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**From Drinking Water to Cancer:
Addressing the Challenge of
Removing Carcinogenic Emerging
Contaminants from Philadelphia's
water through Novel and
Sustainable Treatment
Innovations**

**SUSTAINABLE
DEVELOPMENT
GOALS**



**2025 GRASP Award-
Final Report**



From Drinking Water to Cancer: Addressing the Challenge of Removing Carcinogenic Emerging Contaminants from Philadelphia's water through Novel and Sustainable Treatment Innovations

GRASP Project – Final Report

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ABSTRACT

Per- and polyfluoroalkyl substances (PFAS) and microplastics (MPs) are emerging contaminants of growing global concern due to their widespread occurrence in drinking water and wastewater systems and their association with adverse public health outcomes, including endocrine disruption and increased long-term cancer risk. Conventional water treatment technologies are not fully effective in removing these persistent contaminants, necessitating the development of sustainable and innovative treatment approaches. The primary objective of this project was to develop and evaluate a low-cost, low-chemical, and energy-efficient treatment strategy for the removal of carcinogenic emerging contaminants from water. Specifically, the project aimed to (i) develop and assess a laboratory-scale foam fractionation process for PFAS and microplastic removal, (ii) evaluate the feasibility of foam fractionation as a sustainable alternative to conventional treatment technologies, and (iii) generate scientific evidence to support water safety policy, community awareness, and environmental justice initiatives.

A laboratory-scale foam fractionation system was designed and operated using real water matrices to ensure practical relevance. The process leveraged the surface-active and hydrophobic properties of PFAS and microplastics to selectively enrich and remove contaminants at the air–water interface. System performance was evaluated by optimizing operational parameters, including aeration time, air flow rate, pH, recirculation, and optimized cationic surfactant input. PFAS concentrations were quantified using liquid chromatography–tandem mass spectrometry (LC–MS/MS), and microplastics were characterized using Fourier transform infrared (FTIR) microscopy. Foam fractionation demonstrated strong time-dependent removal of PFAS and microplastics. Long-chain PFAS (PFOA, PFOS, and PFNA) exhibited rapid removal, achieving greater than 95% removal after extended aeration. Short-chain and replacement PFAS showed comparatively slower removal kinetics; however, optimized cationic surfactant input was observed to accelerate short-chain PFAS removal. Microplastic removal efficiencies exceeded 95% for common polymers, including PE, PP, PS, PA, and PVC, following sufficient aeration. These results are preliminary and reflect ongoing optimization of system performance.

Overall, this proof-of-concept study demonstrates the potential of foam fractionation as a sustainable treatment strategy capable of simultaneously removing multiple classes of emerging contaminants with reduced chemical and energy demands. Ongoing research focuses on further optimization, including the use of natural, non-toxic cationic surfactants and integration with supercritical water oxidation (SCWO) for destruction of concentrated PFAS in the foam phase. The final optimized outcomes will be disseminated through peer-reviewed publications and conferences, contributing to sustainable water treatment innovation and public health protection.

1 INTRODUCTION

The Graduate Research Award Sustainability Program (GRASP), Temple University, has awarded the 2025 GRASP grant to Graduate Student Researcher Md. Saiful Islam, Department of Civil and Environmental Engineering, College of Engineering, Temple University, for the research project titled *“From Drinking Water to Cancer: Addressing the Challenge of Removing Carcinogenic Emerging Contaminants from Philadelphia’s Water through Novel and Sustainable Treatment Innovations.”* The project is conducted under the supervision of Faculty Mentor Dr. Gangadhar Andaluri, Assistant Professor, Civil and Environmental Engineering.

This report summarizes the outcomes and activities of the project carried out under the GRASP Award in alignment with the program’s sustainability and public health objectives.

2 BACKGROUND AND OBJECTIVES

Emerging contaminants, including per- and polyfluoroalkyl substances (PFAS) and microplastics (MPs), are increasingly detected in drinking water and wastewater systems and present growing challenges to public health and environmental sustainability [1], [2], [3]. These persistent contaminants are associated with endocrine disruption, reproductive toxicity, and elevated long-term cancer risks [4]. Due to their chemical stability, small size, and complex transport behavior, PFAS and microplastics are not fully removed by conventional water and wastewater treatment technologies [5], [6], [7]. To address these limitations, this project focused on the development and evaluation of novel fractionation technology as a sustainable treatment alternative. Foam fractionation leverages the surface-active and hydrophobic properties of contaminants, enabling their selective enrichment and removal at the air–water interface. Unlike conventional treatment processes, this approach operates with optimum surfactant input, requires low energy input, and generates minimal secondary waste, making it well suited for sustainable and scalable water treatment applications.

The overarching objective of this project was to develop a low-cost, low-chemical, and energy-efficient treatment strategy for the removal of carcinogenic emerging contaminants from water Figure 1. The specific objectives of the project were to:

1. Develop and evaluate a foam fractionation process for the effective removal of PFAS and microplastics from water.
2. Assess the feasibility of foam fractionation as a sustainable alternative to conventional water treatment technologies with reduced chemical reliance.

3. Generate scientific evidence to support water safety policy development, community awareness, and environmental justice initiatives.

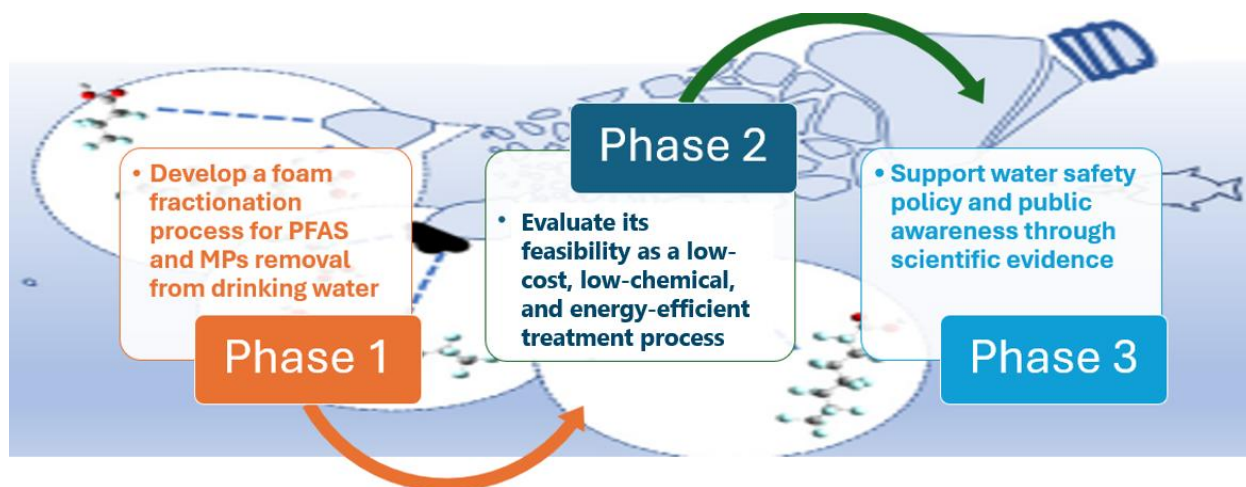


Figure 1: Conceptual framework and phased approach of the GRASP project

The outcomes of this project contribute to improved protection of public health, provide data to inform future water treatment and regulatory strategies, and advance multiple United Nations Sustainable Development Goals, including SDG 6 (Clean Water and Sanitation), SDG 11 (Sustainable Cities and Communities), and SDG 12 (Responsible Consumption and Production).

3 MATERIALS AND METHODS

3.1 Research Approach

This project developed and evaluated a laboratory-scale foam fractionation system for the removal of per- and polyfluoroalkyl substances (PFAS) and microplastics (MPs) from water. Real water was used as the raw water source to ensure practical relevance and to reflect conditions encountered in existing treatment systems. Conventional water treatment technologies face significant challenges in effectively removing these carcinogenic emerging contaminants due to their persistence, chemical stability, and complex behavior in aquatic environments. By focusing on a controlled laboratory-scale system using realistic water matrices, this study aimed to assess the feasibility and performance of foam fractionation as a sustainable treatment approach applicable to real-world drinking water scenarios.

3.2 Experimental Setup

The foam fractionation system consisted of a vertical column equipped with an air injection diffuser at the base, a raw water inlet, a sampling and injection port, a treated water outlet, and a foam collection chamber at the top of the column Figure 2. Air was supplied using an air pump and introduced through the diffuser to generate fine bubbles that rise through the water column. A vacuum pump was connected to the foam collection line to facilitate controlled removal of the generated foam. Foam was generated continuously within the column, allowing surface-active contaminants to preferentially partition to the air–water interface and become enriched in the foam phase as bubbles ascended. The contaminant-laden foam was

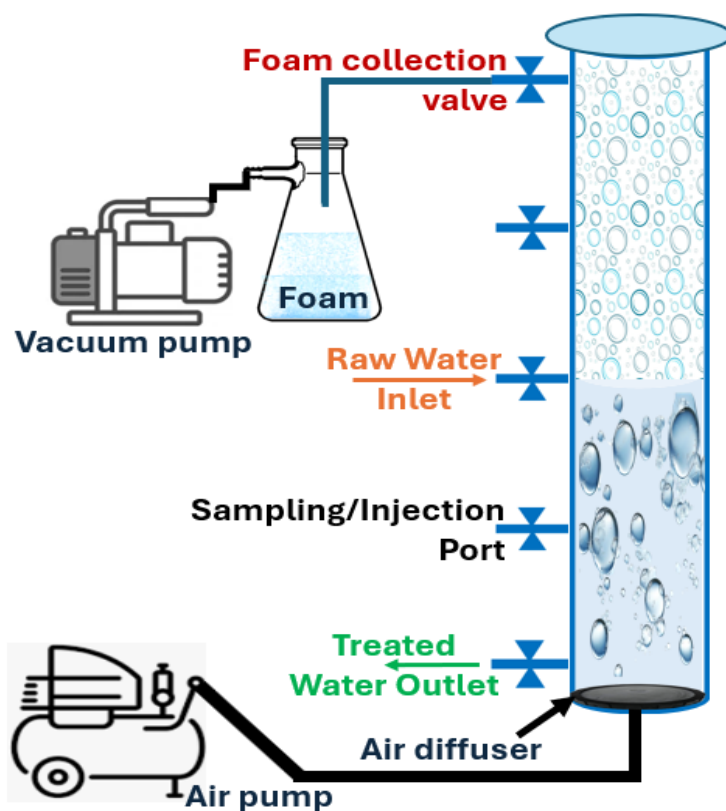


Figure 2: Laboratory-scale foam fractionation system for emerging contaminants removal

collected through the foam collection valve, while treated water was discharged through the outlet port. This configuration enabled controlled operation of the system and effective separation of contaminants from the bulk water phase during treatment.

Initial concentrations of PFAS and microplastics were quantified prior to treatment. System performance was evaluated through optimization of key operational parameters, including air flow rate, pH, contact time, recirculation rate, and optimized surfactant input, with the objective of maximizing contaminant removal while minimizing chemical usage and energy demand.

3.3 Sample Collection and Analysis

Influent water, treated effluent, and collected foam samples were analyzed to quantify contaminant removal efficiency and enrichment. PFAS concentrations were measured using liquid chromatography–tandem mass spectrometry (LC-MS/MS), while microplastics were characterized using Fourier transform infrared (FTIR) microscopy. Removal efficiency was calculated based on differences between influent and treated water concentrations, with foam samples used to assess contaminant enrichment within the foam phase. In addition to contaminant removal efficiency, the treatment process was evaluated for overall operational performance, including foam stability, energy consumption, and waste volume generation. These evaluations were conducted to assess the feasibility and sustainability of foam fractionation as a low-cost, low-chemical, and energy-efficient treatment approach for drinking water applications. The use of local urban water sources ensured relevance to real-world operating conditions and community-level water treatment challenges.



Figure 3: LC-MS/MS analysis of foam fractionation samples at the WET Center

4 RESULTS AND DISCUSSIONS

Foam fractionation demonstrated strong time-dependent removal of both long-chain and short-chain PFAS (Figure 4; Figure 5). For long-chain PFAS (PFOA-C8, PFOS-C8, and PFNA-C9), rapid removal was observed during the initial aeration period, with removal efficiencies exceeding ~65–75% within the first 30 minutes. Removal continued to increase with aeration time, reaching >95% removal after 150–180 minutes. Among these compounds, PFNA (C9) exhibited the highest removal efficiency throughout the experiment, followed by PFOS

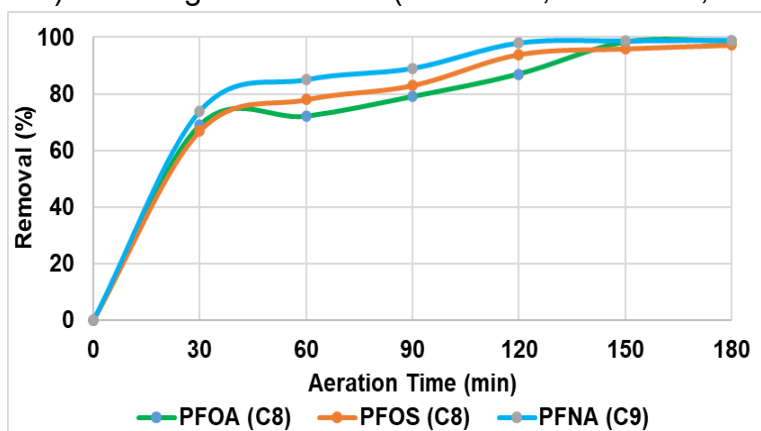
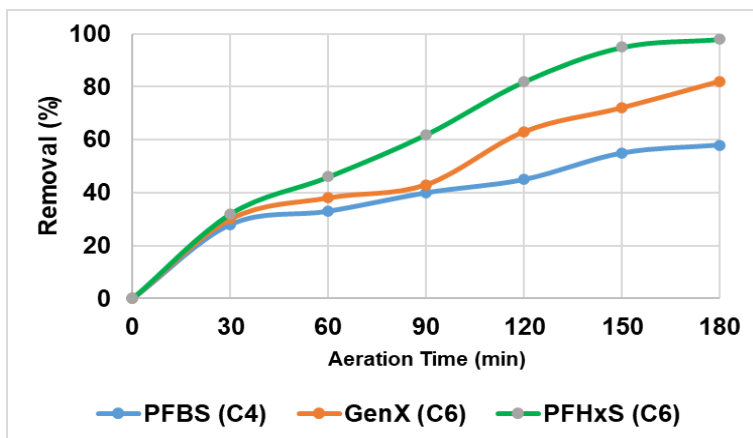


Figure 4: Removal of long-chain PFAS during foam fractionation as a function of aeration time

and PFOA, consistent with increasing hydrophobicity and surface activity with longer fluorinated carbon chains.

Short-chain and replacement PFAS compounds (PFBS-C4, GenX-C6, and PFHxS-C6) exhibited slower removal kinetics compared to long-chain PFAS. Removal efficiencies increased gradually with aeration time, reaching approximately 55–60% for PFBS, ~80% for GenX, and >95% for PFHxS after 150–180 minutes with the use of surfactant. The reduced removal of PFBS relative to other PFAS reflects its lower hydrophobicity and weaker affinity for the air–water interface. These results indicate that foam fractionation is particularly effective for longer-chain and more surface-active



PFAS, while extended aeration and cationic surfactant improves removal of shorter-chain compounds. The use of a cationic surfactant was observed to accelerate the removal of short-chain PFAS, likely by enhancing electrostatic interactions and improving bubble–contaminant attachment at the air–water interface. While effective, this study treated surfactant input conservatively, and the reported results represent preliminary optimization conditions. Ongoing work is focused on identifying and evaluating natural, non-toxic cationic surfactants derived from sustainable sources to further enhance short-chain PFAS removal while minimizing chemical input and environmental impact. Foam fractionation system is therefore being continuously optimized with alternative surfactants to improve performance, sustainability, and applicability for drinking water treatment. These results indicate that foam fractionation is particularly effective for longer-chain and more surface-active PFAS, while optimized surfactant selection and extended aeration and surfactant can significantly improve the removal of short-chain PFAS compounds.

Foam fractionation was also effective for the removal of common microplastic polymers, including polyethylene (PE), polypropylene (PP), polystyrene (PS), polyamide (PA), and polyvinyl chloride (PVC) (Figure 6). Removal efficiencies increased steadily with aeration time for all polymers. After 30 minutes, removal ranged from approximately 28–45%, depending on polymer type. Extended aeration resulted in substantially higher removal, with efficiencies exceeding 95% for all polymers after 150–180 minutes. Differences in removal behavior among polymers were observed during early aeration stages. More hydrophobic polymers such as PA and PVC exhibited faster initial removal compared to

PE and PP, likely due to stronger hydrophobic interactions with rising air bubbles. PS showed comparatively slower removal during intermediate aeration times, which may be attributed to differences in surface charge, density, or particle-bubble attachment behavior. However, these differences diminished with extended aeration, suggesting that sufficient contact time allows effective capture of diverse microplastic types.

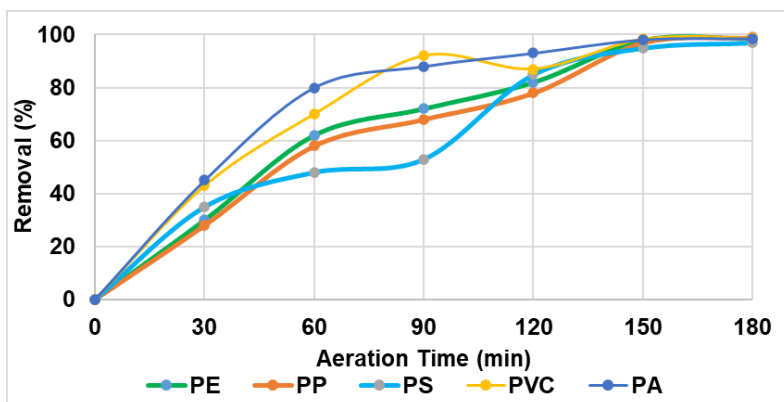


Figure 6: Removal of microplastics during foam fractionation.

The observed removal trends are consistent with the fundamental principles of foam fractionation. PFAS molecules and microplastics preferentially adsorb at the air–water interface due to hydrophobic interactions, electrostatic forces, and surface tension effects. Longer-chain PFAS exhibits stronger interfacial affinity, resulting in faster and more efficient enrichment within the foam phase. Similarly, hydrophobic microplastics readily attach to bubble surfaces and are transported upward with rising foam. The time dependent increase in removal efficiency highlights the importance of aeration time and bubble–contaminant contact for effective separation. Optimized surfactant input was observed to improve foam stability and enhance contaminant capture while maintaining relatively low overall chemical usage. However, these results represent preliminary mechanistic observations, and continued optimization of surfactant type, dosage, and operating conditions is ongoing to further improve system performance and sustainability.

5 PERFORMANCE AND SUSTAINABILITY IMPLICATIONS

The high removal efficiencies achieved for both PFAS and microplastics demonstrate the potential feasibility of foam fractionation as a low-cost, low-chemical, and energy-efficient treatment approach. The ability to target multiple contaminant classes within a single treatment step represents an important advantage over conventional treatment technologies that often require multiple unit operations. The strong performance observed using real drinking water matrices further supports the relevance of this approach under realistic operating conditions. It is important to note that these findings are preliminary, and the foam fractionation system is currently undergoing continued optimization to refine operational parameters, evaluate alternative and more sustainable surfactant options, and assess long-term performance and scalability. Ongoing work focuses on improving

the removal of short-chain PFAS, minimizing chemical input, and evaluating broader applicability for drinking water treatment systems.

This project supports multiple United Nations Sustainable Development Goals (SDGs) through the development of a sustainable treatment strategy for emerging contaminants in drinking water. Specifically, the work aligns with SDG 11 (Sustainable Cities and Communities) by addressing urban drinking water quality challenges; SDG 12 (Responsible Consumption and Production) by promoting low-chemical and resource-efficient treatment approaches; SDG 14 (Life Below Water) by reducing the release of PFAS and microplastics into aquatic ecosystems; and SDG 15 (Life on Land) by mitigating contaminant transfer from water systems to terrestrial environments and human populations.



Figure 7: Alignment of the foam fractionation project with United Nations Sustainable Development Goals (SDGs)

6 CONCLUSIONS AND IMPLICATIONS FOR FUTURE RESEARCH

This project successfully demonstrated the potential of foam fractionation as a sustainable treatment approach for the removal of per- and polyfluoroalkyl substances (PFAS) and microplastics from drinking water. Using a laboratory-scale system and real drinking water matrices, the study showed that foam fractionation can achieve high removal efficiencies for multiple contaminant classes, particularly long-chain PFAS and common microplastic polymers. These findings highlight the ability of foam fractionation to target diverse emerging contaminants within a single treatment step, offering an important advantage over conventional treatment technologies that often require multiple unit operations, higher chemical inputs, and greater energy demand.

The results further revealed clear time dependent removal behavior, underscoring the importance of aeration time, bubble–contaminant contact, and interfacial interactions in

driving treatment performance. While long-chain PFAS exhibited rapid and efficient removal due to stronger hydrophobic and surface-active properties, short-chain and replacement PFAS showed comparatively slower removal kinetics. The use of optimized cationic surfactant input was observed to accelerate short-chain PFAS removal by enhancing bubble attachment and foam stability, while maintaining relatively low overall chemical usage. These outcomes support the feasibility of foam fractionation as a low-cost, low-chemical, and energy-efficient treatment strategy for emerging contaminants in drinking water.

It is important to emphasize that the findings presented in this report represent preliminary results, and the foam fractionation system is currently undergoing continuous optimization. Ongoing research efforts are focused on refining operational parameters, including aeration conditions, surfactant dosage, and recirculation strategies, to further enhance removal efficiency and system sustainability. In particular, future work will prioritize the identification and evaluation of natural, non-toxic, and sustainable cationic surfactants derived from environmentally benign sources to improve the removal of short-chain PFAS while minimizing chemical inputs and potential secondary impacts.

In addition to contaminant removal, future research will address the management and treatment of the concentrated foam phase generated during foam fractionation. Planned work includes the destruction of concentrated PFAS-containing foam using supercritical water oxidation (SCWO) as a complementary treatment step, enabling complete contaminant destruction and preventing secondary waste generation. This integrated treatment framework combining foam fractionation for contaminant separation with SCWO for destruction represents a promising pathway toward holistic and sustainable PFAS management.

Extensive testing is currently ongoing to evaluate long-term system performance, scalability, energy requirements, and robustness under variable water quality conditions. The final, fully optimized results from this work are intended for dissemination through peer-reviewed journal publications and national and international conference presentations, contributing to the broader scientific understanding of sustainable treatment technologies for emerging contaminants.

Acknowledgement

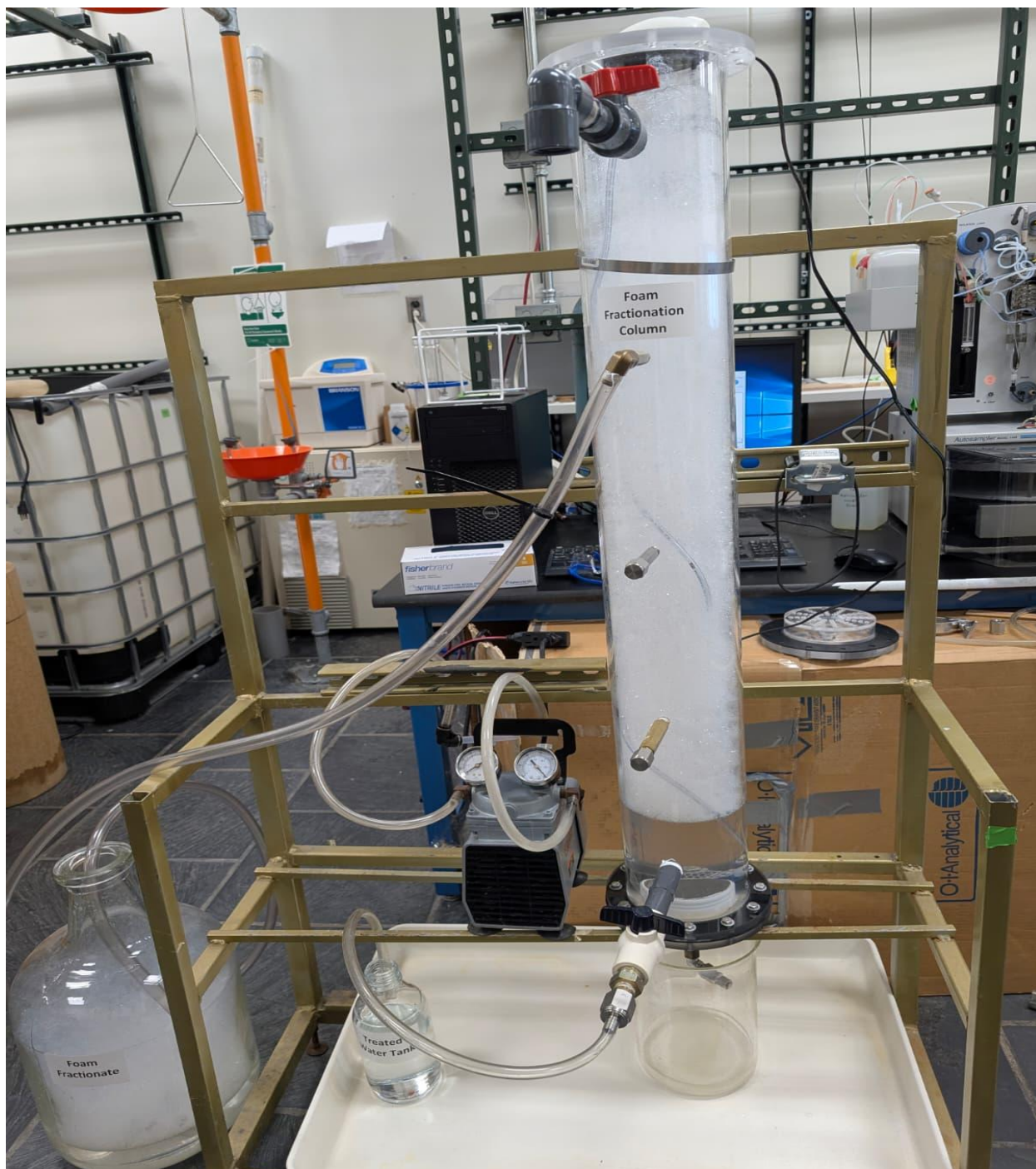
The author gratefully acknowledges the **Office of Sustainability at Temple University** for their generous support through the Graduate Research Award Sustainability Program (GRASP). The Office of Sustainability's commitment to advancing sustainability-focused research and supporting student-led innovation was instrumental in the successful execution of this project.

The author expresses sincere gratitude to the Faculty Mentor, Dr. Gangadhar Andaluri, for his outstanding guidance, mentorship, and continuous support throughout the project. Dr. Andaluri's technical expertise, thoughtful advice, and encouragement were critical in shaping the experimental design, data interpretation, and overall direction of the research. The author also thanks the Department of Civil and Environmental Engineering, Temple University for support and the Water and Environmental Technology (WET) Center at Temple University for providing access to the LC-MS/MS facility, which was essential for PFAS analysis conducted in this study.

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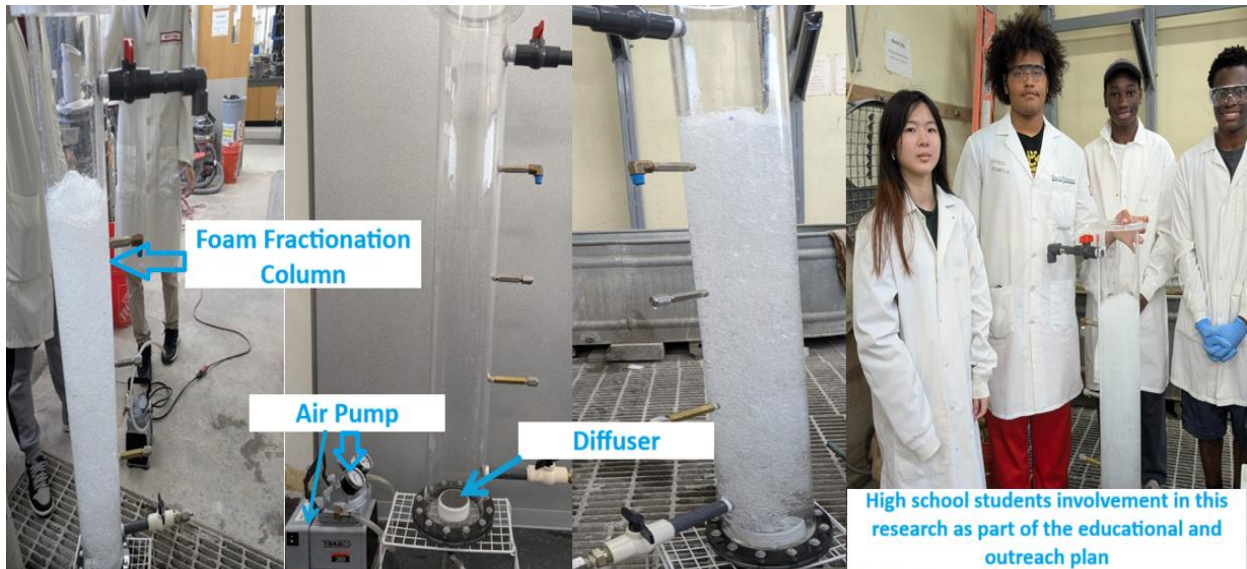
Annex A: Laboratory-scale foam fractionation system assembled for PFAS and microplastics removal experiments



Laboratory-scale foam fractionation column in operation. The setup includes the foam fractionation column, air pump, and collection containers for foam fractionate and treated water. This system is being used to evaluate the removal efficiency of PFAS and microplastics as part of the GRASP project.

Annex B: High school students participating in the GRASP project during Summer 2025 as part of the educational and outreach plan.

Outreach and Education: In addition to the technical milestones, high school students participated in the project during Summer 2025 as part of the educational and outreach plan. They were introduced to the principles of foam fractionation, assisted in the assembly of the laboratory-scale foam fractionation reactor, and observed laboratory experiments. Their involvement not only enhanced STEM learning but also highlighted the broader educational and community impact of this research.



Laboratory-scale foam fractionation system developed for the GRASP project, showing the foam fractionation column, air pump, and diffuser. The setup was assembled and tested during Summer 2025. High school students actively participated in this research as part of the educational and outreach plan, gaining hands-on experience with sustainable water treatment technologies.

Annex C: Participation in Campus Sustainability Month: Educational Outreach and Engagement Activities

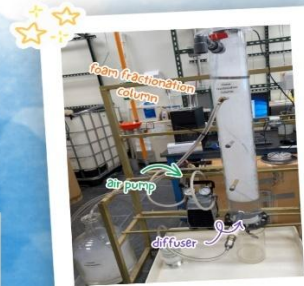
During the fall semester of the award period, a hands-on demonstration of foam fractionation technology for sustainable water treatment was conducted as part of the GRASP-supported project during Campus Sustainability Week. The demonstration highlighted the principles of emerging contaminant removal, including PFAS and microplastics, and showcased the system's relevance to sustainability and public health. The photograph shown below documents this demonstration activity, which contributed to increased awareness and engagement with sustainability-focused research within the Temple University community.

**Sustainable
Treatment Innovation:**
Addressing the Challenge of Removing
Emerging Contaminants from Water
with GRASP winner, Md Saiful Islam

Wed, 11/5 at 3PM
Engineering Building
Teaching Lab 502



More info
here



Foam Fractionation Technology
removes chronogegetic emerging contaminants such
as PFAS and microplastics from water and wastewater!

