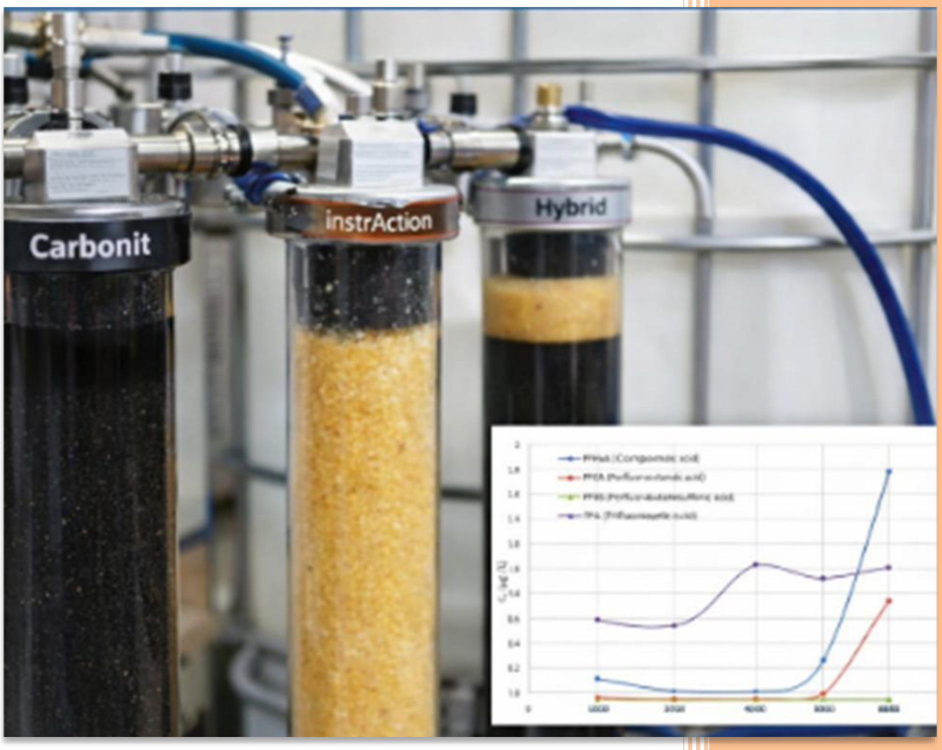
2026

Evaluation of PFAS Removal Performance Using Activated Carbon, Resin, and Hybrid Filtration Medias



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1. Executive Summary

This report presents the results of a laboratory-scale evaluation of different filtration technologies for the removal of selected per- and polyfluoroalkyl substances (PFAS) from drinking water. The study was conducted at the laboratory of the Institute for Sanitary Engineering, Water Quality and Waste Management (ISWA), University of Stuttgart.

Three filtration configurations were investigated:

- Activated Carbon (Carbonit GmbH)
- Resin-based system (instrAction GmbH)
- Hybrid system (Activated Carbon + Resin)

The tested PFAS compounds included:

- Trifluoroacetic acid (TFA)
- Perfluorooctanoic acid (PFOA)
- Perfluorohexanoic acid (PFHxA)
- Perfluorobutanesulfonic acid (PFBS)

The results indicate that:

- TFA removal is very limited across all systems
- Resin-based filtration significantly outperforms activated carbon
- Hybrid systems show the best overall performance
- Activated carbon exhibits earlier breakthrough for most PFAS

2. Introduction

Per- and polyfluoroalkyl substances (PFAS) are a class of persistent environmental contaminants that have gained increasing attention due to their widespread occurrence in water resources and their potential health impacts.

Particular concern is associated with:

- **Short-chain PFAS** (e.g., PFHxA, PFBS)
- **Ultra-short-chain PFAS**, especially **TFA**

These compounds are:

- Highly mobile in aquatic systems
- Difficult to remove using conventional treatment technologies
- Increasingly detected in drinking water sources

Activated carbon is widely used for PFAS removal but has known limitations, particularly for short-chain compounds. Recently, **functionalized resin-based materials** have been developed to enhance selectivity and removal efficiency.

This study aims to:

Evaluate and compare the performance of activated carbon, resin-based filtration, and hybrid systems under realistic point-of-use conditions.

3. Materials and Methods

3.1 Test Location

All experiments were conducted at the laboratory facilities of the Institute for Sanitary Engineering (ISWA), University of Stuttgart.

3.2 Water Matrix

The experiments were carried out using tap water with characteristics representative of Lake Constance (Bodensee) drinking water:

- pH ≈ 7.0
- Electrical conductivity ≈ 170 µS/cm
- Water hardness ≈ 8–12 °dH

3.3 PFAS Preparation

A mixture of PFAS compounds was **synthetically prepared and added** to an intermediate bulk container (IBC tank). The solution was thoroughly mixed to ensure homogeneous distribution before being introduced into the filtration system.

The following compounds were included:

- TFA (Trifluoroacetic acid)
- PFOA (Perfluorooctanoic acid)
- PFHxA (Perfluorohexanoic acid)
- PFBS (Perfluorobutanesulfonic acid)

3.4 Experimental Setup

The experimental system consisted of:

- IBC tank (feed solution)
- Mixing system
- Centrifugal pump
- Filtration columns
- Post-treatment unit

Operating conditions:

- Flow rate: **1.5–2.0 L/min**
- Operation time: **8 hours/day**
- Total loading: up to **6000 bed volumes (BV ≈ 3000 L)**

3.5 Filtration Configuration

Each test system included:

- **Prefilter, Vorfilter, (1 µm)** for particle removal
- **Main filtration unit**:
  - Activated Carbon (Carbonit)
  - Resin (instrAction)
  - Hybrid (AC + Resin)
- **Post-filter stage**:
  - Installed to prevent PFAS discharge into the laboratory drainage system

4. Filtration System Configurations

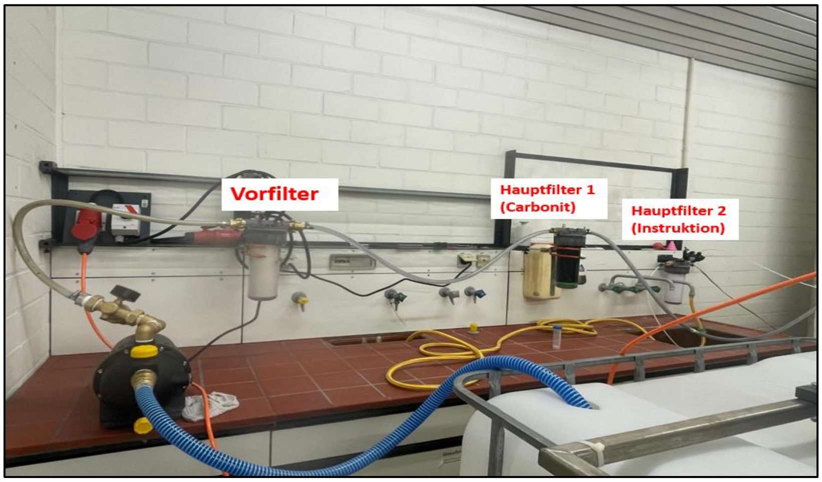

Figure 1: Schematic representation of the activated carbon filtration system (Carbonit configuration), including prefilter, main carbon block, and post-treatment stage.

Figure 2: Schematic representation of the resin-based filtration system (instrAction configuration), illustrating selective adsorption media.

Figure 3: Schematic representation of the hybrid filtration system; matrix of activated carbon and resin media.

5. Results and Discussion

5.1 Activated Carbon System (Carbonit)

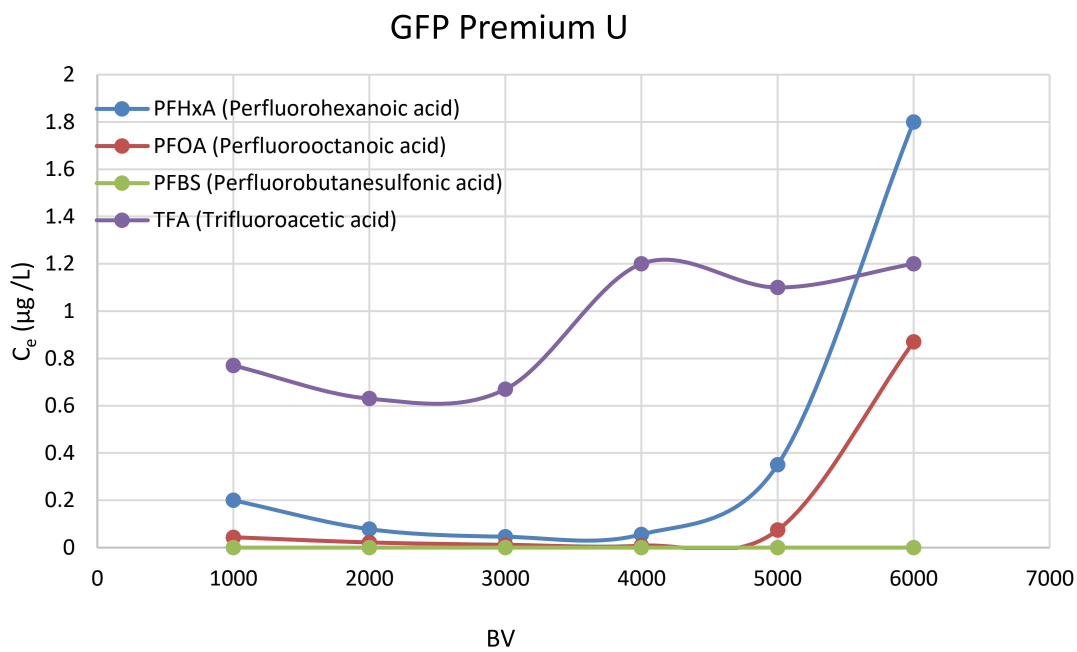

Figure 4: Breakthrough behavior of PFAS compounds (TFA, PFOA, PFHxA, PFBS) for the activated carbon system (GFP Premium U) as a function of bed volumes (BV).

The activated carbon system shows high removal performance for PFBS, very good performance for PFOA and PFHxA, and poor performance for ultra-short-chain PFAS (TFA).

- **PFHxA and PFOA**:
  - Initially retained
  - Significant breakthrough observed at higher BV
  - Rapid increase in effluent concentration after ~5000–6000 BV
- **PFBS**:
  - High adsorption
  - Near-zero retention throughout
- **TFA**:
  - Poor removal performance
  - Effluent concentrations remain high
  - Indicates minimal interaction with activated carbon

Interpretation:
Activated carbon exhibits decreasing adsorption efficiency with decreasing PFAS chain length. Ultra-short-chain compounds such as TFA are not effectively retained.

5.2 Resin-Based System (instrAction)

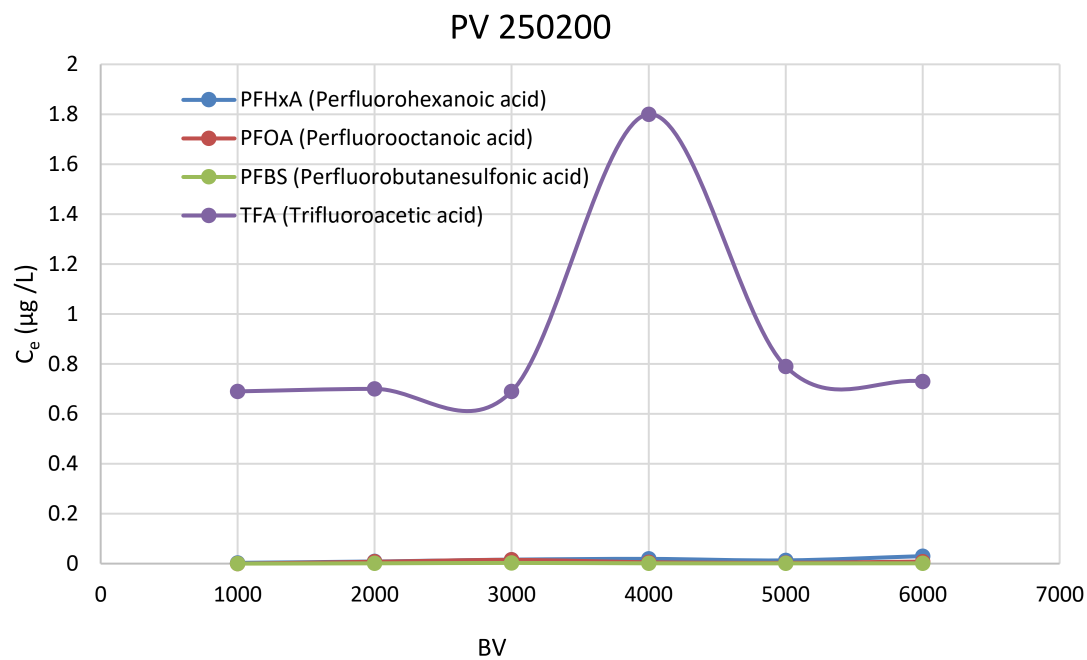

Figure 5: Breakthrough behavior of PFAS compounds (TFA, PFOA, PFHxA, PFBS) for the resin-based system (PV 250200).

The resin system demonstrates **improved performance** compared to activated carbon.

- **PFBS, PFOA, and PFHxA**:
    - Strong retention
    - No breakthrough over the tested BV range
- **TFA**:
    - Highly variable behavior
    - Limited removal overall
    - Temporary adsorption observed but not stable

Interpretation:
The resin exhibits **higher selectivity and affinity** toward PFAS compared to activated carbon, particularly for short-chain compounds. However, TFA remains difficult to remove.

5.3 Hybrid System (Activated Carbon + Resin)

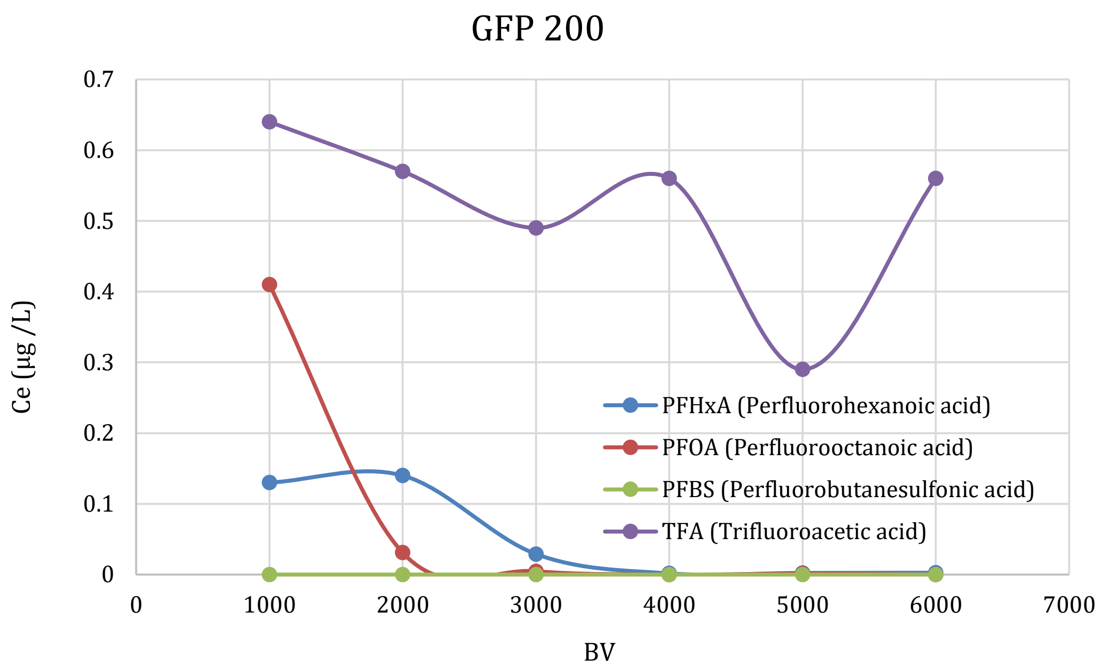

Figure 6: Breakthrough behavior of PFAS compounds (TFA, PFOA, PFHxA, PFBS) for the hybrid filtration system (GFP 200).

The hybrid system shows the **best overall performance**.

- **PFOA**:
  - Rapid reduction to near-zero levels
  - Stable performance
- **PFBS and PFHxA**:
  - Strong removal
  - Delayed breakthrough
- **TFA**:
  - Slight improvement compared to single systems
  - Still not effectively removed

Interpretation:
The combination of activated carbon and resin provides a **synergistic effect**:

- Carbon acts as a **pre-conditioning stage**
- Resin provides **selective adsorption**

5.4 Comparative Analysis

Overall performance ranking:

1. **Hybrid system (best performance)**
2. **Resin system (high performance)**
3. **Activated carbon (limited performance)**

Key findings:

- **TFA is not effectively removed by any tested system**
- **Resin application improves the removal of PFAS**
- **Activated carbon brings some restrictions towards advanced PFAS treatment**

6. Conclusions

This study demonstrates that:

- Activated carbon alone shows **limitations for** PFAS removal under very high BVs implementation.
- Resin-based systems provide **improved removal performance, no evidence of breakthrough under examined BVs (ca. 3000 L) for short and long chain PFAS.**
- Hybrid systems offer a **robust and effective solution for short and long-chain PFAS.**
- TFA remains a **major challenge** due to its high mobility and low adsorption affinity, although an extent of removal was observed when applying resin-based filters.

These findings highlight the importance of **advanced and combined treatment approaches** for PFAS removal in drinking water applications.

7. Important Notice

This report was prepared based on a specific request from **Carbonit GmbH** and **instrAction GmbH** for the purpose of presenting results to their customers.

The content of this report is intended solely for **demonstration and communication purposes** and does not represent a comprehensive scientific evaluation.

Further technical analysis, detailed interpretation, and scientific discussion will be presented in **future peer-reviewed scientific publication(s)**.

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