

FINAL REPORT

Electrically Assisted Sorption and Desorption of PFAS

SERDP Project ER18-1395

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List of Acronyms

CDI – capacitive deionization
EDL – electrical double layer
AFFF – aqueous film-forming foam
DOM – dissolved organic matter
WTP – water treatment plant
OCV – open circuit voltage
CNT – carbon nanotube
AC – activated carbon
GAC – granular activated carbon
PAC – powdered activated carbon
ACC – activated carbon cloth
UPW – ultrapure water
TCE – trichloroethylene
PFAS – per- and polyfluoroalkyl substances
PFBA – perfluorobutanoic acid
PFBS – perfluorobutane sulfonic acid
PFHxS – perfluorohexane sulfonic acid
PFNA – perfluorononanoic acid
PFOA – perfluorooctanoic acid
PFOS – perfluorooctane sulfonic acid
LC – liquid chromatograph
MS – mass spectrometer
MS/MS – tandem mass spectrometer

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Abstract

Introduction and Objectives. There are more than 4,000 per- and polyfluoroalkyl substances (PFAS), many of which have been used in aqueous film-forming forms (AFFF) for fire-fighting activities at DoD sites across the US. The growing presence of PFAS in surface and groundwater is raising concern due to their potential toxicity to humans. As a result, the US EPA and several states have set health advisory goals or regulatory limits on many PFAS. Since PFAS are stable and persistent in the environment, contaminated sites face numerous remediation challenges. Among *ex situ* treatment options, granular activated carbon (GAC) adsorption is a widely used approach, wherein groundwater is pumped through beds of GAC before being reintroduced into the aquifer. Many long-chain PFAS adsorb well to GAC because of their moderate to high hydrophobicity. Some PFAS, especially short-chain species, do not adsorb well to GAC, resulting in limited removal if treatment criteria are based on long-chain PFAS removal or high GAC use rates if short-chain PFAS removal is targeted. The objective of this limited-scope project was to determine if PFAS adsorption to activated carbon (AC) by applying low levels of electricity.

Technical Approach. To fulfill our overall objective, we completed four primary tasks. First, after validating and benchmarking a continuous-flow, capacitive electrochemical cell using NaCl, we compared the adsorption of PFOA onto AC cloth electrodes with and without an applied voltage (1.0 V). Second, we used our standard operating procedure developed for PFOA to test the adsorption of five other representative PFAS (PFBS, PFOS, PFNA, PFHxS, PFHpA) in the presence and absence of an applied voltage. Third, we examined the effect of the inorganic ion Cl^- (an abundant anion in groundwater) on the electrosorption of PFBS, a model short-chain PFAS. Last, we qualitatively assessed electrode short-circuiting as a method to desorb PFAS from AC.

Results. The adsorption of all PFAS increased when we applied a voltage across two AC electrodes. The magnitude of the enhancement was dependent on PFAS properties. Short-chain species (e.g., PFBS, PFHpA) yielded the largest enhancement with voltage (2.6–3.7 times), while long-chain species (e.g., PFOS, PFNA) had the smallest enhancement (1.5–1.7 times). The carboxylic acids generally had greater enhanced adsorption than the sulfonic acids (e.g., PFOA > PFOS). When Cl^- was present at a low concentration (1 mM), the electrosorption of PFBS was not negatively impacted. At a higher Cl^- concentration (10 mM), electrosorption was similar to non-electrically assisted adsorption. A qualitative desorption test conducted with PFOA showed that effluent PFOA concentrations decreased relative to the influent when the electrodes were short-circuited. Application of a voltage after short-circuiting the electrodes resulted in a large increase in PFOA concentration in the effluent, suggesting that some of the PFOA that physically adsorbed during short-circuit operation was released back until solution.

Benefits. The findings of our limited-scope project indicate that PFAS adsorption onto AC can be increased with the application of a low voltage. The enhancement depended on PFAS properties and ranged from 1.5 – 3.7 times, with greater enhancement for short-chain PFAS. In a real world situation, our work implies that integrating electrodes into existing GAC systems might provide a simple approach to increase the lifetime of GAC beds. Future research needs include identifying optimal GAC properties for enhanced PFAS electrosorption and assessing the benefits of electrosorption in electrically-controlled GAC columns. Completing these additional tasks will lay the foundation for large-scale testing and adoption of electrosorption for enhanced PFAS removal.

1.0 Introduction

1.1 Objectives

Activated carbon (AC) is a widely used sorbent to remove per- and polyfluoroalkyl substances (PFAS) from groundwater. Two limitations of AC are (1) the inability to effectively remove some PFAS, especially short-chain species, and (2) the lack of cost-effective regeneration methods. The overall objective of this proposal was to electrically enhance the adsorption of PFAS onto AC and electrically discharge them as an *in situ* means to regenerate AC. The technology that we investigated was capacitive deionization (CDI), an emerging electrochemical method that removes charged species from water. Our objectives aligned well with the SERDP statement of need (SON) for *ex situ* strategies to improve PFAS removal from groundwater. Our primary criterion of success for this proof-of-concept stage was to show an increase in the adsorption of PFAS onto AC when it was electrically charged with a low voltage. By completing this proof-of-concept stage, we have reduced the risk necessary to conduct a more extensive follow-on project focused on testing materials and operating conditions under more realistic conditions.

1.2 Background

Granular activated carbon (GAC) is a widely used *ex situ* treatment option because it is effective at removing some PFAS species, such as PFOA and PFOS¹⁻⁴. GAC is a low-cost material, and it can be regenerated, although at a substantial energy and financial cost. GAC is not effective for removing all PFAS because PFAS adsorbability is strongly affected by PFAS structure. PFAS adsorbability increases with increasing number of perfluorinated carbon atoms, and sulfonic acids are more adsorbable than carboxylic acids with the same number of perfluorinated carbon atoms^{3,5}. For example, Dudley et al.⁵ showed that adsorbability of PFAS with six or more perfluorinated carbon atoms was relatively high, but PFAS adsorbability decreased by almost three orders of magnitude as the number of perfluorinated carbon atoms decreased from six to three. Field-scale and bench-scale granular activated carbon (GAC) column data show the same trends in PFAS adsorbability that were observed in isotherm experiments⁶⁻⁹. In field-scale adsorbers, breakthrough of even strongly adsorbing PFAS such as PFOA and PFOS can occur quite rapidly due to slow PFAS sorption kinetics and sorption site saturation by background organic matter¹⁰. In one full-scale water treatment plant (WTP), a new GAC adsorber initially removed PFOA to below detection limits, but after only two months of operation, PFOA appeared in the effluent¹¹. Tri-monthly GAC replacement was required in one WTP to remove high levels (1.9-8.5 µg/L) of PFOA¹². Breakthrough of short-chain PFAS occurs sooner, making GAC adsorption processes cost-prohibitive for their control⁹. For example, PFBA breakthrough at one groundwater treatment facility occurred after only six weeks of operation¹³.

Frequent AC regeneration is required to maintain effective PFAS removal, especially when influent PFAS concentrations are high or when short-chain PFAS removal is required. Reactivating AC using chemicals or replacing entire filter beds imparts considerable cost, but is necessary sometimes within a few months of putting a new filter online⁴. Regeneration methods using alcohols or sulfate and hydroxyl radicals require expensive chemicals and generate ancillary waste streams that require further treatment¹⁴. Decreased removal performance is often observed after these regeneration techniques are applied^{15,16}.

This limited-scope project focused on improving the adsorption of PFAS onto AC using an electrochemical approach. We studied a method that is similar in principle to capacitive deionization (CDI), a scalable technology that can remove a variety of dissolved species (primarily those that are charged) from water¹⁷⁻²¹. Removal occurs via ion electrosorption when a voltage is applied between two oppositely placed electrodes (i.e., anode and cathode). Under this polarized state, cations travel toward the negatively charged cathode, and anions migrate to the positively charged anode. Typically the electrodes are porous (e.g., AC), allowing ions to travel through the macropores (interparticle space between particles) and adsorb within the micropores (intraparticle porosity)²¹. As the ions adsorb, an electrical double layer (EDL) forms and expands from the pores, immobilizing the ions. After ion saturation, the electrical field can either be reversed or short-circuited to desorb the ions back into solution. Operating charge-discharge cycles, therefore, results in the generation of water with no to low concentrations of ions during the charging step and discharge of water containing high concentrations of ions for disposal or further treatment during the discharging step.

While electrosorption has been used for a variety of contaminants, including polycyclic aromatic dyes and herbicides, there was only one report of PFAS electrosorption when this project commenced²²⁻²⁵. When a carbon nanotube (CNT) electrode was fixed at a potential of +0.6 V, initial adsorption rates increased 60 and 41-fold for PFOA and PFOS, respectively, relative to an open circuit voltage (OCV) control²⁶. Maximum sorption capacities also increased 150-fold (PFOA) and 94-fold (PFOS) for concentrations ranging from 50 µg/L to 10 mg/L²⁶. Many of these studies used standard three-electrode electrochemical cell configurations, which are not a scalable design for field applications and/or nano-scale materials, such as CNTs, that are both cost-prohibitive and technically challenging to scale-up.^{23,26,27} Finally, there is no information available on electrically assisted removal of PFAS other than PFOS and PFOA²⁶.

Our overarching hypothesis was that application of a voltage between two AC electrodes could enhance the adsorption of PFAS. We also postulated that removing the voltage after electrosorption and short-circuiting the electrodes would release the adsorbed PFAS back into solution, providing an *in situ* method to regenerate AC. Two key technical objectives were pursued to test our hypotheses. First, we conducted tests with single-solute PFAS solutions in the presence and absence of an applied voltage. Second, we determined the removals of a model PFAS (PFBS) in the presence of different Cl⁻ concentrations to assess if Cl⁻ might compete with PFBS for adsorption sites. Finally, we qualitatively examined the desorption of PFAS by short-circuiting electrodes to which PFAS were electrosorbed.

2.0 Materials and Methods

2.1 Chemicals and standards

Sodium perfluorooctanoate (PFOA), perfluoroheptanoic acid (PFHpA), and potassium nonafluoro-1-butanesulfonate (PFBS) were purchased from Fisher Scientific, and of 98+% purity. Heptadecafluorooctanesulfonic acid potassium salt (PFOS), perfluorononanoic acid (PFNA), and tridecafluorohexane-1-sulfonic acid potassium salt (PFHxS) were purchased from Sigma Aldrich, and of 98+% purity. The acid form PFASs, namely PFNA and PFHpA, were transferred to sodium salt form by dissolving in NaOH solutions and adjust pH to 6-7. The salt form PFASs, namely PFOA, PFBS, PFOS, PFHxS, were dissolved in laboratory grade water ($>18\text{ M}\Omega\cdot\text{cm}$). For all single-solute tests, we targeted a working PFAS concentration of around 0.5 mM in order to provide sufficient conductivity in our electrochemical cells.

2.2 Electrochemical cell design and operation

We chose to use AC cloth (ACC) for our tests for the following reasons. First, preparing conventional GAC-based electrodes requires mixing the GAC particles with a binder in order for them to adhere to a current collector. Conventional binders, such as Nafion, are fluorinated, which we considered problematic because PFAS may adhere to the binders and/or present challenges for analyzing PFAS using our analytical techniques. Second, preparing GAC electrode pastes requires several days, limited primarily by several drying steps. Because of these limitations, we decided to use ACC. This material did not require a binder, could be replaced after each test, and has been well studied in the CDI literature^{28–31}. The ACC (ACC-507-15, Nippon Kynol, Japan) was cut into pieces of 3 cm $\times$ 3 cm sizes, soaked in laboratory grade water for 24 h, dried in incubator at 60 °C for 2 h, and stored in a desiccator until needed³². Two piece of ACC were placed on either side of a 25 μm thick porous polypropylene separator (Celgard 3501, Charlotte, NC). The sandwich made of the two ACC electrodes and separator was placed in the opening area of the polypropylene gaskets between two graphite plate current collectors (6.4 cm $\times$ 6.4 cm). Two neoprene rubber gaskets (0.15 mm thick) were placed between the graphite plates and terminal polycarbonate plates to seal the cell. The e-cell was clamped shut by four electrically insulated threaded bolts (Fig. 1).

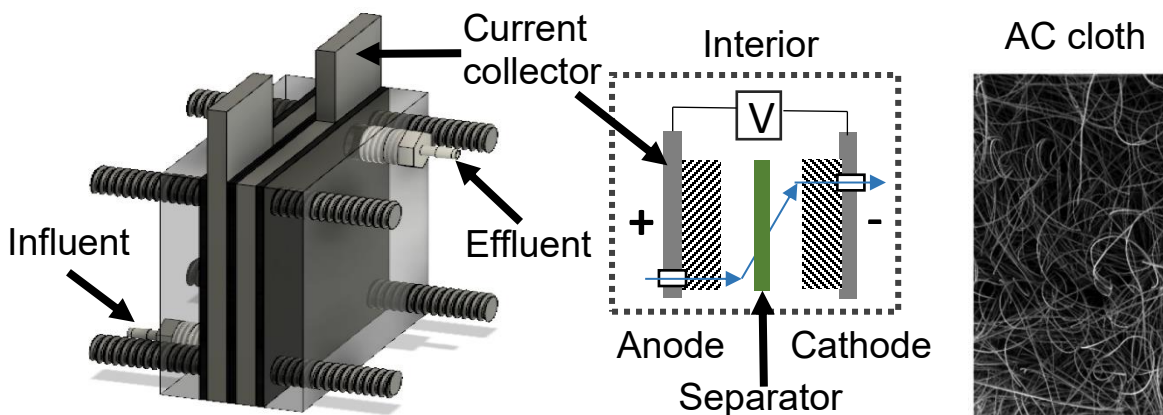


Fig. 1. Schematic of the e-cell used in this study. Activated carbon (AC) cloth was used as both the anode and cathode. Graphite plate current collectors were compressed against the AC cloth to minimize contact resistance. A mesh separator was placed between the anode and cathode to

prevent electrical short-circuiting of the electrodes. The flow (shown with blue arrows) entered near the bottom of the anode, passed through the middle of the chamber, and exited near the top of the cathode. AC cloth image from³².

In order to provide a continuous flow through the e-cell, a peristaltic pump was used at a rate of 2 ml/min. The voltage was applied and the current recorded by a potentiostat (VMP3, Biologic, France). An applied voltage of 1.0 V was applied between the electrodes during “With Voltage” experiments, and the cell was operated at OCV condition in the “No Voltage” experiments. The conductivity and pH of the influent and effluent were measured using a Thermo Scientific Orion Duraprobe and Double Junction pH electrode, respectively.

2.3 PFAS measurements

PFAS concentrations were determined by liquid chromatography-tandem mass spectrometry (LC-MS/MS) using a large-volume (0.8 mL) injection method. The LC-MS system consisted of the following components:

- A. Agilent 1260 Liquid Chromatography System with Multisampler and Agilent Ultivo triple quadrupole mass spectrometer (Note: all Teflon solvent lines were replaced with PEEK (polyether ether ketone) tubing; stainless steel tubing was used between the injection port and the analytical column and the detector. A 900 μ L stainless steel sample loop is used to allow large volume injections (LVI).
- B. 1290 Infinity II inline filter, 0.3 μ m (Agilent, Santa Clara, CA), P/N 5067-6189 and Frit for 1290 Inline filter, 0.3 μ m (Agilent, Santa Clara, CA), P/N 5023-0271 installed after the injection port and before the analytical column
- C. ZORBAX Eclipse Plus C18 analytical column (4.6 x 50 mm, 3.5 μ m particle size; Agilent, Santa Clara, CA), P/N 359943-902K
- D. Mobile phase A
- E. Mobile phase B

Prior to analysis, all samples that were expected to fall outside of the calibration range (10 – 1,000 ng/L) were diluted with ultrapure water. All (diluted) samples, calibration standards, and quality control samples were spiked with isotopically labeled internal standards. An 800 μ L aliquot of each sample (including calibration standards and quality control samples) was injected into the LC system equipped with a 900 μ L sample loop. Analytes were separated on a C18 analytical column. The column oven temperature is held constant at 50°C. The eluent flow rate is held at 0.70 mL/min, and eluent composition is ramped from 90% mobile phase A (5 mM Optima LC/MS grade ammonium acetate in deionized water) to 100% mobile phase B (5 mM Optima LC/MS grade ammonium acetate in 95% HPLC grade methanol and 5% deionized water) over 8 minutes and held until 13 minutes (end of run), then switched to 90% mobile phase A at 13.1 minutes and held to 19 minutes (post-run). Retention times for the analyte and corresponding internal standard were within 0.1 minutes.

PFAS were detected using an Agilent Ultivo triple quadrupole mass spectrometer using electrospray ionization in negative mode (ESI-) in multiple reaction monitoring (MRM) mode. Ion

source parameters are given in **Table 1**. For each of the six PFAS targeted here, two ion transitions were monitored, one representing the quantitation ion and the other the confirmation ion.

Table 1. Mass spectrometer ion source parameters

Parameter	Setting
Drying gas temperature (°C)	230
Drying gas flow rate (L/min)	11
Sheath gas temperature (°C)	350
Sheath gas flow rate (L/min)	11
Nebulizer pressure (psi)	20

A calibration curve for each analyte was determined for quantification of PFAS concentrations in samples. At a minimum, a 7-point calibration curve (calibration standard concentrations ranging from 10 to 1,000 ng/L) was developed. The regression equation for the calibration curve was quadratic with 1/x weighting. The lower limit of quantitation (LOQ) was determined as the higher of the following: (1) lowest calibration standard calculated to be within 30% of the true value, and (2) lowest calibration standard with a response that exceeded that of the highest blank (instrument blank, method blank) by a factor of two. In addition, the signal to noise ratio (S/N) had to be >10:1 at the LOQ. For the six analytes targeted in this project (PFHpA, PFOA, PFNA, PFBS, PFHxS, and PFOS), LOQs were 10 ng/L. When quantitated using the calibration curve, each calibration point for each analyte was within 70-130% of its true value. Calibration range, LOQ, and fit (r^2) of calibration curves for all analytes were recorded for each analytical run.

3.0 Results and Discussion

3.1 Validating and Benchmarking the Electrochemical Cell

We first built and validated our electrochemical cell (e-cell) using a defined solution containing the inorganic salt NaCl. We did this to ensure that our setup was performing as expected and was in agreement with similar e-cells in the literature. To perform these tests, we continuously flowed a solution containing deionized (DI) water and NaCl (0.5 mM) through the cell with or without an applied voltage (1.0 V). We monitored the effluent solution conductivity continuously during the two hour test using an in-line conductivity probe. We then converted conductivity to NaCl concentrations using established molar conductivity conversion factors.

In the absence of an applied voltage, the effluent NaCl concentration increased rapidly toward the influent value, indicating that only a small amount of NaCl physically adsorbed to the ACC electrodes (**Fig. 2A**). When a voltage was applied between the two electrodes, the salt concentration remained below the influent value for the duration of the test. The lower effluent concentrations indicate that the applied voltage was driving ions into the electrodes and storing them within electrical double layers. In the CDI literature, a common metric used to report the performance of a system is the salt adsorption capacity (SAC), measured in units of either mass (e.g., mg) or moles of salt adsorbed per unit mass of total electrode mass (anode plus cathode)^{20,21}. We calculated our SAC values as a function of time (**Fig. 2B**). The SAC increased over time, reaching a maximum of 6 mg-NaCl / g-ACC after the two hour period. This value is consistent with literature values for ACC electrodes and similar operating conditions^{28–31}. The results of this test indicate that our e-cell was working well and in agreement with prior studies.

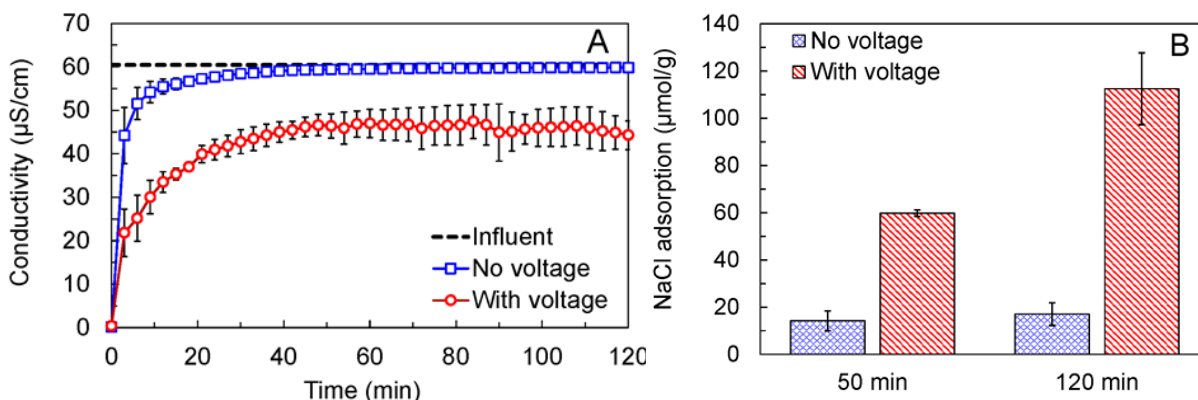


Fig. 2. Validation of the e-cell using a solution of NaCl (0.5 mM). (A) Effluent conductivity profiles over time with and without an applied voltage (1.0 V) between the anode and cathode. (B) NaCl adsorption normalized to total mass of both electrodes after 50 min and 120 min of cycle.

3.2 Establishing standard operating procedures for the PFAS electrosorption tests

To establish our standard operating procedure for testing the six PFAS in this study, we conducted a first set of tests using NaPFOA. We selected a high target concentration of 0.4 mM PFOA for the following reasons. First, it allowed us to monitor PFOA removal based on changes in the effluent conductivity as we did with NaCl (**Fig. 2A**). Second, it provided an ionic strength within the range of typical groundwater. We chose not to conduct our single solute tests with trace

levels of PFOA (e.g., ng/L) in DI water because the low solution conductivity would lead to extremely high internal resistance.

During the tests, the effluent PFOA concentrations were different between the voltage and no voltage treatments. Without an applied voltage, PFOA concentrations rapidly approached, but did not reach, the influent value (**Fig. 3A**). For the remainder of the test, the effluent concentration remained below the influent. This behavior was different than that observed with NaCl and can be explained by the higher physical adsorption of PFOA than NaCl. With an applied voltage, effluent PFOA concentrations remained below both the influent and effluent concentrations during the no voltage control test. This trend was consistent throughout the entire two hour test. During the applied voltage tests, we noticed a gradual increase in pH in the effluent, possibly due to Faradaic reactions involving the consumption of H^+ at the cathode (e.g., O_2 reduction to H_2O_2 or H_2O). The pH changes were sufficient enough to influence the solution conductivity. As a result, we adjusted our raw conductivity values for these pH changes and only report those values here and in the rest of the report.

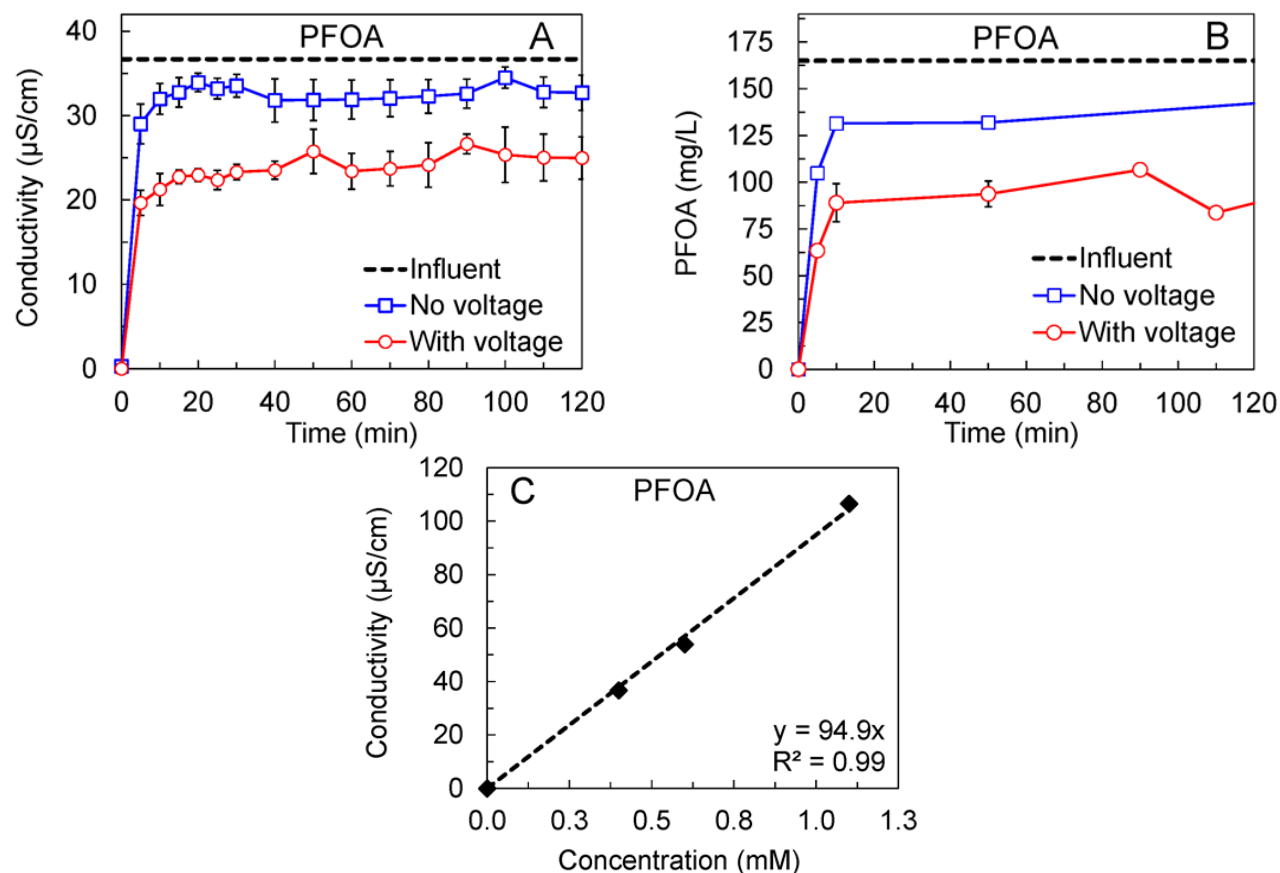


Fig. 3. (A) Effluent conductivity profiles with and without an applied voltage for solutions containing NaPFOA (~ 0.4 mM). (B) PFOA concentrations measured at several time points during the adsorption cycle using LC/MS/MS. (C) Correlation between PFOA conductivity and PFOA concentration.

We measured our PFOA SAC based on solution conductivity changes and LC/MS/MS measurements of samples taken over time. To show the trend between our conductivity profiles and LC/MS/MS measurements we plotted both over time (**Fig. 3A & B**). The LC/MS/MS data

agreed well with the conductivity trend and confirmed that applying a voltage led to a decrease in PFOA concentrations. Our calculations of SAC based on these two methods were in good agreement as well, indicating that using conductivity changes can provide us with a reasonable estimate of actual PFAS removals (**Fig. 3C**).

The SAC increased sharply to *ca.* 104.5 $\mu\text{mol-PFOA/g}$ (based on LC/MS/MS results) when we applied a voltage, which was an increase of almost 2.5 relative to the no-voltage control. We consistently observed this enhancement with an applied voltage across multiple replicates. We minimized carry over of PFOA between replicates by disassembling the e-cell, cleaning it, and installing new electrodes for all replicates. In summary, these initial tests with PFOA provided two key takeaways: (1) it helped us establish a standard workflow for testing the remaining PFAS, and (2) it provided preliminary results that an applied voltage can enhance the adsorption of PFOA.

3.3 Electrosorption tests with PFBS, PFHxS, PFOS, PFHpA, and PFNA

We next conducted adsorption tests with and without a voltage on the remaining five PFAS (PFBS, PFHxS, PFOS, PFHpA, and PFNA). Consistent with our approach to test PFOA, we first established molar conductivity relationships for each species using a set of standards and validation using LC/MS/MS (**Fig. 4A-E**). With our calibrated conversion factors for PFAS concentrations using conductivity, we conducted our adsorption tests using only changes in effluent conductivity.

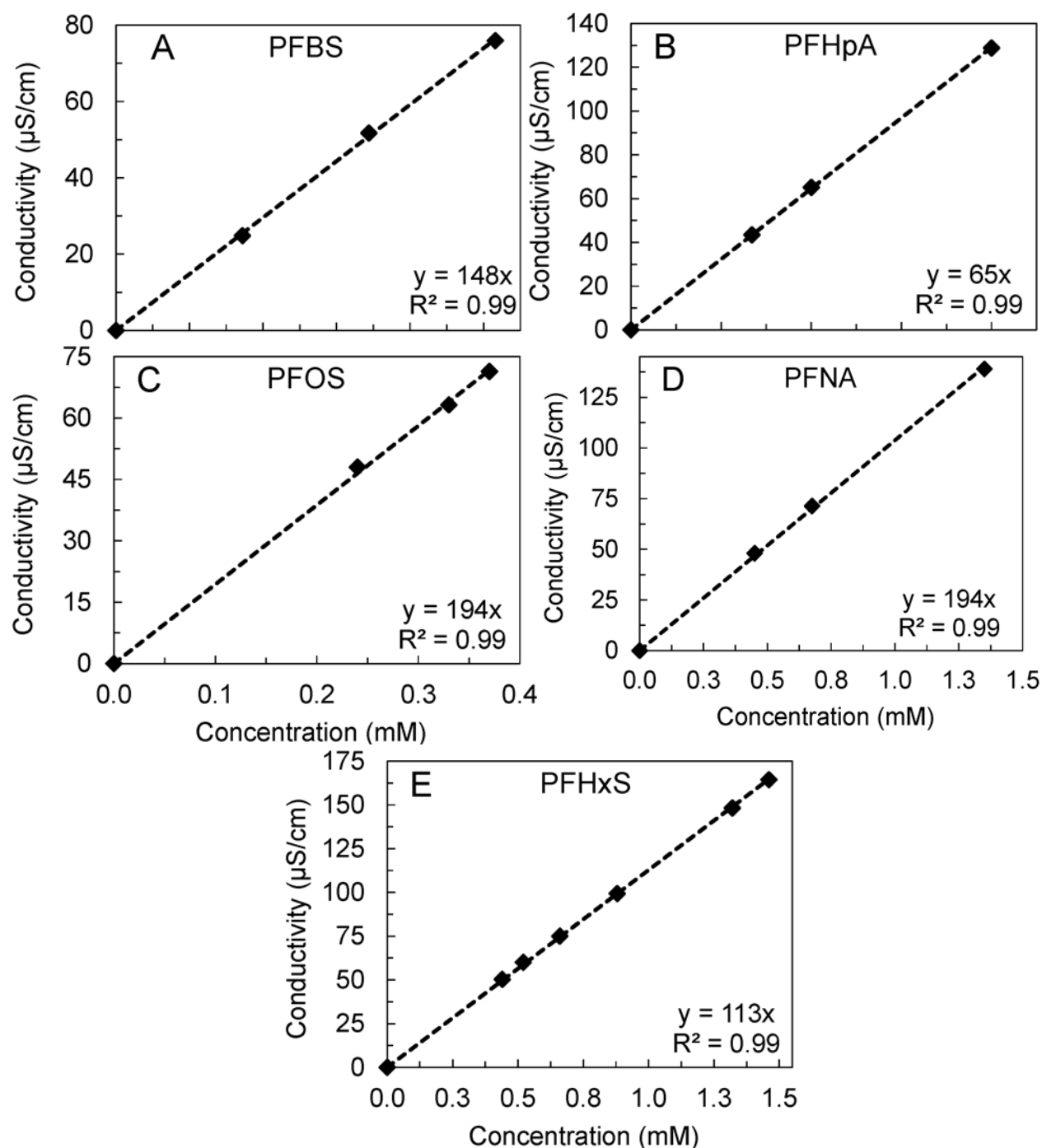


Fig. 4. Linear correlations of conductivity and concentration for (A) PFBS, (B) PFHpA, (C) PFOS, (D) PFNA, (E) PFHxS.

Our tests with the remaining PFAS were consistent with the PFOA tests: enhanced removal with a voltage. Over several cycles, however, we observed that the effluent concentrations with and without a voltage became similar. To assess if our e-cell was not functioning correctly, we repeated our original tests with PFOA. The effluent conductivities were nearly identical with and without an applied voltage in those tests. We hypothesized that PFAS were accumulating within

our e-cell. Considering that before each test we used new ACC electrodes, new tubing, and rinsed the cell parts with alcohol, we realized that the graphite plate current collectors, which were not replaced in each test, might be the cause of the performance change. We conducted a suite of additional tests to confirm that when we either flipped the plates around or used new plates that the enhancement with voltage returned (**Fig. A1**). These results suggest that the PFAS were accumulating on the current collectors over time, causing an increase in resistance in our cell. Since we could not determine when this effect began, we cut all new graphite plates and repeated all of our tests. Using new plates for each test, we were now able to observe a consistent enhancement with voltage (**Fig. 5A-E**).

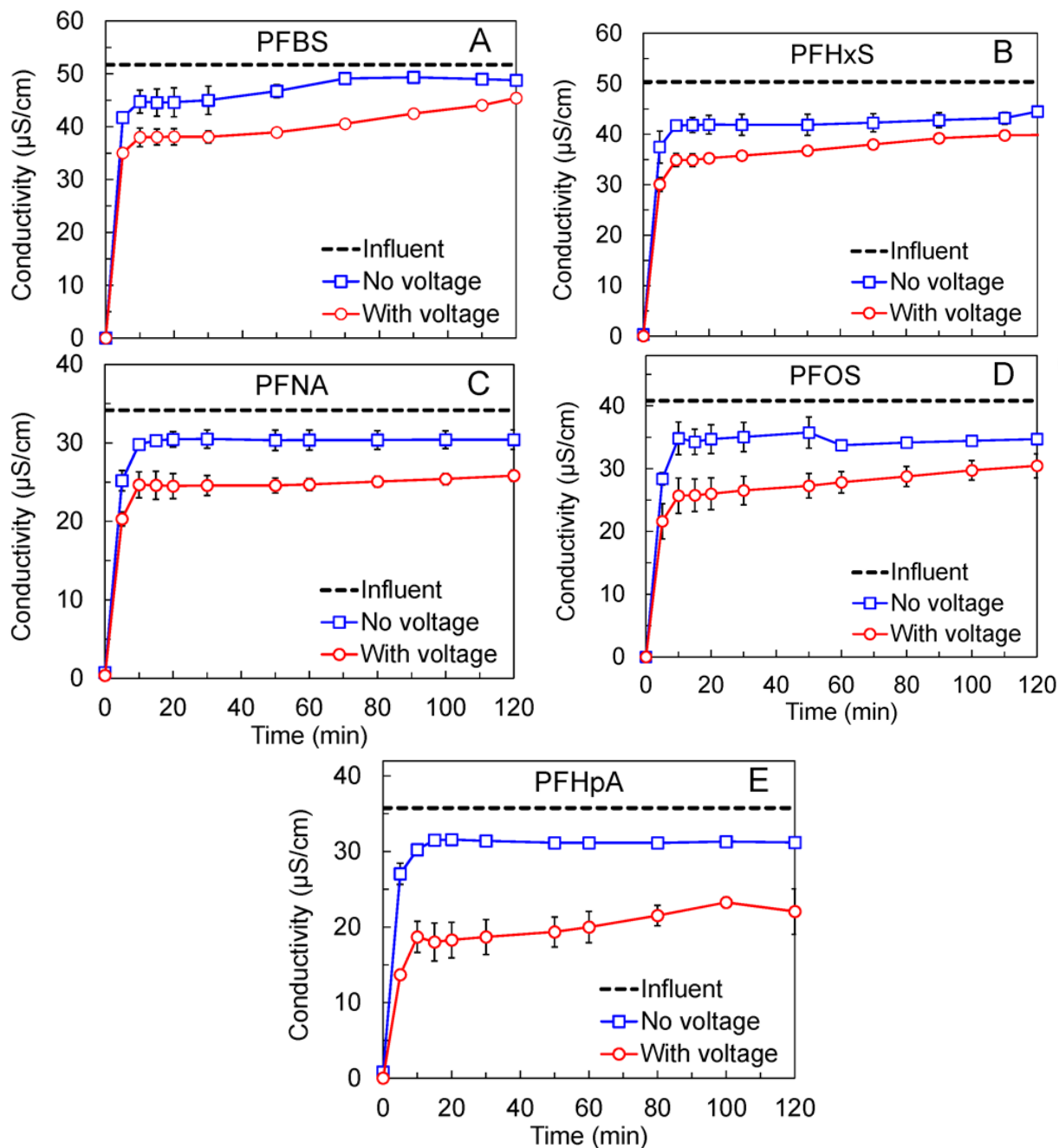


Fig. 5. Effluent conductivity profiles during adsorption tests with and without an applied voltage for (A) PFBS, (B) PFHxS, (C) PFNA, (D) PFOS, (E) PFHpA.

After our adsorption tests were complete, we calculated normalized adsorption values for each PFAS (**Fig. 6**). Since the initial concentrations of our PFAS varied slightly, we normalized our absolute adsorption values to each respective effluent concentration recorded during the final 20 minutes of the cycle. This variable, which has units of mL / g-ACC, is analogous to a partition coefficient, K_d as described in the Freundlich adsorption isotherm equation.

$$q = K_d * C \quad (1)$$

Where q is the solid phase concentration (e.g., $\mu\text{mole/g}$), K_d is the partition coefficient (e.g., mL/g), and C is the aqueous phase concentration in the e-cell effluent ($\mu\text{mole/L}$). In the absence of a voltage, the adsorption trend was relatively consistent with prior literature reports. We observed that the longer-chain species (e.g., PFOS, PFNA) had the highest adsorption, and the shortest chain species had the lowest (e.g., PFBS, PFHpA). The sulfonic acids generally had higher adsorption than the carboxylic acids (e.g., PFOS > PFOA). When we applied a voltage, the partition coefficients increased for all PFAS. The increase, or enhancement, was dependent on PFAS identity. Generally, shorter chain species (e.g., PFBS, PFHpA) had the greatest enhancement (2.6 – 3.7 times). Longer chain species (e.g., PFNA, PFOS) had the lowest enhancement (1.5 – 1.7) (**Fig. 7**).

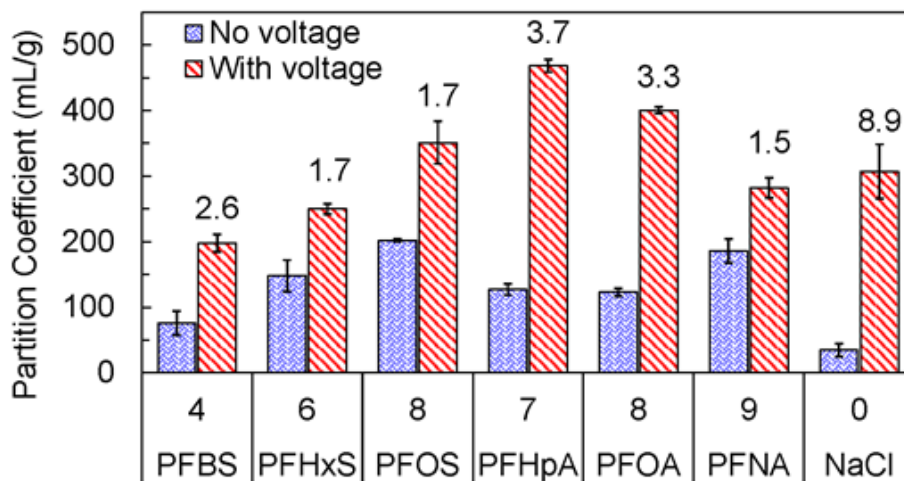


Fig. 6. Partition coefficients (calculated by dividing the number of moles of PFAS removed per gram of total electrode area by the effluent PFAS concentration measured during the last 20 minutes of the cycle) with and without an applied voltage for the six PFAS tested in this study and NaCl. The values listed above the red bars indicate the enhancement with voltage relative to the no voltage control. The numbers above the chemical abbreviations represent the number of carbons in the compound.

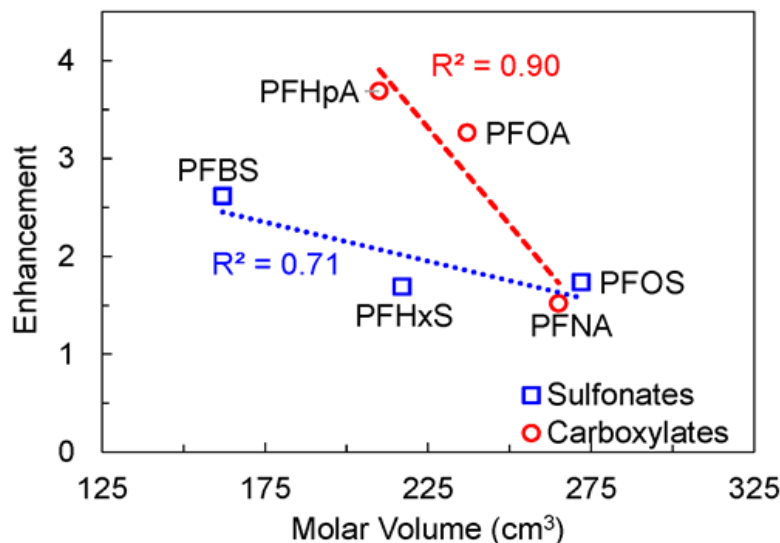


Fig. 7. Enhancement in PFAS removal with the applied voltage relative to the removal without the voltage as a function of the molar volume of the PFAS tested. Blue squares and dotted line represent the sulfonic acids. Red circles and dotted line represent the carboxylic acids.

3.4 Electrosorption of PFBS in the presence of Cl⁻

In real environmental matrices, there are many constituents that may impact the electrosorption of PFAS. Examples include anions (e.g., Cl⁻, SO₄²⁻), natural organic matter (e.g., humic/fulvic acids), and co-contaminants (e.g., TCE). In our tests above, we used single-solute PFAS solutions understand electrosorption in the absence of competing anions. In this section, we focus on the electrosorption of PFAS in the presence of Cl⁻ because in most groundwaters it is the most abundant anion and therefore might compete with PFAS for sorption sites. We tested two different Cl⁻ concentrations (1 and 10 mM) in the presence of PFBS at either 10 or 20 µg-PFBS/L. We chose PFBS for these tests because it is one of the more challenging PFAS for AC to remove.

Our results show that the removal of PFBS under an applied voltage is dependent on the Cl⁻ concentration. In the presence of 1 mM Cl⁻, the solution conductivity of the mixture was around 200 µS/cm. Upon application of the voltage, the effluent conductivity dropped and remained below the effluent during the entire duration of the two hour test (data not shown). Since Cl⁻ was the primary contributor to conductivity, we cannot determine PFBS removals based on conductivity changes. Using LC/MS/MS, we quantified PFBS effluent concentrations at several time points (**Fig. 8A**). We targeted an influent concentration of 20 µg-PFBS/L, but the actual concentration was slightly lower. Without an applied voltage, the effluent concentration remained steady around 14 µg-PFBS/L. With an applied voltage, the concentration was around 9-10 µg-PFBS/L. The total amount of PFBS adsorbed per total mass of electrodes was 2.7 times larger after two hours when a voltage was applied. When a higher Cl⁻ concentration was present (10 mM) and we lowered the PFBS to 10 µg-PFBS/L, effluent PFBS concentrations over time were similar, and at many points within the measurement error, with and without an applied voltage (**Fig. 8B**). Under this treatment, there was no clear difference between PFBS adsorption with and without a voltage. In summary, these preliminary tests suggest that Cl⁻, when present at high concentrations may outcompete PFBS for adsorptions site. Further investigation of Cl⁻, and other anions is required to fully understand their competitive and synergistic effects with PFAS.

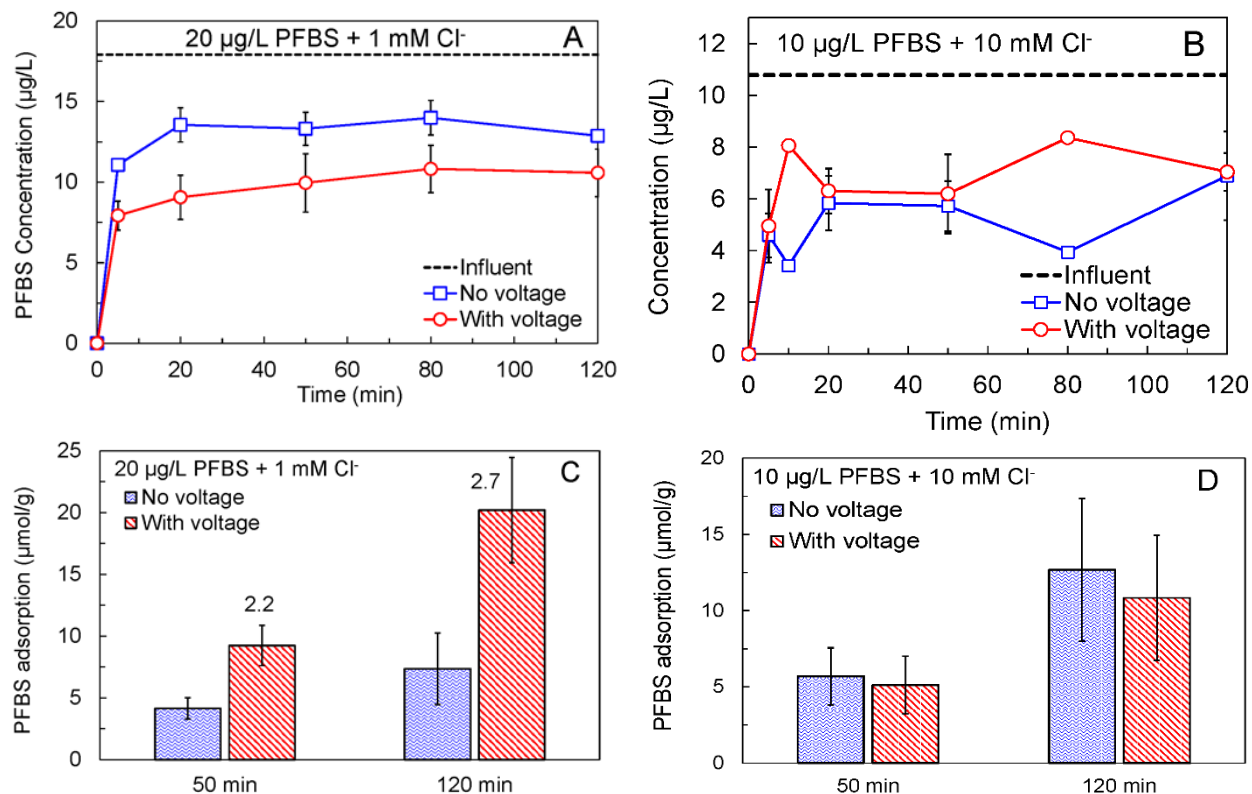


Fig. 8. (A) PFBS concentrations over time in the effluent of the e-cell with and without an applied voltage. Cl⁻ (1 mM) was added to the PFBS (20 μg/L) solution. (B) Identical to (A) except different concentrations of PFBS (10 μg/L) and Cl⁻ (10 mM) were used. PFBS adsorption after 50 min and 120 min of the adsorption cycle normalized to the total mass of electrodes for solutions containing (C) 20 μg/L PFBS with 1 mM Cl⁻ or (D) 10 μg/L PFBS with 10 mM Cl⁻.

3.5 Electrically-assisted desorption of PFAS

In this section, we describe the results of tests in which we electrically desorbed PFAS from our AC electrodes. We were not able to fully explore this aspect in our limited scope project, but here we provide a brief summary of our observations from a small set of tests. In a typical CDI cycle, a voltage is first applied to adsorb ions into the electrical double layer. Then, the electrodes are short-circuited, causing collapse of the electrical double layer and release of ions into solution. These charge-discharge cycles are often run sequentially over time for several hours. To provide an example of the typical effluent profile during these cycles, we conducted tests using only NaCl (10 mM) under an applied voltage (1.0 V) using 30 minutes for each of the charge and discharge steps (**Fig. 9A**). During charging, a clear decrease in effluent conductivity can be observed for the entire 30 minutes. As soon as the electrodes are short-circuited ($t = 30$ min.), the conductivity increases rapidly due to the large release of ions back into solution and then decreases rapidly toward the influent value. With NaCl, this trend is consistent across multiple cycles ($n = 4$ in **Fig. 9A**).

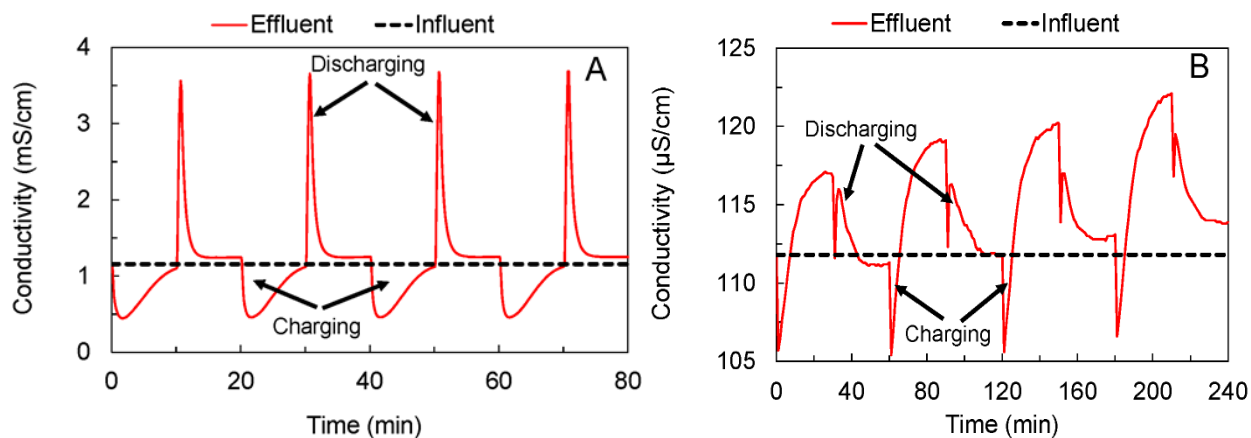


Fig. 9. Effluent conductivity profiles during multiple charging (with an applied voltage) and discharging (electrode short-circuiting to release ions back into solution) cycles with (A) NaCl (10 mM; 10 min charging, 10 min discharging) and (B) NaPFOA (1.7 mM; 30 min charging, 30 min discharging). With NaCl, a consistent decrease in effluent conductivity during charging and a spike in conductivity during discharging was observed. With NaPFOA, we observed a brief decrease in conductivity but then an increase above the influent value during charging, suggesting that NaPFOA was released from the electrodes during charging.

In contrast, when we used this same approach with NaPFOA (1.7 mM), we observed a much different trend. In the first few cycles, we observed similar charge-discharge profiles as we saw with NaCl, indicating that we were able to desorb PFOA from the electrodes (data not shown). However, after multiple cycles, we noticed an increase in solution conductivity during charging (**Fig. 9B**). We explain this atypical behavior as follows. First, PFOA has a stronger affinity for AC than NaCl in the absence of a voltage. During the short-circuit step (i.e., discharge), the electrodes essentially function as one large surface to which PFOA, that is continuously flowing through the cell, can adsorb. We hypothesize that in this step physical adsorption of PFOA to the electrodes is occurring. Second, we postulate that some PFOA ions that physically adsorbed were released back to solution when the electrode they were adsorbed to became negative upon application of the voltage. If these mechanisms were occurring, then we would expect to see an increase in conductivity during charging (via release of PFOA that adsorbed during discharge) and a decrease in conductivity during discharging (via physical adsorption to the short-circuited electrodes). In summary, these results are inconclusive with respect to the ability of electrical assistance to enhance the desorption of PFAS from AC. They suggest that conventional CDI operation (i.e., alternating charge/discharge) cycling may not be the best method when trying to remove ions that have a high affinity for AC, but they also provide some evidence that PFAS might be released if the desorption voltage is controlled. It is important to note that these preliminary tests were done with PFOA, which has a relatively high affinity for AC across the spectrum of PFAS. Tests with shorter chain PFAS, such as PFBS, may yield different results with respect to desorption due to the lower affinity of those species for AC.

3.6 Electrically-assisted sorption of PFAS in real waters

To determine if an applied voltage could increase the removal of PFAS mixtures, we conducted a preliminary test using a real water sample. The sample was collected in November 2019 from the BW-MW-15 well cluster at the former Naval Air Station (NAS) Joint Reserve Base (JRB) Willow Grove in Horsham Township, Montgomery County, Pennsylvania. The water quality analysis from May 2019 provided by the SERDP contact for that site included 18 different PFAS. Of the 18, PFBS, PFHxS, PFHxA, PFHpA, PFOS, and PFOA were > 160 ng/L (**Table 2**). In our tests, we focused only on these six PFAS and measured their concentration over time in the effluent.

Table 2. Concentrations of six PFAS detected in the real water sample from NAS JRB Willow Grove in May 2019 (provided by SERDP contact) and June 2020 (conducted at NCSU).

ng/L	PFBS	PFHxS	PFHxA	PFHpA	PFOS	PFOA
May-19	402±10	3196±185	805±27	161±3	28823±3582	658±90
Jun-20	251±13	2133±203	951±81	239±16	7932±638	2272±276

All tests were conducted in the same electrochemical cell as described above in the single-solute tests. Briefly, new electrodes were installed in the cell, the cell was operated overnight under a constant flow of DI water, and the feed was switched to the real water sample and the cell operated for four hours. This procedure was repeated for the applied voltage (1.0 V) and no voltage controls. Effluent samples were collected at several time points during the four hour test and then analyzed (raw data and QA/QC available in the Appendix).

Our preliminary tests show that there was no significant difference in the removal of the six PFAS with versus without an applied voltage (**Fig. 10**). Only PFHxS had an observable difference. The error associated with the measurements of the remaining PFAS overlapped between treatments, which makes it challenging to ascertain meaningful differences. These findings are not entirely unexpected considering that the electrochemical cell was not optimized for PFAS removal. The design we used was well suited for proof-of-concept electrosorption tests, especially for small inorganic ions such as Na⁺ and Cl⁻. The short retention time (~10 seconds) and poor mass transfer through the electrodes (i.e., flow-by rather than flow-through) are not optimized for contact time between the electrodes and PFAS. Both of these properties are important in field-scale adsorbers. Designs that can improve contact time while maintaining electrical control of the carbon bed are needed to adequately assess PFAS removal from real waters. It is also possible that constituents in the real water, such as dissolved solids (total dissolved solids concentration was 203±6 mg/L and Cl⁻ was 22.5±0.7 mg/L), negatively impacted PFAS adsorption. While our results above show that Cl⁻ concentrations around 1 mM did not negatively impact PFBS electrosorption (**Fig. 8A**), there were likely other anions in the real water that could have “competed” with PFAS for electrosorption sites. Further studies of the influence of matrix components on PFAS electrosorption are thus warranted.

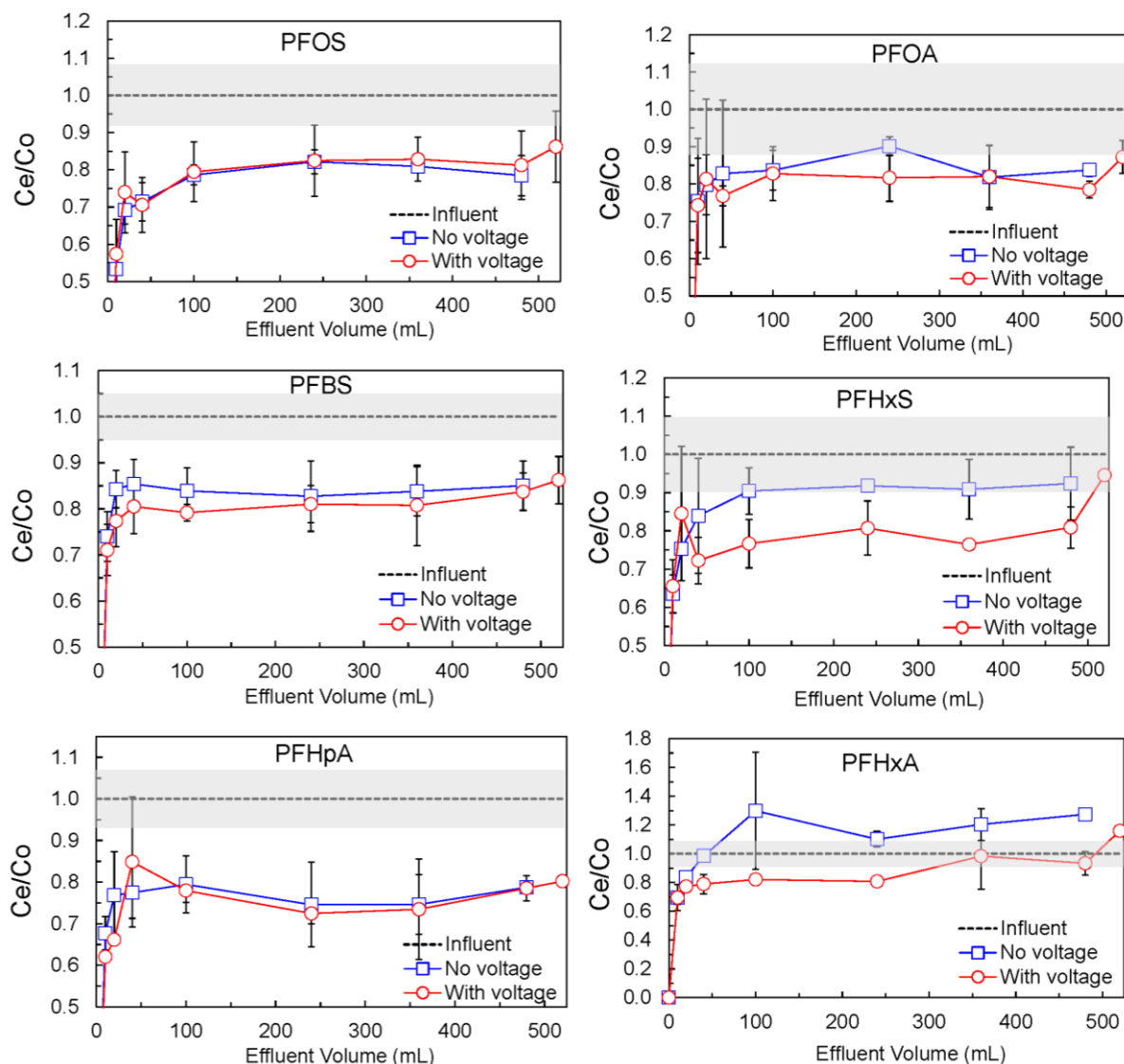


Fig. 10. Effluent concentrations of PFAS from a real water sample with and without an applied voltage (1.0 V) across two AC cloth electrodes. The effluent concentrations (C_e) are normalized to the average influent concentrations (C_o ; $n=4$). The shaded box shows the standard deviation of the average influent measurements. Error bars represent the average of measurements from two independent samples. X-axis represents the volume of water treated over time.

4.0 Conclusions and Implications for Future Research

Our results show that applying a low voltage (1.0 V) between two activated carbon (AC) electrodes can enhance the adsorption of PFAS onto AC by almost four times compared to AC electrodes without an applied voltage. The enhancement was dependent on PFAS species. In general, within the sulfonates and carboxylates, shorter chain species had a greater enhancement with voltage than the longer chain species. For similarly sized molecules, the carboxylates yielded a greater enhancement with voltage. In the presence of Cl^- (1 mM), an abundant anion in groundwater, PFBS electrosorption was not significantly lowered. At a higher Cl^- concentration

(10 mM), PFBS removals with and without a voltage were similar, suggesting Cl^- had a stronger competitive effect at higher concentrations. Preliminary tests on electrodesorption were inconclusive and suggested that electrical assistance may not be able to fully desorb physically adsorbed PFAS. In summary, the findings of this proof-of-concept, limited-scope project provide a foundation for continued investigation into the following areas: (1) systematic evaluation of granular AC materials to determine optimal conductivity and porosity properties to electrosorb PFAS, (2) investigation of desorption under a wider set of electrochemical conditions (e.g., reverse voltage/current), and (3) bench-scale column tests under equilibrium conditions using defined and real waters. The following describes our proposed tasks to complete the next steps.

Year 1

Task 1.1: Evaluation of GAC electrode materials. We will transition from using the AC cloth in this study to GAC, which is more commonly used in the field and better suited for column testing. To select the optimal GAC for Year 2, we will evaluate a suite of different GAC that vary in properties relevant to our electrochemical method. Most importantly, we will study PFAS electrosorption onto GAC that vary in electrical conductivity to identify the optimal balance between conductivity and surface area.

Task 1.2: Electrically-assisted desorption testing. We did not have the opportunity to fully explore electrically-assisted desorption in our proof-of-concept study. We will study a variety of different techniques, including reverse voltage and current. We will quantify and track PFAS desorption in our electrochemical cells to understand the ability of electrochemical methods to desorb physically- and electrically-adsorbed PFAS.

Year 2

Task 2.1: Column testing. We will design, build, and test GAC-based columns to conduct equilibrium PFAS breakthrough tests. Our proof-of-concept design was not optimized for such tests, so we conducted tests for a limited amount of time (two hours). We will conduct equilibrium breakthrough tests with defined PFAS solutions using small-scale columns that have been modified for electrical control of the GAC. We have preliminary results on such a design showing that a bed of GAC can be used to electrosorb NaCl .

Task 2.2: Evaluation of matrix effects and real water testing. Once the electroactive GAC column is validated and tested with defined PFAS solutions (Task 2.1), we will systematically study the effects of matrix components that are common to many contaminated sites. Examples include dissolved inorganic ions, natural organic matter, and alkalinity. We will also conduct tests to determine the effectiveness of the GAC columns to remove PFAS from real water samples.

Task 2.3: Techno-economic assessment. We will complete a techno-economic assessment of our bench-scale column systems and include a recommendation for pilot- and larger-scale systems.

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6.0 Appendix

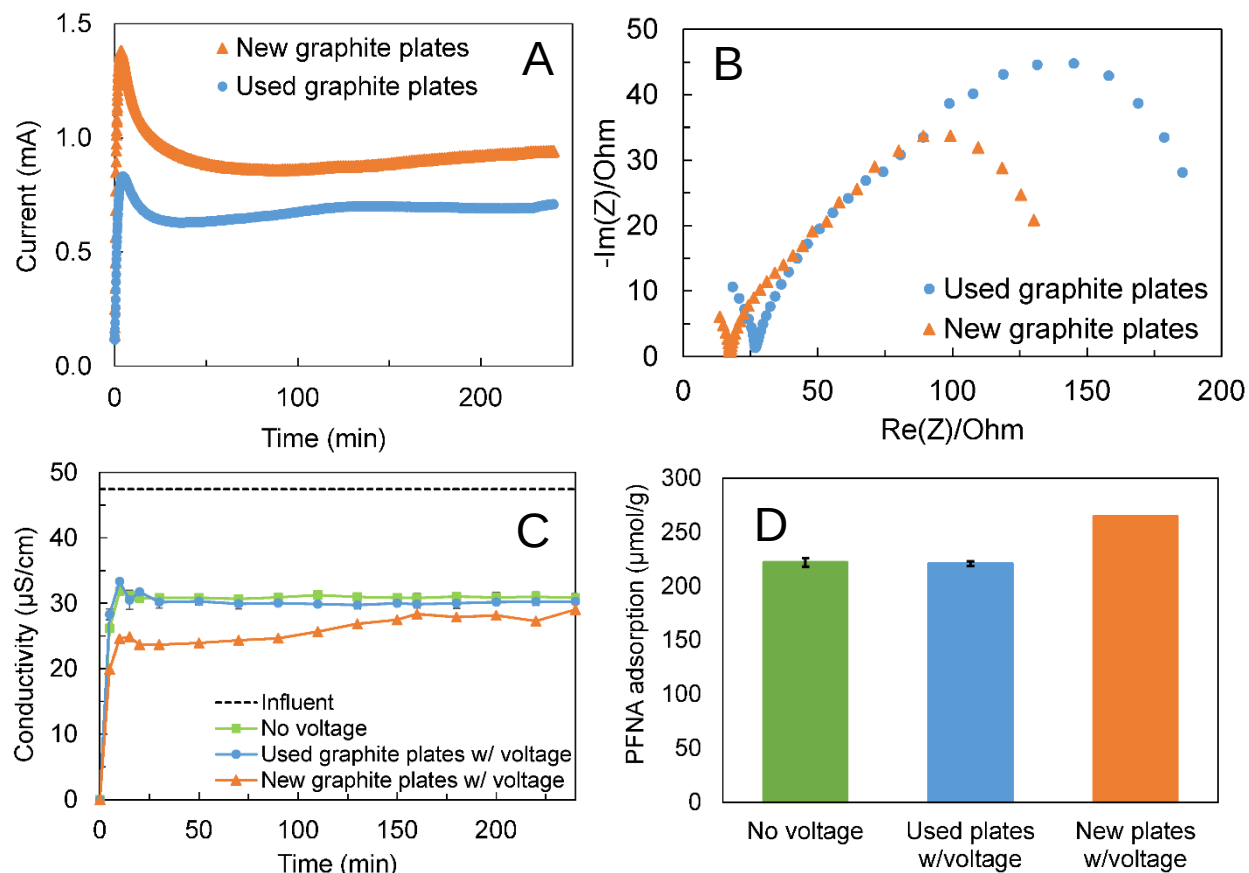


Fig. A1. Comparison of performance with old and new graphite current collectors. (A) The electrical current recorded during the application of 1.0 volt in the presence of PFAS. (B) Nyquist plot showing impedance (i.e., resistance). The used graphite plates (blue circles) had a much larger charge transfer resistance as shown in the larger semi-circle. (C) Effluent conductivity overtime for the PFNA test. (D) Difference in PFNA adsorption.

Data used to generate figures

Data for Fig. 2A

Time (min)	Conductivity - No voltage ($\mu\text{S}/\text{cm}$)	Error ($\mu\text{S}/\text{cm}$)	Conductivity - With voltage ($\mu\text{S}/\text{cm}$)	Error ($\mu\text{S}/\text{cm}$)	Conductivity - Influent ($\mu\text{S}/\text{cm}$)
0	0.1	0.1	0.4	0.0	60.4
3	44.2	6.4	21.8	5.5	60.4
6	51.6	3.7	25.2	5.3	60.4
9	54.2	2.4	30.0	3.8	60.4
12	55.5	1.7	33.5	2.4	60.4
15	56.1	1.4	35.3	1.3	60.4
18	56.7	1.0	37.0	0.2	60.4
21	57.2	0.6	39.9	2.0	60.4
24	57.7	0.4	40.9	2.3	60.4
27	58.1	0.3	41.8	2.5	60.4
30	58.4	0.2	42.8	2.7	60.4
33	58.6	0.3	43.5	2.7	60.4
36	58.9	0.3	44.3	2.5	60.4
39	59.0	0.2	45.0	2.4	60.4
42	59.2	0.2	45.4	2.1	60.4
45	59.3	0.3	46.2	2.2	60.4
48	59.3	0.2	46.6	2.5	60.4
51	59.4	0.2	46.4	2.8	60.4
54	59.5	0.3	45.9	3.7	60.4
57	59.4	0.2	46.8	3.0	60.4
60	59.5	0.2	47.0	3.3	60.4
63	59.5	0.2	46.6	3.5	60.4
66	59.7	0.2	46.7	3.6	60.4
69	59.6	0.2	46.7	3.8	60.4
72	59.7	0.2	45.8	4.8	60.4
75	59.7	0.1	46.4	4.4	60.4
78	59.8	0.2	46.6	4.5	60.4
81	59.7	0.1	46.6	4.6	60.4
84	59.7	0.2	47.5	3.9	60.4
87	59.8	0.1	46.7	4.7	60.4
90	59.7	0.1	44.9	6.6	60.4
93	59.8	0.1	45.1	4.5	60.4
96	59.8	0.1	45.7	3.4	60.4
99	59.8	0.1	46.0	4.3	60.4
102	59.8	0.1	46.1	4.4	60.4

105	59.8	0.1	46.2	4.5	60.4
108	59.9	0.1	46.4	4.4	60.4
111	59.8	0.1	45.9	4.8	60.4
114	59.8	0.1	45.2	4.5	60.4
117	59.8	0.0	44.9	3.8	60.4
120	59.8	0.0	44.3	3.3	60.4

Data for Fig. 2B

Time (min)	Adsorption - No voltage ($\mu\text{mol/g}$)	Error ($\mu\text{mol/g}$)	Adsorption - With voltage ($\mu\text{mol/g}$)	Error ($\mu\text{mol/g}$)
50	14.2	4.2	59.8	1.4
120	17.1	4.8	112.5	15.2

Data for Fig. 3A

Time (min)	Conductivity - No voltage ($\mu\text{S/cm}$)	Error ($\mu\text{S/cm}$)	Conductivity - With voltage ($\mu\text{S/cm}$)	Error ($\mu\text{S/cm}$)	Conductivity - Influent ($\mu\text{S/cm}$)
0	0.3	0.3	0.0	0.0	36.7
5	29.0	2.4	19.7	1.5	36.7
10	32.0	1.8	21.3	1.9	36.7
15	32.8	1.7	22.7	0.8	36.7
20	33.9	1.1	23.0	0.8	36.7
25	33.2	1.2	22.4	1.2	36.7
30	33.5	1.4	23.3	0.9	36.7
40	31.8	2.6	23.5	1.1	36.7
50	31.8	2.4	25.8	2.6	36.7
60	31.9	2.3	23.4	2.1	36.7
70	32.1	2.2	23.7	2.0	36.7
80	32.3	2.0	24.2	2.6	36.7
90	32.6	1.7	26.6	1.2	36.7
100	34.5	1.3	25.4	3.3	36.7
110	32.8	1.8	25.0	2.8	36.7
120	32.7	2.1	25.0	2.5	36.7

Data for Fig. 3B

No voltage			With voltage			Influent (mg/L)
Time (min)	PFOA (mg/L)	Error (mg/L)	Time (min)	PFOA (mg/L)	Error (mg/L)	
0	0.0	--	0	0	0	165
5	104.9	--	5	63.4	2.9	165

10	131.4	--	10	89.0	10.2	165
50	131.9	--	50	93.7	6.9	165
150	146.6	9.3	90	106.7	--	165
200	128.5	--	110	83.7	--	165
240	157.1	--	150	104.2	11.0	165
			200	112.3	9.7	165
			240	115.2	1.6	165

Data for Fig. 3C

PFOA (mM)	Conductivity (μ S/cm)
0.0	0.0
0.4	36.7
0.6	54.0
1.1	106.5

Data for Fig. 4A

PFBS (mM)	Conductivity (uS/cm)
0.0	0.0
0.2	24.9
0.3	51.7
0.5	76.0

Data for Fig. 4B

PFHpA (mM)	Conductivity (uS/cm)
0.0	0.0
0.7	43.5
1.0	65.2
2.0	128.8

Data for Fig. 4C

PFOS (mM)	Conductivity (uS/cm)
0.0	0.0
0.2	48.0
0.3	63.2
0.4	71.4

Data for Fig. 4D

PFNA (mM)	Conductivity (uS/cm)
0.0	0.0
0.5	48.0
0.7	71.3
1.4	139.0

Data for Fig. 4E

PFHxS (mM)	Conductivity (uS/cm)
0.0	0.0
0.4	50.4
0.5	60.1
0.7	75.0
0.9	99.3
1.3	148.2
1.5	164.4

Data for Fig. 5A

Time (min)	Conductivity - No voltage (μ S/cm)	Error (μ S/cm)	Conductivity - With voltage (μ S/cm)	Error (μ S/cm)	Conductivity - Influent (μ S/cm)
0	0.0	0.0	0.0	0.0	51.7
5	41.7	0.6	35.0	0.7	51.7
10	44.7	2.2	38.0	1.8	51.7
15	44.6	2.6	38.0	1.5	51.7
20	44.6	2.8	38.1	1.6	51.7
30	45.0	2.7	38.1	1.2	51.7
50	46.7	1.3	38.9	0.8	51.7
70	49.1	0.5	40.5	0.0	51.7
90	49.3	0.6	42.5	0.3	51.7
110	49.0	0.0	44.0	0.5	51.7
120	48.8	0.0	45.4	0.0	51.7

Data for Fig. 5B

Time (min)	Conductivity - No voltage (μ S/cm)	Error (μ S/cm)	Conductivity - With voltage (μ S/cm)	Error (μ S/cm)	Conductivity - Influent (μ S/cm)
0	0.4	0.0	0.0	0.0	50.4
5	37.5	3.2	30.1	1.4	50.4
10	41.7	0.9	34.9	1.3	50.4

15	41.8	1.5	34.9	1.3	50.4
20	41.9	1.9	35.3	0.9	50.4
30	41.9	2.1	35.8	0.6	50.4
50	41.9	2.1	36.7	0.3	50.4
70	42.3	1.8	38.0	0.1	50.4
90	42.8	1.5	39.2	0.7	50.4
110	43.2	1.2	39.8	0.6	50.4
120	44.5	0.0	39.9	0.3	50.4

Data for Fig. 5C

Time (min)	Conductivity - No voltage ($\mu\text{S/cm}$)	Error ($\mu\text{S/cm}$)	Conductivity - With voltage ($\mu\text{S/cm}$)	Error ($\mu\text{S/cm}$)	Conductivity - Influent ($\mu\text{S/cm}$)
0	0.7	0.1	0.4	0.3	34.2
5	25.2	1.3	20.3	0.9	34.2
10	29.8	0.2	24.7	1.7	34.2
15	30.3	0.5	24.6	1.8	34.2
20	30.4	1.0	24.5	1.6	34.2
30	30.5	1.2	24.6	1.3	34.2
50	30.3	1.3	24.6	1.0	34.2
60	30.4	1.3	24.7	0.8	34.2
80	30.4	1.2	25.1	0.7	34.2
100	30.4	1.1	25.4	0.7	34.2
120	30.4	1.2	25.8	0.7	34.2

Data for Fig. 5D

Time (min)	Conductivity - No voltage ($\mu\text{S/cm}$)	Error ($\mu\text{S/cm}$)	Conductivity - With voltage ($\mu\text{S/cm}$)	Error ($\mu\text{S/cm}$)	Conductivity - Influent ($\mu\text{S/cm}$)
0	0.0	0.0	0.0	0.0	40.8
5	28.4	1.0	21.6	2.8	40.8
10	34.8	2.6	25.7	2.8	40.8
15	34.3	2.0	25.8	2.6	40.8
20	34.7	2.3	26.0	2.5	40.8
30	35.0	2.3	26.5	2.3	40.8
50	35.8	2.5	27.3	2.0	40.8
60	33.7	0.0	27.8	1.7	40.8
80	34.2	0.0	28.7	1.6	40.8
100	34.4	0.0	29.7	1.6	40.8
120	34.7	0.0	30.5	1.9	40.8

Data for Fig. 5E

Time (min)	Conductivity - No voltage ($\mu\text{S/cm}$)	Error ($\mu\text{S/cm}$)	Conductivity - With voltage ($\mu\text{S/cm}$)	Error ($\mu\text{S/cm}$)	Conductivity - Influent ($\mu\text{S/cm}$)
0	0.8	0.2	0.0	0.0	35.8
5	27.1	1.4	13.7	0.3	35.8
10	30.2	0.7	18.7	2.1	35.8
15	31.5	0.3	18.0	2.5	35.8
20	31.6	0.5	18.3	2.3	35.8
30	31.4	0.6	18.7	2.3	35.8
50	31.2	0.5	19.3	2.0	35.8
60	31.2	0.5	20.0	2.1	35.8
80	31.1	0.6	21.5	1.3	35.8
100	31.3	0.5	23.3	0.7	35.8
120	31.2	0.0	22.0	3.0	35.8

Data for Fig. 6

	No voltage		With voltage	
	Partition coefficient (mL/g)	Error (mL/g)	Partition coefficient (mL/g)	Error (mL/g)
PFBS	75.7	18.3	197.9	13.2
PFHxS	148.0	23.9	250.0	7.9
PFOS	202.2	1.9	351.2	32.4
PFHpA	127.0	8.7	468.5	9.8
PFOA	122.8	6.2	400.6	5.0
PFNA	185.9	18.6	282.1	15.1
NaCl	34.5	9.8	307.1	41.4

Data for Fig. 7

	Molar volume (cm^3)	Enhancement due to voltage
PFBS	162	2.6
PFHxS	217	1.7
PFOS	272	1.7
PFHpA	210	3.7
PFOA	237	3.3
PFNA	265	1.5

Data for Fig. 8A

No voltage			With voltage			Influent ($\mu\text{g/L}$)
Time (min)	PFBS ($\mu\text{g/L}$)	Error ($\mu\text{g/L}$)	Time (min)	PFBS ($\mu\text{g/L}$)	Error ($\mu\text{g/L}$)	
0	0.0	0.0	0	0.0	0.0	17.9
5	11.1	0.3	5	7.9	0.9	17.9
20	13.6	1.1	20	9.1	1.4	17.9
50	13.3	1.0	50	9.9	1.8	17.9
80	14.0	1.1	80	10.8	1.5	17.9
120	12.9	0.1	120	10.6	1.5	17.9

Data for Fig. 8B

No voltage			With voltage			Influent ($\mu\text{g/L}$)
Time (min)	PFBS ($\mu\text{g/L}$)	Error ($\mu\text{g/L}$)	Time (min)	PFBS ($\mu\text{g/L}$)	Error ($\mu\text{g/L}$)	
0	0.0	0.0	0	0.0	0.0	10.8
5	4.6	0.8	5	5.0	1.4	10.8
10	3.4	0.0	10	8.1	0.1	10.8
20	5.8	1.1	20	6.3	0.9	10.8
50	5.7	1.0	50	6.2	1.5	10.8
80	3.9	0.1	80	8.4	0.0	10.8
120	6.9	1.7	120	7.0	0.7	10.8

Data for Fig. 8C

Time (min)	No voltage		With voltage	
	Adsorption ($\mu\text{mol/g}$)	Error ($\mu\text{mol/g}$)	Adsorption ($\mu\text{mol/g}$)	Error ($\mu\text{mol/g}$)
50	4.1	0.9	9.2	1.6
120	7.4	2.9	20.2	4.3

Data for Fig. 8D

Time (min)	No voltage		With voltage	
	Adsorption ($\mu\text{mol/g}$)	Error ($\mu\text{mol/g}$)	Adsorption ($\mu\text{mol/g}$)	Error ($\mu\text{mol/g}$)
50	5.7	1.9	5.1	1.9
120	12.7	4.7	10.8	4.1

Data for Fig. 9A

Time (min)	Effluent conductivity (mS/cm)	Influent conductivity (mS/cm)
---------------	--	--

0.0	1.2	1.2
0.1	1.2	1.2
0.2	1.0	1.2
0.3	0.9	1.2
0.4	0.7	1.2
0.5	0.7	1.2
0.6	0.6	1.2
0.7	0.6	1.2
0.8	0.5	1.2
0.9	0.5	1.2
1.0	0.5	1.2
1.1	0.5	1.2
1.2	0.5	1.2
1.3	0.5	1.2
1.4	0.5	1.2
1.5	0.4	1.2
1.6	0.4	1.2
1.7	0.4	1.2
1.8	0.4	1.2
1.9	0.4	1.2
2.0	0.5	1.2
2.1	0.5	1.2
2.2	0.5	1.2
2.3	0.5	1.2
2.4	0.5	1.2
2.5	0.5	1.2
2.6	0.5	1.2
2.7	0.5	1.2
2.8	0.5	1.2
2.9	0.5	1.2
3.0	0.5	1.2
3.1	0.5	1.2
3.2	0.5	1.2
3.3	0.5	1.2
3.4	0.6	1.2
3.5	0.6	1.2
3.6	0.6	1.2
3.7	0.6	1.2
3.8	0.6	1.2

3.9	0.6	1.2
4.0	0.6	1.2
4.1	0.6	1.2
4.2	0.6	1.2
4.3	0.7	1.2
4.4	0.7	1.2
4.5	0.7	1.2
4.6	0.7	1.2
4.7	0.7	1.2
4.8	0.7	1.2
4.9	0.7	1.2
5.0	0.7	1.2
5.1	0.7	1.2
5.2	0.7	1.2
5.3	0.8	1.2
5.4	0.8	1.2
5.5	0.8	1.2
5.6	0.8	1.2
5.7	0.8	1.2
5.8	0.8	1.2
5.9	0.8	1.2
6.0	0.8	1.2
6.1	0.8	1.2
6.2	0.9	1.2
6.3	0.9	1.2
6.4	0.9	1.2
6.5	0.9	1.2
6.6	0.9	1.2
6.7	0.9	1.2
6.8	0.9	1.2
6.9	0.9	1.2
7.0	0.9	1.2
7.1	0.9	1.2
7.2	0.9	1.2
7.3	1.0	1.2
7.4	1.0	1.2
7.5	1.0	1.2
7.6	1.0	1.2
7.7	1.0	1.2
7.8	1.0	1.2
7.9	1.0	1.2

8.0	1.0	1.2
8.1	1.0	1.2
8.2	1.0	1.2
8.3	1.0	1.2
8.4	1.0	1.2
8.5	1.0	1.2
8.6	1.0	1.2
8.7	1.0	1.2
8.8	1.0	1.2
8.9	1.1	1.2
9.0	1.1	1.2
9.1	1.1	1.2
9.2	1.1	1.2
9.3	1.1	1.2
9.4	1.1	1.2
9.5	1.1	1.2
9.6	1.1	1.2
9.7	1.1	1.2
9.8	1.1	1.2
9.9	1.1	1.2
10.0	1.1	1.2
10.1	1.1	1.2
10.2	1.4	1.2
10.3	2.1	1.2
10.4	2.7	1.2
10.5	3.1	1.2
10.6	3.5	1.2
10.7	3.6	1.2
10.8	3.4	1.2
10.9	3.1	1.2
11.0	2.8	1.2
11.1	2.6	1.2
11.2	2.3	1.2
11.3	2.2	1.2
11.4	2.0	1.2
11.5	1.9	1.2
11.6	1.8	1.2
11.7	1.7	1.2
11.8	1.7	1.2
11.9	1.6	1.2
12.0	1.5	1.2

12.1	1.5	1.2
12.2	1.5	1.2
12.3	1.4	1.2
12.4	1.4	1.2
12.5	1.4	1.2
12.6	1.4	1.2
12.7	1.4	1.2
12.8	1.3	1.2
12.9	1.3	1.2
13.0	1.3	1.2
13.1	1.3	1.2
13.2	1.3	1.2
13.3	1.3	1.2
13.4	1.3	1.2
13.5	1.3	1.2
13.6	1.3	1.2
13.7	1.3	1.2
13.8	1.3	1.2
13.9	1.3	1.2
14.0	1.3	1.2
14.1	1.3	1.2
14.2	1.3	1.2
14.3	1.3	1.2
14.4	1.2	1.2
14.5	1.2	1.2
14.6	1.2	1.2
14.7	1.2	1.2
14.8	1.2	1.2
14.9	1.2	1.2
15.0	1.2	1.2
15.1	1.2	1.2
15.2	1.2	1.2
15.3	1.2	1.2
15.4	1.2	1.2
15.5	1.2	1.2
15.6	1.2	1.2
15.7	1.2	1.2
15.8	1.2	1.2
15.9	1.2	1.2
16.0	1.2	1.2
16.1	1.2	1.2

16.2	1.2	1.2
16.3	1.2	1.2
16.4	1.2	1.2
16.5	1.2	1.2
16.6	1.2	1.2
16.7	1.2	1.2
16.8	1.2	1.2
16.9	1.2	1.2
17.0	1.2	1.2
17.1	1.2	1.2
17.2	1.2	1.2
17.3	1.2	1.2
17.4	1.2	1.2
17.5	1.2	1.2
17.6	1.2	1.2
17.7	1.2	1.2
17.8	1.2	1.2
17.9	1.2	1.2
18.0	1.2	1.2
18.1	1.2	1.2
18.2	1.2	1.2
18.3	1.2	1.2
18.4	1.2	1.2
18.5	1.2	1.2
18.6	1.2	1.2
18.7	1.2	1.2
18.8	1.2	1.2
18.9	1.2	1.2
19.0	1.2	1.2
19.1	1.2	1.2
19.2	1.2	1.2
19.3	1.2	1.2
19.4	1.2	1.2
19.5	1.2	1.2
19.6	1.2	1.2
19.7	1.2	1.2
19.8	1.2	1.2
19.9	1.2	1.2
20.0	1.2	1.2
20.1	1.2	1.2
20.2	1.2	1.2

20.3	0.9	1.2
20.4	0.8	1.2
20.5	0.7	1.2
20.6	0.6	1.2
20.7	0.6	1.2
20.8	0.5	1.2
20.9	0.5	1.2
21.0	0.5	1.2
21.1	0.5	1.2
21.2	0.5	1.2
21.3	0.5	1.2
21.4	0.5	1.2
21.5	0.5	1.2
21.6	0.5	1.2
21.7	0.5	1.2
21.8	0.5	1.2
21.9	0.5	1.2
22.0	0.5	1.2
22.1	0.5	1.2
22.2	0.5	1.2
22.3	0.5	1.2
22.4	0.5	1.2
22.5	0.5	1.2
22.6	0.5	1.2
22.7	0.5	1.2
22.8	0.5	1.2
22.9	0.5	1.2
23.0	0.5	1.2
23.1	0.5	1.2
23.2	0.5	1.2
23.3	0.6	1.2
23.4	0.6	1.2
23.5	0.6	1.2
23.6	0.6	1.2
23.7	0.6	1.2
23.8	0.6	1.2
23.9	0.6	1.2
24.0	0.6	1.2
24.1	0.6	1.2
24.2	0.6	1.2
24.3	0.7	1.2

24.4	0.7	1.2
24.5	0.7	1.2
24.6	0.7	1.2
24.7	0.7	1.2
24.8	0.7	1.2
24.9	0.7	1.2
25.0	0.7	1.2
25.1	0.8	1.2
25.2	0.8	1.2
25.3	0.8	1.2
25.4	0.8	1.2
25.5	0.8	1.2
25.6	0.8	1.2
25.7	0.8	1.2
25.8	0.8	1.2
25.9	0.8	1.2
26.0	0.9	1.2
26.1	0.9	1.2
26.2	0.9	1.2
26.3	0.9	1.2
26.4	0.9	1.2
26.5	0.9	1.2
26.6	0.9	1.2
26.7	0.9	1.2
26.8	0.9	1.2
26.9	0.9	1.2
27.0	0.9	1.2
27.1	1.0	1.2
27.2	1.0	1.2
27.3	1.0	1.2
27.4	1.0	1.2
27.5	1.0	1.2
27.6	1.0	1.2
27.7	1.0	1.2
27.8	1.0	1.2
27.9	1.0	1.2
28.0	1.0	1.2
28.1	1.0	1.2
28.2	1.0	1.2
28.3	1.0	1.2
28.4	1.1	1.2

28.5	1.1	1.2
28.6	1.1	1.2
28.7	1.1	1.2
28.8	1.1	1.2
28.9	1.1	1.2
29.0	1.1	1.2
29.1	1.1	1.2
29.2	1.1	1.2
29.3	1.1	1.2
29.4	1.1	1.2
29.5	1.1	1.2
29.6	1.1	1.2
29.7	1.1	1.2
29.8	1.1	1.2
29.9	1.1	1.2
30.0	1.1	1.2
30.1	1.1	1.2
30.2	1.3	1.2
30.3	2.0	1.2
30.4	2.6	1.2
30.5	3.1	1.2
30.6	3.5	1.2
30.7	3.7	1.2
30.8	3.6	1.2
30.9	3.3	1.2
31.0	3.0	1.2
31.1	2.7	1.2
31.2	2.4	1.2
31.3	2.2	1.2
31.4	2.1	1.2
31.5	2.0	1.2
31.6	1.8	1.2
31.7	1.8	1.2
31.8	1.7	1.2
31.9	1.6	1.2
32.0	1.6	1.2
32.1	1.5	1.2
32.2	1.5	1.2
32.3	1.5	1.2
32.4	1.4	1.2
32.5	1.4	1.2

32.6	1.4	1.2
32.7	1.4	1.2
32.8	1.4	1.2
32.9	1.3	1.2
33.0	1.3	1.2
33.1	1.3	1.2
33.2	1.3	1.2
33.3	1.3	1.2
33.4	1.3	1.2
33.5	1.3	1.2
33.6	1.3	1.2
33.7	1.3	1.2
33.8	1.3	1.2
33.9	1.3	1.2
34.0	1.3	1.2
34.1	1.3	1.2
34.2	1.3	1.2
34.3	1.3	1.2
34.4	1.3	1.2
34.5	1.3	1.2
34.6	1.3	1.2
34.7	1.3	1.2
34.8	1.3	1.2
34.9	1.3	1.2
35.0	1.2	1.2
35.1	1.2	1.2
35.2	1.2	1.2
35.3	1.2	1.2
35.4	1.2	1.2
35.5	1.2	1.2
35.6	1.2	1.2
35.7	1.2	1.2
35.8	1.2	1.2
35.9	1.2	1.2
36.0	1.2	1.2
36.1	1.2	1.2
36.2	1.2	1.2
36.3	1.2	1.2
36.4	1.2	1.2
36.5	1.2	1.2
36.6	1.2	1.2

36.7	1.2	1.2
36.8	1.2	1.2
36.9	1.2	1.2
37.0	1.2	1.2
37.1	1.2	1.2
37.2	1.2	1.2
37.3	1.2	1.2
37.4	1.2	1.2
37.5	1.2	1.2
37.6	1.2	1.2
37.7	1.2	1.2
37.8	1.2	1.2
37.9	1.2	1.2
38.0	1.2	1.2
38.1	1.2	1.2
38.2	1.2	1.2
38.3	1.2	1.2
38.4	1.2	1.2
38.5	1.2	1.2
38.6	1.2	1.2
38.7	1.2	1.2
38.8	1.2	1.2
38.9	1.2	1.2
39.0	1.2	1.2
39.1	1.3	1.2
39.2	1.2	1.2
39.3	1.3	1.2
39.4	1.3	1.2
39.5	1.3	1.2
39.6	1.3	1.2
39.7	1.3	1.2
39.8	1.3	1.2
39.9	1.3	1.2
40.0	1.3	1.2
40.1	1.3	1.2
40.2	1.2	1.2
40.3	1.0	1.2
40.4	0.8	1.2
40.5	0.7	1.2
40.6	0.6	1.2
40.7	0.6	1.2

40.8	0.5	1.2
40.9	0.5	1.2
41.0	0.5	1.2
41.1	0.5	1.2
41.2	0.5	1.2
41.3	0.5	1.2
41.4	0.5	1.2
41.5	0.5	1.2
41.6	0.5	1.2
41.7	0.5	1.2
41.8	0.5	1.2
41.9	0.5	1.2
42.0	0.5	1.2
42.1	0.5	1.2
42.2	0.5	1.2
42.3	0.5	1.2
42.4	0.5	1.2
42.5	0.5	1.2
42.6	0.5	1.2
42.7	0.5	1.2
42.8	0.5	1.2
42.9	0.5	1.2
43.0	0.5	1.2
43.1	0.5	1.2
43.2	0.5	1.2
43.3	0.5	1.2
43.4	0.6	1.2
43.5	0.6	1.2
43.6	0.6	1.2
43.7	0.6	1.2
43.8	0.6	1.2
43.9	0.6	1.2
44.0	0.6	1.2
44.1	0.6	1.2
44.2	0.6	1.2
44.3	0.7	1.2
44.4	0.7	1.2
44.5	0.7	1.2
44.6	0.7	1.2
44.7	0.7	1.2
44.8	0.7	1.2

44.9	0.7	1.2
45.0	0.7	1.2
45.1	0.7	1.2
45.2	0.8	1.2
45.3	0.8	1.2
45.4	0.8	1.2
45.5	0.8	1.2
45.6	0.8	1.2
45.7	0.8	1.2
45.8	0.8	1.2
45.9	0.8	1.2
46.0	0.8	1.2
46.1	0.9	1.2
46.2	0.9	1.2
46.3	0.9	1.2
46.4	0.9	1.2
46.5	0.9	1.2
46.6	0.9	1.2
46.7	0.9	1.2
46.8	0.9	1.2
46.9	0.9	1.2
47.0	0.9	1.2
47.1	1.0	1.2
47.2	1.0	1.2
47.3	1.0	1.2
47.4	1.0	1.2
47.5	1.0	1.2
47.6	1.0	1.2
47.7	1.0	1.2
47.8	1.0	1.2
47.9	1.0	1.2
48.0	1.0	1.2
48.1	1.0	1.2
48.2	1.0	1.2
48.3	1.0	1.2
48.4	1.1	1.2
48.5	1.1	1.2
48.6	1.1	1.2
48.7	1.1	1.2
48.8	1.1	1.2
48.9	1.1	1.2

49.0	1.1	1.2
49.1	1.1	1.2
49.2	1.1	1.2
49.3	1.1	1.2
49.4	1.1	1.2
49.5	1.1	1.2
49.6	1.1	1.2
49.7	1.1	1.2
49.8	1.1	1.2
49.9	1.1	1.2
50.0	1.1	1.2
50.1	1.1	1.2
50.2	1.2	1.2
50.3	1.9	1.2
50.4	2.5	1.2
50.5	3.1	1.2
50.6	3.5	1.2
50.7	3.7	1.2
50.8	3.6	1.2
50.9	3.3	1.2
51.0	3.0	1.2
51.1	2.7	1.2
51.2	2.5	1.2
51.3	2.3	1.2
51.4	2.1	1.2
51.5	2.0	1.2
51.6	1.9	1.2
51.7	1.8	1.2
51.8	1.7	1.2
51.9	1.6	1.2
52.0	1.6	1.2
52.1	1.5	1.2
52.2	1.5	1.2
52.3	1.5	1.2
52.4	1.4	1.2
52.5	1.4	1.2
52.6	1.4	1.2
52.7	1.4	1.2
52.8	1.4	1.2
52.9	1.4	1.2
53.0	1.3	1.2

53.1	1.3	1.2
53.2	1.3	1.2
53.3	1.3	1.2
53.4	1.3	1.2
53.5	1.3	1.2
53.6	1.3	1.2
53.7	1.3	1.2
53.8	1.3	1.2
53.9	1.3	1.2
54.0	1.3	1.2
54.1	1.3	1.2
54.2	1.3	1.2
54.3	1.3	1.2
54.4	1.3	1.2
54.5	1.3	1.2
54.6	1.3	1.2
54.7	1.3	1.2
54.8	1.3	1.2
54.9	1.3	1.2
55.0	1.3	1.2
55.1	1.3	1.2
55.2	1.3	1.2
55.3	1.3	1.2
55.4	1.3	1.2
55.5	1.3	1.2
55.6	1.3	1.2
55.7	1.3	1.2
55.8	1.3	1.2
55.9	1.3	1.2
56.0	1.3	1.2
56.1	1.3	1.2
56.2	1.3	1.2
56.3	1.2	1.2
56.4	1.2	1.2
56.5	1.2	1.2
56.6	1.2	1.2
56.7	1.2	1.2
56.8	1.2	1.2
56.9	1.2	1.2
57.0	1.2	1.2
57.1	1.2	1.2

57.2	1.2	1.2
57.3	1.2	1.2
57.4	1.2	1.2
57.5	1.3	1.2
57.6	1.3	1.2
57.7	1.3	1.2
57.8	1.3	1.2
57.9	1.3	1.2
58.0	1.3	1.2
58.1	1.3	1.2
58.2	1.3	1.2
58.3	1.3	1.2
58.4	1.3	1.2
58.5	1.3	1.2
58.6	1.3	1.2
58.7	1.3	1.2
58.8	1.3	1.2
58.9	1.3	1.2
59.0	1.3	1.2
59.1	1.3	1.2
59.2	1.3	1.2
59.3	1.3	1.2
59.4	1.3	1.2
59.5	1.3	1.2
59.6	1.3	1.2
59.7	1.3	1.2
59.8	1.3	1.2
59.9	1.3	1.2
60.0	1.3	1.2
60.1	1.3	1.2
60.2	1.2	1.2
60.3	1.0	1.2
60.4	0.9	1.2
60.5	0.7	1.2
60.6	0.7	1.2
60.7	0.6	1.2
60.8	0.6	1.2
60.9	0.5	1.2
61.0	0.5	1.2
61.1	0.5	1.2
61.2	0.5	1.2

61.3	0.5	1.2
61.4	0.5	1.2
61.5	0.5	1.2
61.6	0.5	1.2
61.7	0.5	1.2
61.8	0.5	1.2
61.9	0.5	1.2
62.0	0.5	1.2
62.1	0.5	1.2
62.2	0.5	1.2
62.3	0.5	1.2
62.4	0.5	1.2
62.5	0.5	1.2
62.6	0.5	1.2
62.7	0.5	1.2
62.8	0.5	1.2
62.9	0.5	1.2
63.0	0.5	1.2
63.1	0.5	1.2
63.2	0.5	1.2
63.3	0.5	1.2
63.4	0.6	1.2
63.5	0.6	1.2
63.6	0.6	1.2
63.7	0.6	1.2
63.8	0.6	1.2
63.9	0.6	1.2
64.0	0.6	1.2
64.1	0.6	1.2
64.2	0.6	1.2
64.3	0.7	1.2
64.4	0.7	1.2
64.5	0.7	1.2
64.6	0.7	1.2
64.7	0.7	1.2
64.8	0.7	1.2
64.9	0.7	1.2
65.0	0.7	1.2
65.1	0.8	1.2
65.2	0.8	1.2
65.3	0.8	1.2

65.4	0.8	1.2
65.5	0.8	1.2
65.6	0.8	1.2
65.7	0.8	1.2
65.8	0.8	1.2
65.9	0.8	1.2
66.0	0.9	1.2
66.1	0.9	1.2
66.2	0.9	1.2
66.3	0.9	1.2
66.4	0.9	1.2
66.5	0.9	1.2
66.6	0.9	1.2
66.7	0.9	1.2
66.8	0.9	1.2
66.9	0.9	1.2
67.0	1.0	1.2
67.1	1.0	1.2
67.2	1.0	1.2
67.3	1.0	1.2
67.4	1.0	1.2
67.5	1.0	1.2
67.6	1.0	1.2
67.7	1.0	1.2
67.8	1.0	1.2
67.9	1.0	1.2
68.0	1.0	1.2
68.1	1.0	1.2
68.2	1.0	1.2
68.3	1.1	1.2
68.4	1.1	1.2
68.5	1.1	1.2
68.6	1.1	1.2
68.7	1.1	1.2
68.8	1.1	1.2
68.9	1.1	1.2
69.0	1.1	1.2
69.1	1.1	1.2
69.2	1.1	1.2
69.3	1.1	1.2
69.4	1.1	1.2

69.5	1.1	1.2
69.6	1.1	1.2
69.7	1.1	1.2
69.8	1.1	1.2
69.9	1.1	1.2
70.0	1.1	1.2
70.1	1.1	1.2
70.2	1.2	1.2
70.3	1.8	1.2
70.4	2.4	1.2
70.5	3.0	1.2
70.6	3.4	1.2
70.7	3.7	1.2
70.8	3.7	1.2
70.9	3.4	1.2
71.0	3.1	1.2
71.1	2.8	1.2
71.2	2.5	1.2
71.3	2.3	1.2
71.4	2.1	1.2
71.5	2.0	1.2
71.6	1.9	1.2
71.7	1.8	1.2
71.8	1.7	1.2
71.9	1.7	1.2
72.0	1.6	1.2
72.1	1.6	1.2
72.2	1.5	1.2
72.3	1.5	1.2
72.4	1.5	1.2
72.5	1.4	1.2
72.6	1.4	1.2
72.7	1.4	1.2
72.8	1.4	1.2
72.9	1.4	1.2
73.0	1.3	1.2
73.1	1.3	1.2
73.2	1.3	1.2
73.3	1.3	1.2
73.4	1.3	1.2
73.5	1.3	1.2

73.6	1.3	1.2
73.7	1.3	1.2
73.8	1.3	1.2
73.9	1.3	1.2
74.0	1.3	1.2
74.1	1.3	1.2
74.2	1.3	1.2
74.3	1.3	1.2
74.4	1.3	1.2
74.5	1.3	1.2
74.6	1.3	1.2
74.7	1.3	1.2
74.8	1.3	1.2
74.9	1.3	1.2
75.0	1.3	1.2
75.1	1.3	1.2
75.2	1.3	1.2
75.3	1.3	1.2
75.4	1.3	1.2
75.5	1.3	1.2
75.6	1.3	1.2
75.7	1.3	1.2
75.8	1.3	1.2
75.9	1.3	1.2
76.0	1.3	1.2
76.1	1.3	1.2
76.2	1.3	1.2
76.3	1.3	1.2
76.4	1.3	1.2
76.5	1.3	1.2
76.6	1.3	1.2
76.7	1.3	1.2
76.8	1.3	1.2
76.9	1.3	1.2
77.0	1.3	1.2
77.1	1.3	1.2
77.2	1.2	1.2
77.3	1.3	1.2
77.4	1.3	1.2
77.5	1.3	1.2
77.6	1.3	1.2

77.7	1.3	1.2
77.8	1.3	1.2
77.9	1.3	1.2
78.0	1.3	1.2
78.1	1.3	1.2
78.2	1.3	1.2
78.3	1.3	1.2
78.4	1.3	1.2
78.5	1.3	1.2
78.6	1.3	1.2
78.7	1.3	1.2
78.8	1.3	1.2
78.9	1.3	1.2
79.0	1.3	1.2
79.1	1.3	1.2
79.2	1.3	1.2
79.3	1.3	1.2
79.4	1.3	1.2
79.5	1.3	1.2
79.6	1.3	1.2
79.7	1.3	1.2
79.8	1.3	1.2
79.9	1.3	1.2
80.0	1.3	1.2
80.1	1.3	1.2
80.2	1.3	1.2
80.3	1.3	1.2
80.4	1.3	1.2
80.5	1.3	1.2
80.6	1.3	1.2
80.7	1.3	1.2
80.8	1.3	1.2
80.9	1.2	1.2
81.0	1.2	1.2
81.1	1.2	1.2
81.2	1.2	1.2
81.3	1.2	1.2
81.4	1.2	1.2
81.5	1.2	1.2
81.6	1.2	1.2
81.7	1.2	1.2

81.8	1.2	1.2
81.9	1.2	1.2
82.0	1.2	1.2
82.1	1.2	1.2
82.2	1.2	1.2
82.3	1.2	1.2
82.4	1.2	1.2
82.5	1.2	1.2
82.6	1.2	1.2

Data for Fig. 9B

Time (min)	Effluent conductivity ($\mu\text{S}/\text{cm}$)	Influent conductivity ($\mu\text{S}/\text{cm}$)
1	105.7	111.8
2	106.5	111.8
3	107.7	111.8
4	108.6	111.8
5	109.5	111.8
6	110.6	111.8
7	111.6	111.8
8	112.5	111.8
9	113.3	111.8
10	113.7	111.8
11	114.2	111.8
12	114.8	111.8
13	115.3	111.8
14	115.5	111.8
15	115.6	111.8
16	115.9	111.8
17	116.0	111.8
18	116.2	111.8
19	116.4	111.8
20	116.5	111.8
21	116.6	111.8
22	116.7	111.8
23	116.8	111.8
24	116.9	111.8
25	117.0	111.8
26	117.1	111.8

27	117.0	111.8
28	117.0	111.8
29	117.0	111.8
30	116.8	111.8
31	111.6	111.8
32	115.3	111.8
33	116.0	111.8
34	115.8	111.8
35	115.0	111.8
36	114.3	111.8
37	113.6	111.8
38	113.3	111.8
39	113.1	111.8
40	112.7	111.8
41	112.4	111.8
42	112.1	111.8
43	111.8	111.8
44	111.5	111.8
45	111.4	111.8
46	111.3	111.8
47	111.3	111.8
48	111.2	111.8
49	111.1	111.8
50	111.2	111.8
51	111.2	111.8
52	111.2	111.8
53	111.1	111.8
54	111.2	111.8
55	111.1	111.8
56	111.1	111.8
57	111.2	111.8
58	111.2	111.8
59	111.2	111.8
60	111.3	111.8
61	105.4	111.8
62	106.9	111.8
63	108.6	111.8
64	110.0	111.8
65	111.3	111.8
66	112.5	111.8
67	113.6	111.8

68	114.5	111.8
69	115.3	111.8
70	115.7	111.8
71	116.3	111.8
72	116.9	111.8
73	117.2	111.8
74	117.5	111.8
75	117.7	111.8
76	117.9	111.8
77	118.1	111.8
78	118.3	111.8
79	118.5	111.8
80	118.6	111.8
81	118.7	111.8
82	118.9	111.8
83	118.9	111.8
84	119.0	111.8
85	119.0	111.8
86	119.1	111.8
87	119.2	111.8
88	119.0	111.8
89	119.0	111.8
90	119.1	111.8
91	112.3	111.8
92	116.2	111.8
93	116.3	111.8
94	116.0	111.8
95	115.4	111.8
96	115.0	111.8
97	114.8	111.8
98	114.4	111.8
99	114.0	111.8
100	113.7	111.8
101	113.7	111.8
102	113.4	111.8
103	113.3	111.8
104	112.9	111.8
105	112.8	111.8
106	112.3	111.8
107	112.1	111.8
108	112.2	111.8

109	112.0	111.8
110	111.9	111.8
111	111.8	111.8
112	111.8	111.8
113	111.8	111.8
114	111.9	111.8
115	111.9	111.8
116	111.9	111.8
117	111.7	111.8
118	111.7	111.8
119	111.7	111.8
120	111.8	111.8
121	105.6	111.8
122	107.2	111.8
123	108.5	111.8
124	109.8	111.8
125	111.4	111.8
126	112.7	111.8
127	113.9	111.8
128	114.9	111.8
129	115.7	111.8
130	116.5	111.8
131	116.9	111.8
132	117.4	111.8
133	117.7	111.8
134	118.0	111.8
135	118.3	111.8
136	118.7	111.8
137	119.0	111.8
138	119.3	111.8
139	119.2	111.8
140	119.4	111.8
141	119.5	111.8
142	119.6	111.8
143	119.7	111.8
144	119.8	111.8
145	119.8	111.8
146	119.8	111.8
147	120.1	111.8
148	120.1	111.8
149	120.2	111.8

150	120.2	111.8
151	113.9	111.8
152	117.0	111.8
153	117.0	111.8
154	116.4	111.8
155	115.7	111.8
156	115.0	111.8
157	114.5	111.8
158	114.1	111.8
159	113.9	111.8
160	113.6	111.8
161	113.5	111.8
162	113.4	111.8
163	113.3	111.8
164	113.2	111.8
165	113.0	111.8
166	113.0	111.8
167	112.9	111.8
168	112.8	111.8
169	112.8	111.8
170	112.8	111.8
171	112.8	111.8
172	112.8	111.8
173	112.8	111.8
174	112.8	111.8
175	112.7	111.8
176	113.0	111.8
177	113.0	111.8
178	113.0	111.8
179	113.0	111.8
180	113.1	111.8
181	106.6	111.8
182	107.7	111.8
183	108.8	111.8
184	110.2	111.8
185	111.7	111.8
186	113.1	111.8
187	114.1	111.8
188	115.3	111.8
189	116.2	111.8
190	117.1	111.8

191	117.9	111.8
192	118.4	111.8
193	118.6	111.8
194	119.1	111.8
195	119.5	111.8
196	119.8	111.8
197	120.0	111.8
198	120.5	111.8
199	120.7	111.8
200	120.9	111.8
201	121.1	111.8
202	121.4	111.8
203	121.6	111.8
204	121.5	111.8
205	121.8	111.8
206	121.9	111.8
207	121.9	111.8
208	122.0	111.8
209	122.0	111.8
210	122.1	111.8
211	116.8	111.8
212	119.5	111.8
213	119.0	111.8
214	118.3	111.8
215	117.5	111.8
216	116.9	111.8
217	116.3	111.8
218	115.9	111.8
219	115.6	111.8
220	115.4	111.8
221	115.2	111.8
222	115.0	111.8
223	114.8	111.8
224	114.6	111.8
225	114.4	111.8
226	114.2	111.8
227	114.1	111.8
228	114.0	111.8
229	114.0	111.8
230	114.0	111.8
231	114.0	111.8

232	114.0	111.8
233	114.0	111.8
234	113.9	111.8
235	113.9	111.8
236	113.9	111.8
237	113.8	111.8
238	113.8	111.8
239	113.8	111.8
240	113.9	111.8

Data for Fig. 10

Volume treated (mL)	PFBS				PFHxS			
	With voltage		Without voltage		With voltage		Without voltage	
	AVG	STDEV	AVG	STDEV	AVG	STDEV	AVG	STDEV
0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10	0.71	0.06	0.74	0.05	0.66	0.07	0.64	0.05
20	0.77	0.06	0.84	0.04	0.85	0.18	0.75	0.00
40	0.81	0.06	0.85	0.05	0.72	0.06	0.84	0.15
100	0.79	0.02	0.84	0.05	0.77	0.06	0.90	0.06
240	0.81	0.04	0.83	0.08	0.81	0.07	0.92	0.00
360	0.81	0.09	0.84	0.05	0.76	0.00	0.91	0.08
480	0.84	0.04	0.85	0.05	0.81	0.05	0.92	0.10
520	0.86	0.05			0.95	0.00		

Volume treated (mL)	PFHxA				PFHpA			
	With voltage		Without voltage		With voltage		Without voltage	
	AVG	STDEV	AVG	STDEV	AVG	STDEV	AVG	STDEV
0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10	0.69	0.09	0.69	0.04	0.62	0.00	0.68	0.04
20	0.77	0.00	0.84	0.03	0.66	0.00	0.77	0.10
40	0.79	0.07	0.98	0.00	0.85	0.16	0.77	0.06
100	0.82	0.01	1.30	0.41	0.78	0.03	0.79	0.07
240	0.81	0.01	1.10	0.05	0.72	0.02	0.75	0.10
360	0.98	0.23	1.20	0.11	0.73	0.12	0.75	0.07
480	0.93	0.08	1.27	0.04	0.79	0.03	0.79	0.00
520	1.16	0.01			0.80	0.01		

Volume treated (mL)	PFOS				PFOA			
	With voltage		Without voltage		With voltage		Without voltage	
	AVG	STDEV	AVG	STDEV	AVG	STDEV	AVG	STDEV
0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10	0.57	0.09	0.53	0.01	0.74	0.13	0.75	0.17
20	0.74	0.11	0.69	0.04	0.81	0.21	0.80	0.08
40	0.71	0.07	0.71	0.05	0.77	0.03	0.83	0.20
100	0.79	0.08	0.79	0.03	0.83	0.07	0.84	0.05
240	0.82	0.10	0.82	0.03	0.82	0.06	0.90	0.03
360	0.83	0.06	0.81	0.00	0.82	0.08	0.82	0.09
480	0.81	0.09	0.78	0.05	0.78	0.02	0.84	0.02
520	0.86	0.10			0.87	0.04		

ng/L	PFBS	PFHxS	PFHxA	PFHpA	PFOS	PFOA
influent 1	269	2434	1046	237	13143	2628
influent 2	244	2001	990	229	8159	2176
influent 3	253	2078	897	262	8426	2313
influent 4	241	2018	872	226	7212	1971
AVG	251	2133	951	239	7932	2272
STDEV	13	203	81	16	638	276
UPPER	264	2336	1033	255	8571	2548
LOWER	239	1929	870	222	7294	1996

QA/QC for Fig. 8A

Minimum Reporting Limit (MRL; ng/L)		10
Theoretical Conc. (ng/L)	PFBS	Accuracy
MB (Blank)	<MRL	
10	11.1	111.0
25	25.8	103.3
50	52.7	105.5
100	101.5	101.5
250	253.5	101.4
500	595.0	119.0
1000	1067.4	106.7

MB (Blank)	<MRL	
10	10.8	107.7
25	22.2	88.8
50	45.9	91.8
100	91.3	91.3
250	224.0	89.6
500	457.1	91.4
1000	913.1	91.3
25	20.1	80.6
250	203.9	81.6
25	20.0	80.0
250	185.7	74.3

Experimental Samples, Blanks, and Duplicates (ng/L)	
Blank	<MRL
ZS77_0	<MRL
ZS77_5	222
ZS77_5_duplicate	212
ZS77_20	245
ZS77_50	235
ZS77_80	253
ZS77_120	255
Blank	<MRL
ZS76_0	<MRL
ZS76_5	136
ZS76_20	158
ZS76_20_duplicate	159
ZS76_50	155
ZS76_80	169
ZS76_120	175
Blank	<MRL
ZS75_0	<MRL
ZS75_5	181
ZS75_20	226
ZS75_50	243
ZS75_80	237
ZS75_80_duplicate	243

ZS75_120	248
Blank	<MRL
ZS74_0	<MRL
ZS74_5	230
ZS74_20	297
ZS74_50	291
ZS74_50_duplicate	273
ZS74_80	306
ZS74_120	260
Influent1	376
Influent1_duplicate	340

*note a 50X dilution was performed on the experimental samples

QA/QC for Fig. 8B

Minimum Reporting Limit (MRL; ng/L)		10
Theoretical Conc. (ng/L)	PFBS Measured Conc. (ng/L)	Accuracy
MB (Blank)	<MRL	
10	11.8	118.0
25	22.0	88.0
50	50.1	100.2
100	94.6	94.6
250	254.8	101.9
500	525.8	105.2
1000	1037.5	103.7
MB (Blank)	<MRL	
10	11.3	112.6
25	23.1	92.2
50	50.7	101.4
100	90.0	90.0
250	240.4	96.2
500	510.9	102.2
1000	946.9	94.7
25	20.6	82.5
250	189.3	75.7
25	20.4	81.7
250	186.4	74.6

Experimental Samples, Blanks, and Duplicates (ng/L)	
ZS81_0	<MRL
ZS81_5	126
ZS81_20	159
ZS81_50	153
ZS81_120	163
ZS81_120_duplicate	167
ZS80_5	58
ZS80_10	68
ZS80_20	75
ZS80_50	76
ZS80_80	81
ZS80_80_duplicate	77
ZS80_120	84
ZS79_5	43
ZS79_20	91
ZS79_50	102
ZS79_50_duplicate	98
ZS79_120	112
ZS79_OV_20	69
P2_19073	20
ZS78_0	<MRL
ZS78_5	155
ZS78_10	163
ZS78_10_duplicate	159
ZS78_20	161
ZS78_50	172
ZS78_80	167
ZS78_120	170
ZS78_OV_20	179
ZS78_Influent	216

QA/QC for Fig. 10

	Limit of Quantitation (LOQ)	2.5	
	Theoretical Conc. (ng/L)	PFBS Measured Conc. (ng/L)	Accuracy
Calibration Curves	MB	<2.5	
	1.0	2.1	211.6
	2.5	3.0	119.6

	5.0	4.8	95.2
	10.0	8.9	89.2
	25.0	23.0	91.9
	50.0	52.5	104.9
	100.0	103.0	103.0
	250.0	252.4	101.0
	MB	<2.5	
	1.0	2.3	231.1
	2.5	2.9	117.8
	5.0	4.8	97.0
	10.0	8.9	88.6
	25.0	22.4	89.8
	50.0	51.2	102.4
	100.0	101.4	101.4
	250.0	245.8	98.3
Synquest quality controls	10	8.9	89.3
	10	12.0	119.6
	10	10.6	106.0
	10	9.0	89.6
	10	12.4	123.7
	10	10.4	104.0
	100	81.4	81.4
	100	82.9	82.9
	100	95.8	95.8
	100	80.8	80.8
	100	82.5	82.5
	100	95.3	95.3
NIST SRM 8446 quality control	10		
	10		
	100		
	100		

Continuing calibration standards	10	9.2	91.6
	10	9.1	91.4
	10	9.4	94.2
	100	100.4	100.4
	100	100.4	100.4
	100	100.3	100.3
	250	245.1	98.0
	250	244.8	97.9
	250	246.8	98.7
Samples	DB_Blank_DilutionWater	<2.5	
	119_0	<2.5	
	119_5	189	
	119_10	204	
	119_20	213	
	119_50	202	
	119_120	211	
	119_120	212	
	119_180	219	
	119_240	218	
	119_260	226	
	119_Inf	269	
	120_5	169	
	120_10	185	
	120_20	193	
	120_20	192	
	120_50	196	
	120_120	197	
	120_180	188	
	120_240	203	
	120_260	208	
	120_Inf	244	
	121_5	196	
	121_10	219	
	121_20	224	
	121_50	220	
	121_120	222	

	121_180	220
	121_240	223
	121_Inf	252
	121_Inf	254
	122_0	<2.5
	122_5	176
	122_10	205
	122_20	205
	122_50	202
	122_50	202
	122_120	195
	122_180	201
	122_240	204
	122_Inf	241

	Limit of Quantitation (LOQ)	1.0	
	Theoretical Conc. (ng/L)	PFHxA	
		Measured Conc. (ng/L)	Accuracy
Calibration Curves	MB	<1.0	
	1.0	1.1	113.2
	2.5	2.6	104.4
	5.0	4.8	95.8
	10.0	8.9	88.6
	25.0	22.7	90.8
	50.0	52.0	104.1
	100.0	100.6	100.6
	250.0	253.0	101.2
	MB	<1.0	
	1.0	1.1	114.8
	2.5	2.7	107.9
	5.0	4.7	94.3
	10.0	8.7	87.1
	25.0	22.9	91.4
	50.0	51.4	102.8
	100.0	105.0	105.0
	250.0	244.7	97.9

Synquest quality controls	10	8.9	89.4
	10	8.5	85.3
	10	10.0	99.7
	10	9.5	95.0
	10	19.7	196.8
	10	10.0	100.3
	100	80.9	80.9
	100	75.0	75.0
	100	89.4	89.4
	100	81.7	81.7
	100	71.9	71.9
	100	95.0	95.0
NIST SRM 8446 quality control	8.6	7.5	86.7
	8.6	10.0	116.1
	86.4	61.1	70.8
	86.4	58.8	68.1
Continuing calibration standards	10	9.0	90.3
	10	9.4	93.5
	10	8.7	86.8
	100	100.3	100.3
	100	107.5	107.5
	100	100.5	100.5
	250	256.4	102.6
	250	247.8	99.1
	250	257.5	103.0
Samples	DB_Blank_DilutionWater	<1.0	
	119_0	<1.0	
	119_5	722	
	119_10	3117	
	119_20	810	

119_20	782
119_50	786
119_120	776
119_180	1089
119_240	943
119_260	1094
119_Inf	1046
120_5	600
120_10	735
120_20	706
120_50	775
120_120	761
120_180	782
120_240	823
120_240	845
120_260	1113
120_Inf	990
121_5	690
121_10	816
121_20	937
121_50	1509
121_120	1011
121_180	1189
121_180	1251
121_240	1185
121_Inf	897
122_0	<1.0
122_5	631
122_10	778
122_20	4819
122_50	961
122_120	1085
122_180	1070
122_240	1240
122_Inf	871
122_Inf	873

	Limit of Quantitation (LOQ)	1.0	
	Theoretical Conc. (ng/L)	PFHpA Measured Conc. (ng/L)	Accuracy
Calibration Curves	MB	<1.0	
	1.0	1.1	110.2
	2.5	2.9	115.2
	5.0	4.9	97.8
	10.0	9.6	96.0
	25.0	22.9	91.6
	50.0	54.2	108.3
	100.0	107.1	107.1
	250.0	263.9	105.5
	MB	<1.0	
	1.0	1.0	104.1
	2.5	2.7	106.7
	5.0	4.7	93.3
	10.0	8.2	82.2
	25.0	22.5	90.1
	50.0	51.4	102.8
	100.0	95.1	95.1
	250.0	234.7	93.9
Synquest quality controls	10	7.6	76.2
	10	7.4	73.8
	10	7.2	72.3
	10	7.4	74.3
	10	7.3	73.3
	10	7.9	78.6
	100	72.4	72.4
	100	67.7	67.7
	100	71.6	71.6
	100	70.2	70.2
	100	67.2	67.2
	100	68.6	68.6

NIST SRM 8446 quality control	11.1	7.4	67.0
	11.1	7.5	67.6
	111.1	78.9	71.1
	111.1	75.8	68.3
Continuing calibration standards	10	9.0	89.9
	10	9.1	90.9
	10	9.3	92.6
	100	102.7	102.7
	100	104.7	104.7
	100	102.0	102.0
	250	241.9	96.8
	250	250.0	100.0
	250	245.3	98.1
Samples	DB_Blank_DilutionWater	<1.0	
	119_0	18	
	119_5	439	
	119_10	373	
	119_20	229	
	119_50	191	
	119_120	174	
	119_120	180	
	119_180	196	
	119_240	193	
	119_260	194	
	119_Inf	237	
	120_5	148	
	120_10	158	
	120_20	176	
	120_20	176	
	120_50	181	
	120_120	169	
	120_180	155	
	120_240	182	
	120_260	189	

	120_Inf	229
	121_5	168
	121_10	201
	121_20	195
	121_50	201
	121_120	195
	121_180	190
	121_240	188
	121_Inf	268
	121_Inf	256
	122_0	2.5
	122_5	155
	122_10	166
	122_20	174
	122_50	180
	122_50	176
	122_120	161
	122_180	166
	122_240	188
	122_Inf	226

	Limit of Quantitation (LOQ)	1.0	
	Theoretical Conc. (ng/L)	PFHxS Measured Conc. (ng/L)	Accuracy
Calibration Curves	MB	<1.0	
	1.0	1.3	126.4
	2.5	2.7	108.4
	5.0	4.6	92.6
	10.0	8.8	87.6
	25.0	22.3	89.4
	50.0	52.4	104.9
	100.0	104.6	104.6
	250.0	253.1	101.2
	MB	<1.0	
	1.0	1.2	117.4
	2.5	2.6	102.5

	5.0	4.5	90.1
	10.0	8.3	83.1
	25.0	22.1	88.5
	50.0	51.4	102.8
	100.0	102.7	102.7
	250.0	244.2	97.7
Synquest quality controls	10	6.6	66.4
	10	6.9	68.5
	10	7.3	73.2
	10	7.3	72.8
	10	7.1	71.0
	10	7.2	71.7
	100	62.4	62.4
	100	64.9	64.9
	100	69.1	69.1
	100	60.8	60.8
	100	64.3	64.3
	100	69.6	69.6
NIST SRM 8446 quality control	10		
	10		
	100		
	100		
Continuing calibration standards	10	8.7	86.7
	10	8.8	88.3
	10	8.4	84.1
	100	102.0	102.0
	100	101.0	101.0
	100	101.5	101.5
	250	245.4	98.2
	250	245.4	98.2
	250	249.2	99.7

Samples	DB_Blank_DilutionWater	<1.0
	119_0	3.1
	119_5	1502
	119_10	2068
	119_20	1608
	119_20	1656
	119_50	1730
	119_120	1828
	119_180	6603
	119_240	1806
	119_260	2009
	119_Inf	2434
	120_5	1292
	120_10	1538
	120_20	1448
	120_50	1539
	120_120	1614
	120_180	1629
	120_240	1659
	120_240	1627
	120_260	2023
	120_Inf	2001
	121_5	1428
	121_10	1607
	121_20	2017
	121_50	2020
	121_120	1954
	121_180	2046
	121_180	2064
	121_240	2114
	121_Inf	2078
	122_0	<1.0
	122_5	1281
	122_10	1605
	122_20	1563
	122_50	1837
	122_120	1961

	122_180	1820
	122_240	1826
	122_Inf	2023
	122_Inf	2012

	Limit of Quantitation (LOQ)	5.0	
	Theoretical Conc. (ng/L)	PFOA Measured Conc. (ng/L)	Accuracy
Calibration Curves	MB	<5.0	
	1.0	2.2	218.5
	2.5	3.7	147.8
	5.0	5.7	114.2
	10.0	9.5	95.1
	25.0	24.8	99.2
	50.0	52.6	105.1
	100.0	101.4	101.4
	250.0	251.6	100.6
	MB	<5.0	
	1.0	2.5	250.3
	2.5	3.1	124.0
	5.0	5.1	102.3
	10.0	9.4	93.8
	25.0	22.3	89.3
	50.0	49.9	99.9
	100.0	99.9	99.9
	250.0	247.8	99.1
Synquest quality controls	10	7.6	75.7
	10	7.4	73.8
	10	9.3	93.2
	10	7.8	78.4
	10	10.8	108.2
	10	8.8	87.9
	100	62.3	62.3
	100	69.7	69.7

	100	65.0	65.0
	100	62.6	62.6
	100	62.1	62.1
	100	70.0	70.0
NIST SRM 8446 quality control	8.0	6.2	77.5
	8.0	6.7	83.6
	80.1	55.4	69.1
	80.1	56.5	70.5
Continuing calibration standards	10	9.4	94.2
	10	9.7	97.1
	10	9.9	98.8
	100	99.2	99.2
	100	104.8	104.8
	100	98.0	98.0
	250	239.3	95.7
	250	248.3	99.3
	250	246.3	98.5
Samples	DB_Blank_DilutionWater	<5.0	
	119_0	12.9	
	119_5	1891	
	119_10	2191	
	119_20	1769	
	119_20	1805	
	119_50	1997	
	119_120	1956	
	119_180	1996	
	119_240	1748	
	119_260	1911	
	119_Inf	2628	
	120_5	1484	
	120_10	1505	
	120_20	1703	

	120_50	1764
	120_120	1754
	120_180	1730
	120_240	1874
	120_240	1764
	120_260	2053
	120_Inf	2176
	121_5	1983
	121_10	1943
	121_20	2196
	121_50	1986
	121_120	2088
	121_180	1957
	121_180	2036
	121_240	1930
	121_Inf	2313
	122_0	<5.0
	122_5	1441
	122_10	1683
	122_20	1566
	122_50	1815
	122_120	2008
	122_180	1720
	122_240	1876
	122_Inf	1988
	122_Inf	1955

	Limit of Quantitation (LOQ)	2.5	
	Theoretical Conc. (ng/L)	PFOS Measured Conc. (ng/L)	Accuracy
Calibration Curves	MB	<2.5	
	1.0	1.7	174.6
	2.5	3.3	133.7
	5.0	4.7	93.8
	10.0	8.9	88.5
	25.0	23.7	94.8
	50.0	47.6	95.3

	100.0	109.6	109.6
	250.0	255.9	102.4
	MB	<2.5	
	1.0	1.6	164.0
	2.5	3.2	129.2
	5.0	4.5	89.3
	10.0	8.1	80.7
	25.0	22.2	88.7
	50.0	45.9	91.9
	100.0	105.6	105.6
	250.0	240.6	96.3
Synquest quality controls	10	6.8	68.2
	10	6.5	64.6
	10	7.9	78.6
	10	6.4	63.8
	10	6.5	65.4
	10	7.6	76.4
	100	59.1	59.1
	100	60.3	60.3
	100	64.8	64.8
	100	57.4	57.4
	100	58.7	58.7
	100	64.9	64.9
NIST SRM 8446 quality control	10		
	10		
	100		
	100		
Continuing calibration standards	10	9.2	91.9
	10	9.6	96.1
	10	10.0	100.4
	100	109.9	109.9

	100	108.4	108.4
	100	115.9	115.9
	250	250.1	100.1
	250	248.0	99.2
	250	257.2	102.9
Samples	DB_Blank_DilutionWater	9.8	
	119_0	13.7	
	119_5	5072	
	119_10	6479	
	119_20	6003	
	119_20	6018	
	119_50	6754	
	119_120	7075	
	119_180	6901	
	119_240	6962	
	119_260	7375	
	119_Inf	13143	
	120_5	4033	
	120_10	5258	
	120_20	5185	
	120_50	5854	
	120_120	6004	
	120_180	6238	
	120_240	5930	
	120_240	5925	
	120_260	6303	
	120_Inf	8159	
	121_5	4186	
	121_10	5690	
	121_20	5951	
	121_50	6089	
	121_120	6699	
	121_180	6398	
	121_180	6422	
	121_240	6528	
	121_Inf	8426	

	122_0	<2.5
	122_5	4279
	122_10	5280
	122_20	5379
	122_50	6384
	122_120	6337
	122_180	6423
	122_240	5919
	122_Inf	7220
	122_Inf	7203