TECHNICAL GUIDANCE FOR REMOVAL OF PFAS USING ION EXCHANGE RESINS

INTRODUCTION

The family of synthetic compounds known as per- and polyfluoroalkyl substances (PFAS) have been in use in various applications since the 1940's. These compounds have been used in multiple industries including textile coverings for oil and water repellency, cookware coating, formulation of firefighting foams, and in materials used in the automotive and electronics industries. More recently, detection of PFAS in groundwater sources and the issuance of a health advisory level by the U.S. Environmental Protection agency for PFAS has spurred development of treatment technologies for PFAS containing waters.

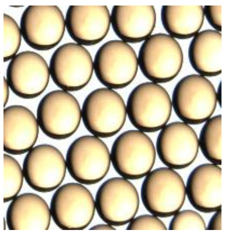
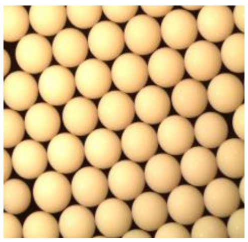
To date, the development of enforceable regulations pertaining to PFAS in water has been led at the state level. A few states have issued Maximum Contaminant Levels (MCL) and several more have issued health advisory levels at or below the level issued by the EPA. In states where concentrations exceed MCLs, water treatment for the removal of PFAS is required.

There are three families of technology generally recognized as currently viable for treatment of PFAS in drinking water. The three technologies are adsorption by ion exchange resins, adsorption by granular activated carbon (GAC), and filtration by reverse osmosis (RO) or nanofiltration (NF) membranes. This document will focus on use of ion exchange resins for removal of PFAS, including an overview of the types of resins that can be considered, the resin chemistries which impart higher selectivity for PFAS, and considerations for pretreatment which can extend resin life and improve PFAS removal.

RESIN MATRIX

The polymer matrix of an ion exchange resin generally falls into two categories – gel or macroporous. Gel type ion exchange resins consist of a continuous polymer network typically made up of polystyrene crosslinked with divinylbenzene. The crosslinking is evenly distributed throughout the resin or bead and the pores or void volumes in the resin are the natural spacing between polymer chains. This pore size is relatively small, and gel type resins appear transparent upon inspection. Gel type resins are more common in standard water treating applications and typically have higher overall capacity and display better regeneration efficiency. A representation of gel type resin is depicted in the figure below on the left.

A macroporous or macroreticular resin is produced with an additional component during manufacturing. This additional additive, called a porogen, introduces larger pores or void volumes than are present in a gel resin. These macro pores are beneficial when a feed water has elevated organic content or where a resin may be subjected to thermal or mechanical shocks. A macroporous resin can be employed in such conditions due to the additional crosslinking in the polymer structure, imparting good overall bead strength. The image in the figure below on the right is a representation of a macroporous type resin.

RESIN SELECTION

Removal of PFAS by anionic ion exchange resins has been demonstrated by multiple vendors in numerous pilot and full-scale studies. Specifically, resins originally designed for perchlorate removal have shown high selectivity and capacity for PFAS, and the chemistries associated with these resins have guided additional resin development. The DuPont resin developed for this market is AMBERLITE™ PSR2 Plus Resin. This resin is a gel type, strong base anion resin functionalized with tri-N-butylamine, a common functional group for resins employed in PFAS removal from water. This functional group gives the ion exchange site a higher degree of hydrophobicity relative to traditional strong base anion exchange resins, which results in a higher affinity for hydrophobic anions like PFAS.

A number of resins developed for this market have similar chemical properties to allow for improved PFAS selectivity, and a table describing a range of offerings and providers is found below. Note that this table outlines a collection of single use ion exchange resins, which to date is the majority of applications, though regenerable resin technology is available in the market.

Ion Exchange Resin	Resin Source/Manufacturer
AMBERLITE™ PSR2 Plus	DuPont Water Solutions
Purofine® PFA694E	Purolite
CalRes 2301	Calgon Carbon Corporation
Sorbix A3F	ECT2 Inc.
ResinTech SIR-110-HP	ResinTech Inc.

PRETREATMENT

Ion exchange resins can remove numerous types of charged species from solution, however the effectiveness of a resin for a specific target molecule can be greatly reduced if certain types of contaminants are also present in a water stream. The typical contaminants that can interfere with resin performance are suspended solids, colloidal species, organic compounds including natural organic matter (NOM), and heavy organics such as oil and grease.

An important first step for any ion exchange process is filtration to remove suspended solids, fine particles, or larger debris that may be present in the water source. If solids or fine particles reach an ion exchange bed, they will deposit on the resin causing a decrease in access to resin surfaces and pores and a potential for increased pressure drop across a column. A variety of filtration media is commercially available and should be selected based on individual water characteristics. Appropriate media include but is not limited to sand filters, multimedia filters, fabric or paper filters, diatomaceous earths, or green sand filters.

Presence of NOM is not uncommon for surface water and can pose several challenges for a single use anion exchange resin. First, anion resins are commonly used for NOM removal and may compete for exchange sites or limit overall capacity. Second, high molecular weight NOM may accumulate on resin and cause fouling. Pretreatment to remove NOM should be considered when treating surface water, and the media may be an additional anion exchange resin or a carbon-based adsorbent.

Oil and other heavy organics must also be removed to prevent surface fouling of ion exchange resin. Removal of oil, grease, or heavy organics may be accomplished with use of synthetic adsorbents.

Alternative, for streams with higher levels of contamination, continuous coalescence processes are also available which utilize oleophilic resins to facilitate phase separation.

SAMPLE OF AVAILABLE DATA

Treatment of PFAS with anion exchange resins has been demonstrated in numerous small and large scale applications. The following collection is a sample of published examples for PFAS removal using ion exchange resin. These examples also highlight potential system providers in the marketplace.

Treatment of drinking water in Stratmoor Hills Water District: Link

Process water treatment at a New England Electronics Manufacturer: Link

Pilot studies on municipal drinking water: Link

Groundwater treatment in Stuart, Florida: Link

RESIN DISPOSAL

Single use ion exchange resins loaded with PFAS must be disposed of in a responsible manner. In the absence of data on the leachability of PFAS from used resins over time, landfilling is not recommended. The current recommendation for spent resin that contains PFAS is disposal by high temperature incineration. It is the users' responsibility to ensure disposal follows applicable local regulatory guidelines.

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