What are you doing about PFAS?

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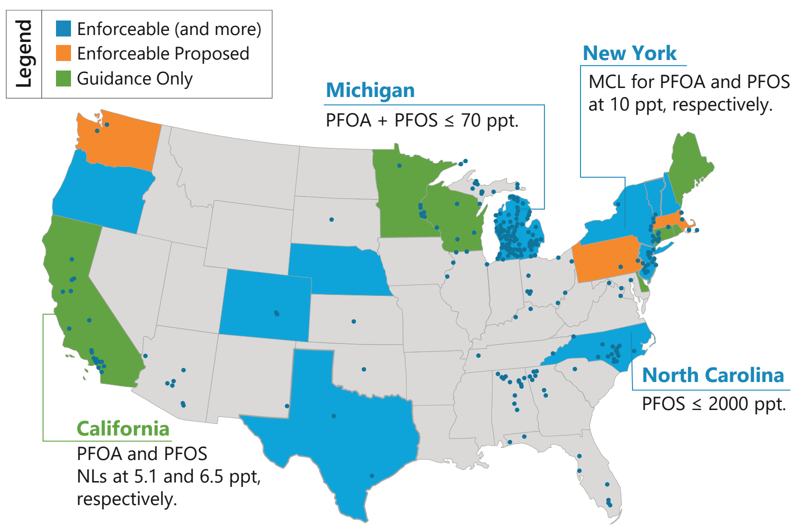
Engineers...Working Wonders With Water®

WHAT ARE PFAS?

Per- and polyfluoroalkyl substances (PFAS) are a large group of synthetic fluorinated organic chemicals that include perfluorooctanoic acid (PFOA) and perfluorooctane sulfonate (PFOS). PFAS unique chemical structure, make them exceptional surfactants for municipal, consumer, and industrial products, with over 3,000 compounds produced globally. However, these properties also make them **highly soluble, mobile, and recalcitrant to chemical and biological processes employed in conventional water and wastewater treatment**. Accordingly, PFAS have been globally detected in environmental ground waters and drinking waters ranging from the sub-ng/L to the mg/L concentrations.

Uses of PFAS for consumer, municipal, and industrial products.



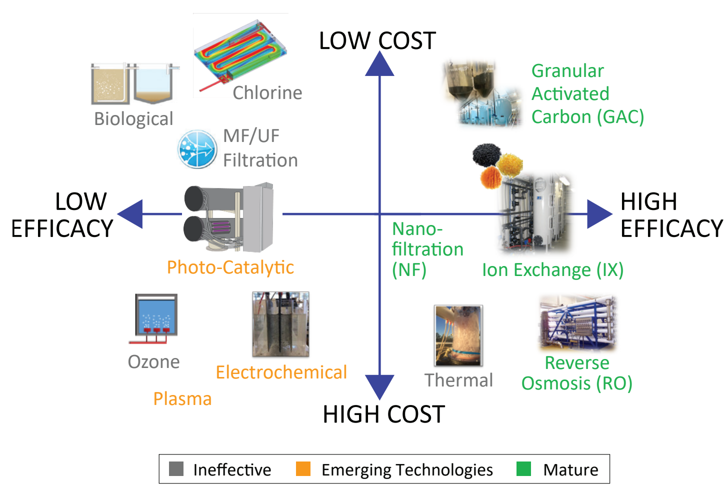
PFAS regulations and occurrence (blue circles) in select US Drinking Water Systems (Dec 2019).

HEALTH EFFECTS AND REGULATIONS

Although the potential health risks of PFAS exposure are not fully understood, epidemiological studies have associated PFAS with **obesity, reproductive impairment, increased cancer incidence, as well as infant and prepubescent hormonal disruption**. The significant social and institutional concern over chronic exposure to PFAS has led to various regulations, including notification levels (NLs) in California of 5.1 ng/L and 6.5 ng/L for PFOA and PFOS, respectively (2018).

PFAS TREATMENT

Membrane-based separation (e.g., NF and RO) and phase-transfer processes onto **granular activated carbon (GAC) or anion exchange (IX) resins** have emerged as the leading PFAS treatment options, with GAC or IX typically preferred due to their modular nature, operational simplicity, lower cost, and lack of liquid concentrate production. While advanced treatment approaches have been investigated for PFAS decomposition, including traditional oxidation processes, sonoysis, photocatalysis, and electrochemical oxidation, their difficulty in achieving complete mineralization and/or lack of scale preclude them as a viable remediation technology at this stage.



Competitive Analysis of PFAS Treatment Technologies.

As adsorption performance varies considerably depending on water quality and the type of adsorbent employed, selecting the **most suitable, site-specific adsorbent** is paramount to ensure minimized media replacement frequency, which comprises between 60% - 90% of life cycle costs. However, assessment of the efficacy of different adsorbents in each new water source using rapid small scale column tests (RSSCTs) or pilot testing is time-consuming and expensive.

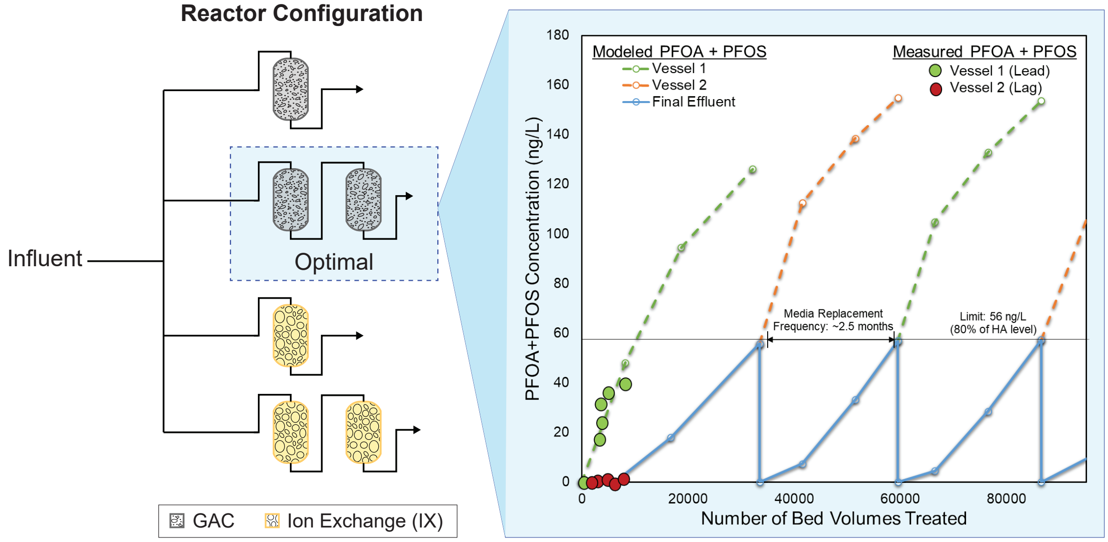
CAROLLO'S PFAS APPROACH

Carollo's proven approach leverages our award-winning water simulation platform, the **Blue Plan-it® (BPI) Decision Support System**, which integrates empirical and mechanism-based algorithms to simulate how various adsorbents and resins remove contaminants. Using the Blue Plan-it® model, the anticipated performance of adsorptive media are simulated using semi-empirical models calibrated with results from a comprehensive database of over 40 RSSCTs for both short-and long-chain compounds, covering PFAS concentrations ranging from 0 to 3,000 ng/L in 15 unique water sources treated with more than 8 different media.

Calibrated with an extensive RSSCT database, Carollo's Blue Plan-it® model:

1. Identifies optimal IX and GAC media and treatment configurations for a given site.
2. Accurately estimates the effluent quality, media replacement frequency, and PFAS treatment costs over anticipated extremes of source water qualities.

Adsorption Selection and Reactor Configuration | **Adsorption Dynamic Simulation**



Simulated full-scale PFAS removal and empirical results for different adsorbents, under different treatment configurations, considering various product water quality goals. Our BPI tool accurately predicts full-scale PFAS breakthrough based on RSSCT results using media type and vessel configuration.

CAROLLO'S PFAS EXPERIENCE

In the past five years, Carollo has been involved with over a dozen PFAS-related projects. This work includes extensive modeling and model calibration, 40+ RSSCTs and column studies, conceptual designs, cost estimates, and four full-scale designs.

Full-scale conversion of GAC for PFAS Removal at TARP (Tucson, AZ)

CASE STUDY: FULL SCALE DESIGN OF A PFAS TREATMENT SYSTEM FOR TUCSON

Carollo provided engineering support services for the Tucson International Airport Area Groundwater Remediation Project (TARP) to address the occurrence of PFAS in an 8.4 mgd facility fed by nine wells. UV/hydrogen peroxide advanced oxidation followed by GAC for excess peroxide quenching were already in use for VOC and 1,4-dioxane treatment. RSSCTs with four GAC media and one IX resin were conducted, and BPI was used to evaluate the test results and compare GAC and IX from operational and cost perspectives. Since eight GAC contactors were already being used and could provide both hydrogen peroxide quenching and PFAS adsorption in the same vessels, Tucson Water opted to continue with GAC for PFAS treatment but also change GAC media type due to RSSCT results, verified by full-scale operations. Carollo is also now helping Tucson Water expand the facility to 10.2 mgd.