | 2009 | 2016 | 2022 |
|---|---|---|---|
| Advisory | Provisional (ppt) | Interim (ppt) | Updated Interim (ppt) |
| PFOA | 400 | | 0.004 |
| PFOS | 200 | | 0.02 |
| Combined PFOA + PFOS | | 70 | |
| Gen X | | | 10 |
| PFBS | | | 2,000 |

*Health advisories are non-enforceable levels at which there are no known health effects.*

# Delaware Drinking Water Standards

## Proposed Standards for Delaware

- Proposed in October 2021
- Expected to take effect in 2023
- Paused due to release of Health Advisory Limits by US EPA in 2023

| Contaminant | Maximum Contaminant Limit (ppt) |
|---|---|
| PFOA | 21 |
| PFOS | 14 |
| Combined PFOA + PFOS | 17 |

## Official Standards for Delaware

- Enacted June 2025
- Compliance required by 2029

| Contaminant | Maximum Contaminant Limit (ppt) |
|---|---|
| PFOA | 4.0 |
| PFOS | 4.0 |
| PFHxS | 10 |
| PFNA | 10 |
| HFPO-DA | 10 |
| Containing two or more of the following: PFHxS, PFNA, HFPO-DA, PFBS | 1 unitless (Hazard Index) |

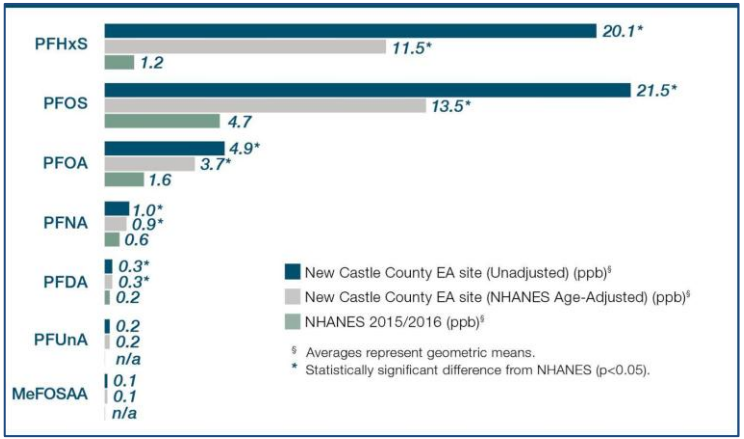
ppt = parts per trillion = ng/L

$$Hazard\ Index = \frac{[HFPO-DA_{ppt}]}{[10_{ppt}]} + \frac{[PFBS_{ppt}]}{[2000_{ppt}]} + \frac{[PFNA_{ppt}]}{[10_{ppt}]} + \frac{[PFHxS_{ppt}]}{[10_{ppt}]}$$

# PFAS in Delaware

- Sources:
  - Industrial Effluent: Wilmington, DE is considered the “chemical capital” of the world
    - Current suit with 16 companies for possibly manufacturing PFAS in Delaware
    - Past settlement: $50 + $25 Million Settlement with DuPont, Nemours, and Corteva
  - Emergency Use AFFF: at New Castle and Dover Air Bases
  - Nonpoint sources

- Past studies:
  - CDC’s Agency for Toxic Substances and Disease Registry (ATSDR) (2014) - *Exposure assessment around New Castle Air National Guard Base*
  - US Geological Survey (2018) - *Groundwater monitoring (30 wells)*




*Graph from the CDC’s Agency for Toxic Substances and Disease Registry*

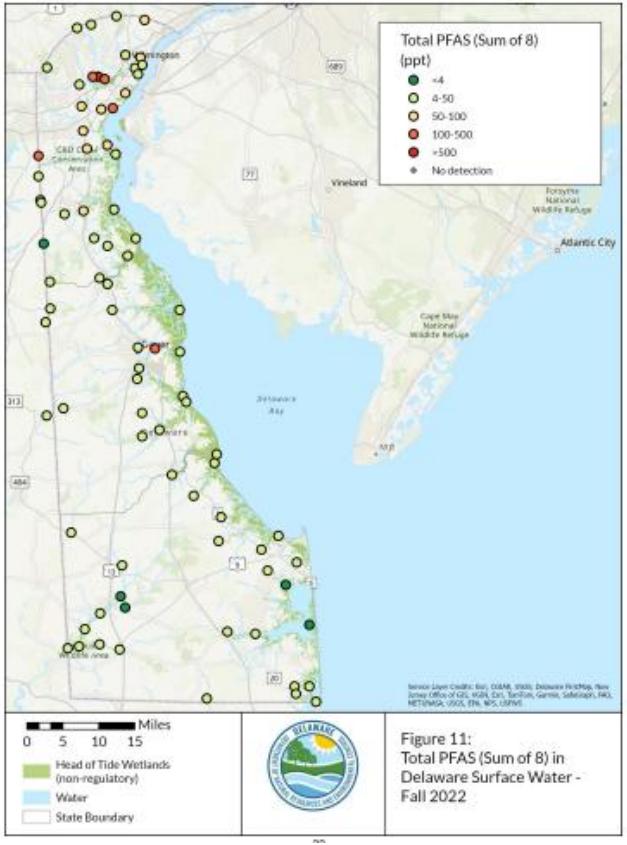
# PFAS Monitoring in Delaware

DNREC

- Surface water sampling - Fall 2022
  - 33 watersheds includes all DE drinking water streams
  - EPA Method 537
- Groundwater sampling - 2020 - 2023
  - 221 wells - both confined and unconfined aquifers
  - EPA Method 537

EPA

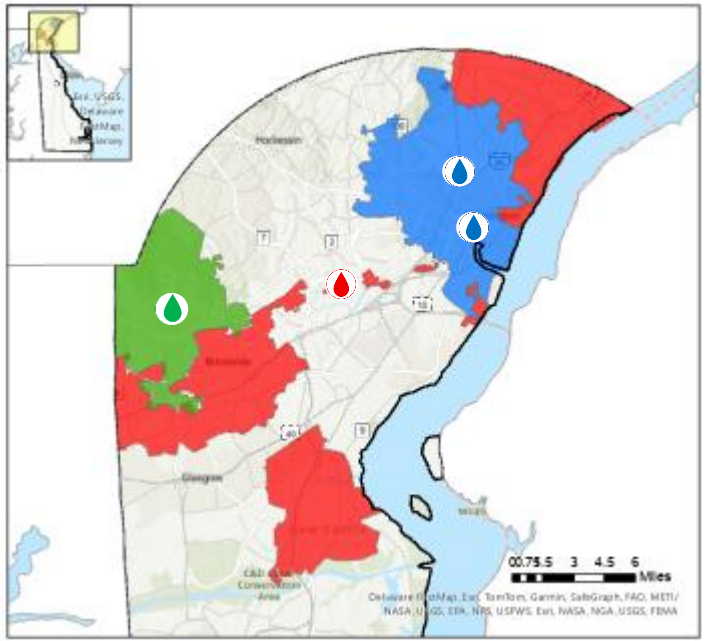
- Fifth Unregulated Contaminant Monitoring Rule 2023 - 2025
  - EPA Methods: 533 (drinking water), 537.1 (drinking water), 200.7 (metals)




*Map form DNREC*

# Understanding the Public Water System in Delaware

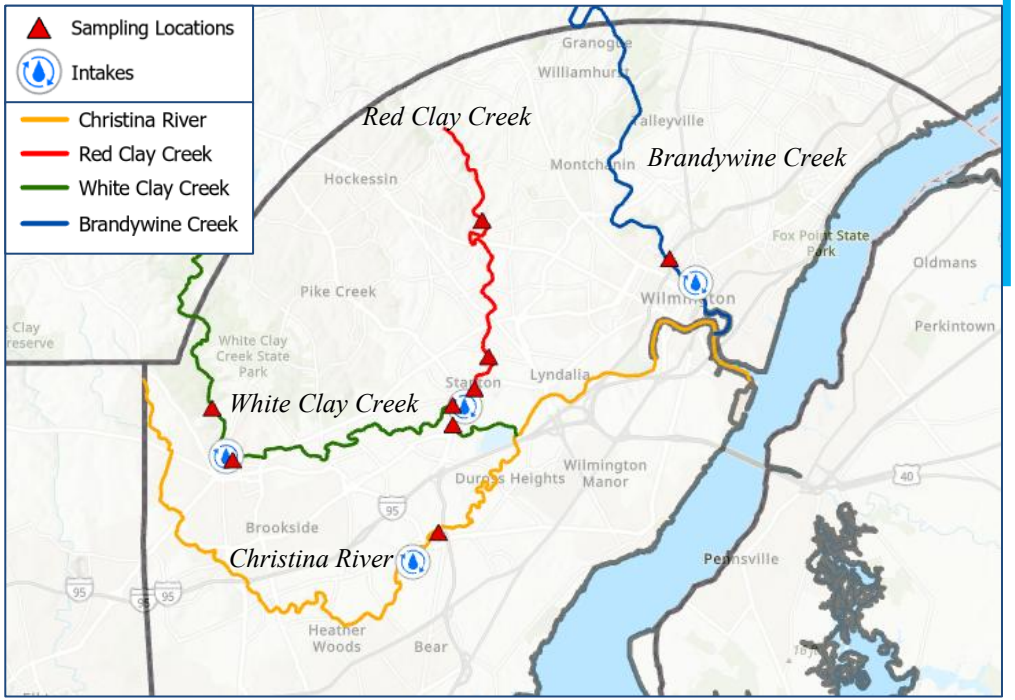
| Water Treatment Plant | Stream | Volume Treated (MGD) |
|---|---|---|
| Porter Filter Plant | Brandywine River at Wilmington | 25 |
| Brandywine Membrane Plant | | |
| Veolia Delaware Water Treatment | Red Clay Creek at Stanton | 10 |
| | White Clay Creek at Stanton | 20 |
| Curtis Water Treatment Plant | White Clay Creek at Newark | 5 |
| Christina Water Treatment Plant | Christina River at Smalley's Pond | 4 |



# Selection of Sampling Locations

- One location selected along every stream
  - Upstream of drinking water intake
  - Sampled from 2021 - 2025

- Repeat sampling
  - If initial results were elevated, other locations were selected upstream
  - Goal: determine a possible source of contamination



# Methods

*EPA Method 1633*
*As of January 2024, this method was finalized for use in the Clean Water Act*

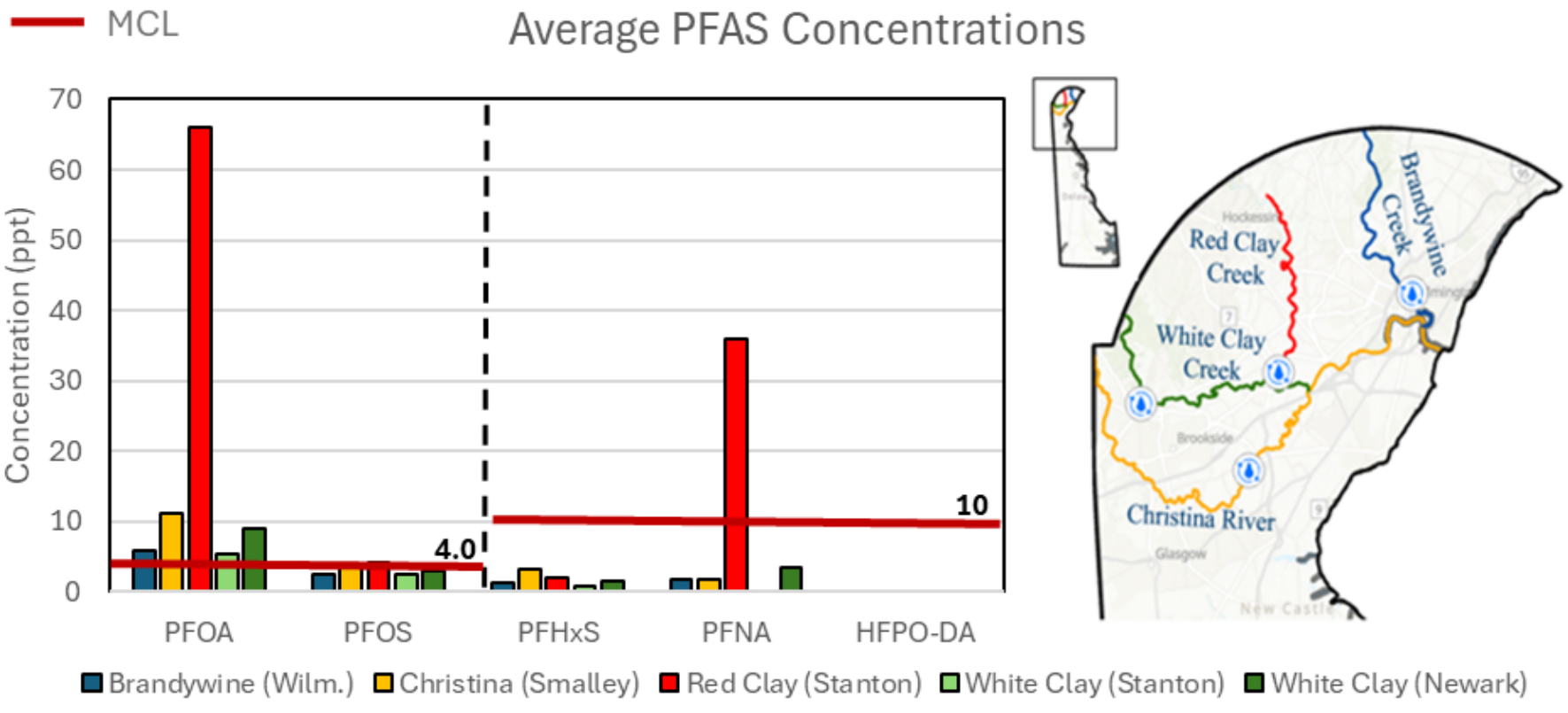
Sampling Method:
- Bottles: Two 250mL HDPE bottles per site
- Depth: Surface level and approximately 1 ft below

Analysis:
- Center for PFAS Solutions in New Castle, Delaware
    - Jess Anton (M.S.), Dr. Seetha Coleman, Dr. Chuck Powley
    - $400 per sample
- Agilent LC-MS/MS mass spectrometer Model G6495C plus Agilent HPLC Model 1290
    - Detects parts per trillion
    - 40 PFAS analytes

*Sampling Red Clay Creek below Hoopes Reservoir*

PFAS Solutions

# Overview of Results



# Red Clay Creek

| Average Concentration (ppt) | | | | |
|---|---|---|---|---|
| | DE MCL | Dam No. 5 | Kiamensi Road | Stanton |
| PFOA | 4.0 | 11 | 59 | 63 |
| PFOS | 4.0 | 6.9 | 2.8 | 4.2 |
| PFHxS | 10 | 1.7 | 1.8 | 1.9 |
| PFNA | 10 | 3.7 | 33 | 36 |
| GenX | 10 | 0.0 | 0 | 0 |

# Red Clay Creek

- Difference in concentrations
  - Significant difference in PFOA, PFNA, and total PFAS concentrations between Dam No. 5 and Kiamensi Road
  - Two-tailed hypothesis test

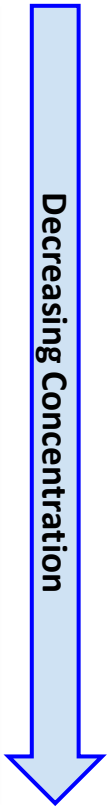
- Source
  - Possible point source of PFOA and PFNA between Dam No. 5 and Kiamensi Road

- Superfund Database
  - 800/900 Greenbank Road
    - Industrial site late 1800s
    - Settlement w/DNREC for PFOA contamination
  - Kiamensi Road
  - Route 48

# Breakdown of Compounds

## All Detected Compounds

| Compound | Type of Compound | Stanton | Kiamensi Road |
|---|---|---|---|
| PFBA | Perfluoroalkyl Carboxylic Acid | 80 | 74 |
| PFOA | Perfluoroalkyl Carboxylic Acid | 75 | 65 |
| PFHxA | Perfluoroalkyl Carboxylic Acid | 74 | 62 |
| PFHpA | Perfluoroalkyl Carboxylic Acid | 74 | 61 |
| PFPeA | Perfluoroalkyl Carboxylic Acid | 66 | 62 |
| PFNA | Perfluoroalkyl Carboxylic Acid | 38 | 31 |
| PFDA | Perfluoroalkyl Carboxylic Acid | 19 | 8.1 |
| PFUnA | Perfluoroalkyl Carboxylic Acid | 8.7 | 2.6 |
| PFDoA | Perfluoroalkyl Carboxylic Acid | 4.9 | <MRL |
| PFOS | Perfluoroalkyl Sulfonic Acid | 4.3 | 2.7 |
| PFBS | Perfluoroalkyl Sulfonic Acid | 4.1 | 4.3 |
| PFTrDA | Perfluoroalkyl Carboxylic Acid | 2.4 | <MRL |
| PFHxS | Perfluoroalkyl Sulfonic Acid | 1.8 | 1.9 |



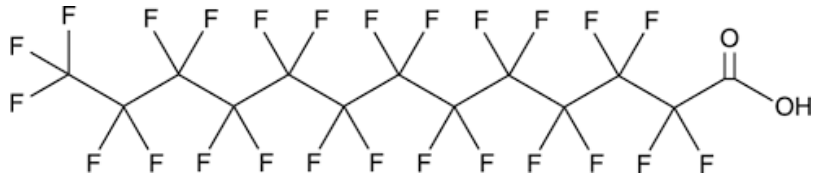

- The majority of detected compounds are considered a Perfluoroalkyl Carboxylic Acid (PFCA):
  - 437.7 ppt out of a total sum of 452.2 ppt in Stanton

- PFCAs
  - Contain carboxylic acid
  - Mainly used in fluoropolymer manufacturing
  - Removal through hydrophobic adsorbents

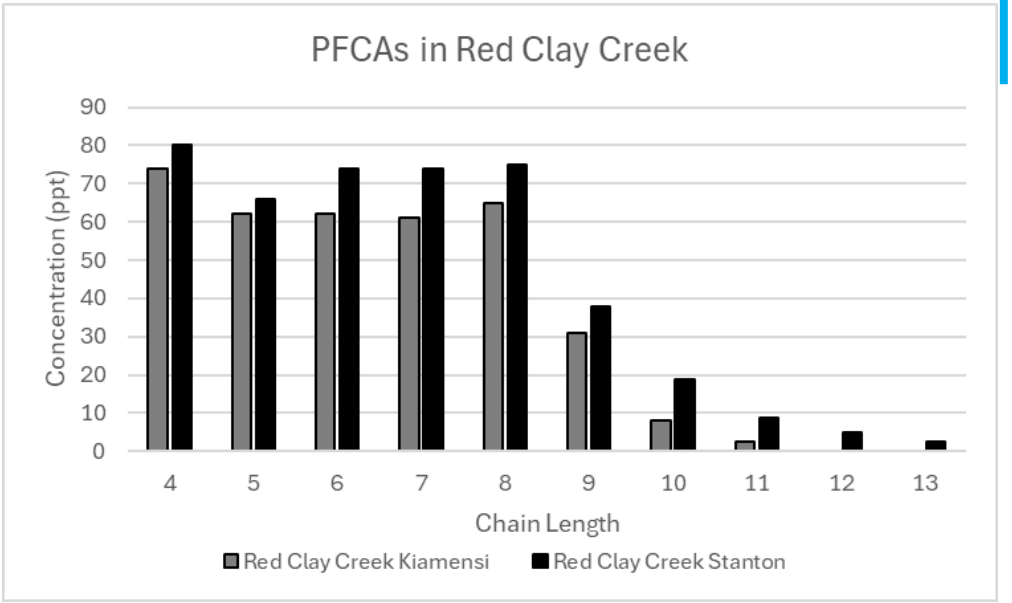
# Breakdown of Compounds

## PFCAs

| Chain Length | Compound | Red Clay Creek Stanton | Red Clay Creek Kiamensi |
|---|---|---|---|
| 4 | PFBA | 80 | 74 |
| 5 | PFPeA | 66 | 62 |
| 6 | PFHxA | 74 | 62 |
| 7 | PFHpA | 74 | 61 |
| 8 | PFOA | 75 | 65 |
| 9 | PFNA | 38 | 31 |
| 10 | PFDA | 19 | 8.1 |
| 11 | PFUnA | 8.7 | 2.6 |
| 12 | PFDoA | 4.9 | <MRL |
| 13 | PFTrDA | 2.4 | <MRL |




*PFTrDA - 13 Carbon Chain*



# Implications for Delaware

**All water treatment systems are above the MCL for PFOA.**

Treatment

- Seperation
  - Granular Activated Carbon
  - Ion Exchange
  - Foam Fractionation
- Disposal
  - Hazardous Waste Landfill
  - Underground Injection
  - Incineration

Mitigation

- Blending
- Remediation

| Compound | Maximum Contaminant Level |
|---|---|
| PFOA | 4.0 ppt |
| PFOS | 4.0 ppt |
| PFHxS | 10 ppt |
| PFNA | 10 ppt |
| HFPO-DA | 10 ppt |
| Containing two or more of the following: PFHxS, PFNA, HFPO-DA, PFBS | 1 unitless (Hazard Index) |

ppt = parts per trillion = ng/L

**Compliance required by 2029.**

Current Treatment in Delaware

- Veolia DE Stanton
  - $35 million facility
  - 42 vessels with GAC
  - 30 million gallons per day
- City of Newark South Well Field
  - $3.3 million facility
  - 4 vessels with GAC and IX Exchange
  - 3 million gallons per day

## Future Research

- Fall 2025
  - Dissertation proposal
  - Verbal and written qualifying exams

- Future Research
  - Groundwater sampling
  - Business side of PFAS policy and treatment

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