Aqueous Film-Forming Foam Collection and Disposal Program: Final Environmental Impact Statement

Appendix A.7: Response to Comments Report

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DEPARTMENT OF
ECOLOGY
State of Washington

PUBLICATION INFORMATION

This is **Appendix A.7** of the Aqueous Film-Forming Foam Collection and Disposal Program Final Programmatic Environmental Impact Statement. This appendix is available on the Washington State Department of Ecology's website at: https://apps.ecology.wa.gov/publications/summarypages/2404040.html.

This report was prepared for Washington State Department of Ecology by TRC Companies, Inc.

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[1] ecology.wa.gov/about-us/contact-us
[2] ecology.wa.gov/accessibility

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Acronyms and Abbreviations

AFFF	aqueous film-forming foam
Ecology	Washington State Department of Ecology
EGLE	Michigan's Department of the Environment, Great Lakes, and Energy
EIS	environmental impact statement
EPA	United States Environmental Protection Agency
GHGs	greenhouse gases
LQG	large quantity generator
MQG	medium quantity generators
PCBs	polychlorinated biphenyls
PFAS	per- and polyfluoroalkyl substances
SCWO	supercritical water oxidation
SEPA	State Environmental Policy Act
SQG	small quantity generator
TSD	treatment, storage, and disposal

1 Introduction

1.1 Background

Washington State Department of Ecology (Ecology, we) proposed a statewide program to dispose of aqueous film-forming foam (AFFF) containing per- and poly-fluorinated alkyl substances (PFAS) currently stockpiled at Washington's municipal fire departments. The environmental impact statement (EIS) analyzes proposed alternatives, describing methods of collection, transport, and disposal of the stored AFFF.

During the past several years, we coordinated a team of state agencies and worked with a wide range of experts to study and collect information on the program area. We collaborated with residents, stakeholders, Tribes, and other state agencies to present the most accurate, science-based information possible.

The State Environmental Policy Act (SEPA) requires that an EIS provides a reasonable range of alternative approaches to the proposed action. The draft EIS describes five options for treatment, storage, and disposal of AFFF stockpiles:

- Alternative 1: Approved Hold in Place
- Alternative 2: Incineration
- Alternative 3: Solidification and Landfilling
- Alternative 4: Class I Deep Well Injection
- Alternative 5: No Action

Regardless of the chosen alternative, Ecology is committed to conducting necessary engagement, consultations, and coordination with federally recognized Tribes. In addition, for all alternatives except the no action alternative, we will adhere to the state's regional spill response plans before foam collection, including mandatory communication and coordination with federal, state, Tribal, and local entities.

1.2 Comment Process

This response to comments report provides a summary of the comments received during the public comment period for the draft EIS, along with Ecology's responses. Responses focus on factual corrections, clarification, and how substantive comments were addressed.

The draft EIS was published on December 20, 2023, and interested parties were notified of the document's availability and opportunities to comment during a 45-day public comment period, through February 5, 2024.

Prior to publishing the report, Ecology sent notices to Native American Tribes requesting comments on the draft EIS during an open comment period beginning November 20, 2023.

On January 17, 2024, Ecology held a public information meeting to provide more information about the proposed program and to answer questions about the draft EIS. A public hearing was held on January 31, 2024, to hear oral comments and document public comments on the draft EIS.

The draft EIS and appendices were available for public review throughout the entire length of the public comment period. Ecology created a program-specific website to provide information through the duration of the State Environmental Policy Act (SEPA) process. Comments were submitted online, via email, during the public hearing, or by writing to Ecology's Northwest Region Office. The draft EIS was available via our AFFF program webpage,[3] the draft EIS summary page,[4] and the SEPA register.[5] Printed copies were available upon request. Americans with Disabilities Act accommodations were also available. News releases were posted to the Ecology website and media lists.

Legal notices were published at the start of the public comment period. Information was published on Ecology's Public Input and Events Listing website, and the project website was updated. Agencies were notified by email, social media, and SEPA register notices.

1.3 Comment Analysis

A comment analysis process was developed to organize and track the comments received during the draft EIS comment period. First, a coding structure was developed to identify each commenter and each of their concerns or questions. Each comment was entered in a spreadsheet along with these codes, referred to as comment codes. Then, common topics and issues were grouped and summarized and provided to Ecology technical experts for their responses.

1.4 Guide to this Report

This document is included as a separate appendix to the final EIS. While the comment analysis process captured the full range of comments received, it is important to note that this report provides a summary of the comments rather than a statistical analysis of general public opinion. The commenting process should not be viewed as a vote-counting process; SEPA emphasizes responding to the content of comments received.

All comments submitted during the public comment period were reviewed and considered in the development of this report and the final EIS. Master responses were prepared to address similar themes where appropriate. Revisions identified in the comments, as well as other substantive changes to the draft EIS, have been incorporated into the final EIS. All substantive comments on the draft EIS have been responded to in this report. Responses to comments in this report rely on information available at the time and identify the analyses

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[3] ecology.wa.gov/afff-eis
[4] apps.ecology.wa.gov/publications/SummaryPages/2304064.html
[5] ecology.wa.gov/sepa-register

that are in development or anticipated to be developed in the future through other processes.

Chapter 2 of this report provides summary information about the commenters and comments received on the draft EIS.

Chapter 3 addresses the common themes in the comments we received. It gives concise responses to six main concerns.

Chapter 4 includes comments sorted into groups by common topic and presented as concern summaries. After each concern summary is a brief response and a list of the comment codes reflected in the concern summary.

Chapter 5 includes a complete record of all the comments, with numbering that corresponds to the comment codes given in the concern summaries. The comment record also gives reference numbers corresponding to the original comment letters, which are provided in Attachment 1.

The final EIS is being issued under Washington Administrative Code (WAC) 197.11.460 and completes the SEPA process.

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2 Comment Analysis

During the comment period for the draft EIS, we received 140 communications in the form of emails, online forms, and verbal testimony at public hearings. These communications were received from 43 commenters, including state agencies, local governments and public institutions, organizations, businesses, and individuals. Table 2-1 summarizes the communications received. Ecology appreciates the time and attention that commenters committed to reviewing the draft EIS.

Table 2-1: Summary of Communications

COMMENTERS	COMMUNICATIONS RECEIVED
Tribes	0
Agencies, Public Institutions, and Elected Officials	3
Individuals	21
Businesses	1
Organizations	18

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3 Master Responses to Comments

The responses presented in this chapter address common themes in multiple written and oral comments we received during the public review period for the draft EIS. The use of master responses in this context avoids repetition and therefore streamlines information presented in the final EIS. Some of the responses in Chapters 4 and 5 contain references to the master responses presented here. Chapter 5 of this document presents all the comments received and our responses.

3.1 Master Response 1: Overview of Ecology's Product Replacement Program and Fire Department Participation

We value your participation in Ecology's Product Replacement Program. The program was initiated by Ecology's Hazardous Waste and Toxic Reduction Program in response to the State of Washington Legislature enacting the Firefighting Agents and Equipment Law (Chapter 70A.400 Revised Code of Washington) in 2018. Ecology is developing this program to help Washington fire departments collect, remove, and dispose of stockpiles of PFAS-containing AFFF.

Municipal fire departments and local fire districts may participate. In addition to municipal fire departments, the program is open to port authorities, fire districts, and training facilities at no cost. At the publication of the draft EIS, over 100 fire departments reported 59,000 gallons of stockpiled AFFF. To date, 147 departments have identified about 70,000 gallons of PFAS-containing AFFF for disposal. Ecology expects this number to grow as more fire departments choose to participate in the program.[6]

3.2 Master Response 2: Regulatory Environment

Ecology is authorized by the U.S. Environmental Protection Agency (EPA) to administer the dangerous waste permitting process in Washington.[7] Unused commercial and Mil-Spec (military specification) PFAS-containing AFFF typically stored and used at municipal fire stations, airports, and military facilities designate as a Washington State–only persistent dangerous waste once the product:

1. Can no longer be used as-is,
2. Cannot be used due to legal restrictions (such as bans or moratoriums), or
3. Designates as a waste under the dangerous waste regulations.

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[6] See EIS Appendix A.2: Washington State Fire Department AFFF Inventory

[7] Ecology's dangerous waste permits webpage: https://ecology.wa.gov/regulations-permits/permits-certifications/dangerous-waste-permits

AFFF is considered a “product” while it is stored at fire departments. It will become a dangerous waste once the program is able to facilitate disposal of the foam and the foam is placed into transportation for disposal.

Under Washington State law, each fire station that disposes of AFFF is classified as one of the following generator categories:

- Small Quantity Generators (SQGs), storing less than 220 pounds of dangerous waste (approximately 23 gallons of AFFF).
- Medium Quantity Generators (MQGs), storing between 220 and 2,200 pounds of dangerous waste (approximately 23 to 234 gallons of AFFF).
- Large Quantity Generators (LQGs), storing more than 2,220 pounds of dangerous waste (approximately 234 gallons of AFFF).

Approximately 19%, 25%, and 56% of the of the 113 fire departments participating in the AFFF disposal program would be classified as SQGs, MQGs, and LQGs, respectively.

Under State law, SQGs may dispose of their dangerous waste in a municipal landfill, provided the SQG meets all other conditions for exemption under WAC 173-303-171. MQGs and LQGs, however, are prohibited from disposing of their dangerous waste at a municipal landfill. MQGs and LQGs must dispose of dangerous waste at a federally permitted hazardous waste treatment, storage, and disposal facility.

SQGs and MQGs may use the state’s episodic generation rules[8] to maintain their current generator category. Using the episodic generator rules is optional. However, if participation in the disposal program would push a generator into a higher generator category, they will face additional restrictions on how they handle their dangerous waste. If fire departments want to maintain their current generator category, they will be highly encouraged to use the episodic generation rules.

For the proposed program, AFFF would be collected from individual fire departments located in larger urban areas. AFFF transported from fire departments in rural areas would be collected in mixed loads from various suppliers and temporarily stored at regulated transfer facilities prior to being transported to facilities for treatment and disposal.[9] Ecology will work with individual fire departments to ensure stockpiles of AFFF are collected, transported, and disposed of or destroyed pursuant to the applicable state and federal rules and regulations in place at the time.

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[8] ecology.wa.gov/regulations-permits/reporting-requirements/dangerous-waste-reporting-requirements/notification-of-dangerous-waste/episodic-generation

[9] The transport portion of the process begins at the location of wherever the foam is loaded onto trucks and taken out of state to its final destination to be incinerated, landfilled, or prepared for deep well injection. The disposal process and requirements are in RCRA permits for each facility.

3.3 Master Response 3: Development of Alternatives

Chapter 2 provides details for each alternative regarding the method of disposal or destruction, as well as the regulatory requirements and approvals controlling each alternative. Development and assessment criteria for selecting the alternatives during the EIS scoping phase included:

- Identification of treatment, storage, and disposal (TSD) facilities currently licensed to treat or dispose of dangerous waste defined by the state of Washington.

- Identification of TSD facilities that maintain active permits to operate in compliance with the federal Resource Conservation and Recovery Act (RCRA).

- Review of TSD facilities authorized to receive state-only dangerous waste.

- Review of technical studies on the efficacy of disposal or destruction technologies.

- Review of other state and federal AFFF disposal programs and the disposal alternatives considered.

- Consultation with the Washington Attorney General's Office, Department of Health, and the following Ecology programs:
  - Product Replacement Program
  - Toxic Reduction Program
  - Regulatory Affairs
  - Reducing Toxic Threats
  - Air Quality Program
  - The Native American Tribal Liaison Office

3.4 Master Response 4: No-Action Alternative

WAC 197-11-440(5) contains requirements for State Environmental Policy Act (SEPA) EIS content. Ecology must evaluate a no action alternative alongside other reasonable alternatives for achieving a proposal's objective. The SEPA Handbook states:

> SEPA requires the evaluation of the no-action alternative, which at times may be more environmentally costly than the proposal or may not be considered 'reasonable' by other criteria. Still, it provides a benchmark from which the other alternatives can be compared.
>
> The identification of a no-action alternative can sometimes be difficult. It is typically defined as what would be most likely to happen if the proposal did not occur.[10]

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[10] SEPA Handbook: ecology.wa.gov/getattachment/4c9fec2b-5e6f-44b5-bf13-b253e72a4ea1/2-2018-SEPA-Handbook-Update.pdf

By choosing the no action alternative, fire departments would continue to use, store, and dispose of their commercial-use AFFF stockpiles independently without Ecology support. Despite this, fire departments are required to comply with Chapter 173-303 WAC when disposing of their waste foam.

Under Washington law most fire departments currently classify as SQGs or MQGs. SQGs may dispose of their dangerous waste in a municipal landfill, provided they meet all other conditions for exemption under WAC 173-303-171. However, MQGs and LQGs, under state law, are prohibited from disposing of their dangerous waste at a municipal landfill. MQGs and LQGs must dispose of dangerous waste at a federally permitted hazardous waste treatment, storage, and disposal facility.

3.5 Master Response 5: Mitigation Measures

Chapter 4: Mitigation Measures in the final EIS explains Ecology's approach to analysis, significance criteria, and identifying mitigation and best practices to reduce potentially significant, adverse environmental impacts from implementation of one or more of the alternatives.

Mitigation measures are outlined in the EIS with varying levels of detail. Because the AFFF program alternatives are still being developed, some mitigation measures lack specific details. Ultimately, to be enforced, those mitigation measures must be identified and included as part of a permit, rule, contract, or participation agreement. The development of a permit, rule, contract, or participation agreement that would include project-specific mitigation and protections would occur after the final EIS is published, and the preferred AFFF disposal option is selected and approved. In addition to the mitigation requirements, the preferred disposal option and any contractors selected to implement it would be required to adhere to federal, state, and local regulations and guidance protecting public safety and environmental health, such as Department of Transportation hazardous waste transport regulations regarding manifests, spill response, and signage.

One potentially significant, adverse impact common to all project alternatives would be the accidental release of AFFF during collection, transport, and disposal activities. Ecology has identified potentially adverse impacts on Tribal resources, as well as proposed mitigation measures on Tribal lands, resulting from implementing one or more action alternatives. These impacts are presented in Section 3.9: Tribal Resources, Section 3.12: Public Services and Utilities, and Chapter 5: Cumulative Impacts of the final EIS. Ecology will develop a Tribal communications plan in order to effectively communicate and coordinate with Washington’s Tribes. The goal will be to minimize or eliminate AFFF collection and transport impacts upon Tribal activities or access to reservations and usual and accustomed areas.

Although potential exposure to PFAS substances is considered limited, many Northwest Native American Tribes are at a higher exposure risk due to their fish consumption and traditional recreational activities in waterbodies that may be contaminated with PFAS. The implementation of the state and regional AFFF spill response plans listed on pages 4-8 through 4-10 of the draft EIS would mitigate the potential significant impacts of AFFF accidental release.

3.6 Master Response 6: Alternatives Considered and Eliminated

During the EIS scoping phase in 2021 and early 2022, Ecology considered and eliminated two alternatives not deemed to be legally viable or physically available. Section 2.2.6 Alternatives and Actions Eliminated from Further Consideration in the final EIS discusses the alternatives considered but ultimately eliminated, along with the reasons those options were not considered “reasonable alternatives.”

As noted in Section 2.2.6.1 Collection and Storage of AFFF at a Centralized Location, Ecology investigated collection and transport of AFFF to either a private or government-operated TSD facility capable of storing, managing, and monitoring AFFF indefinitely in an indoor or covered environment. Ecology reached out its Nuclear Waste Program about the possibility of indefinitely storing AFFF at the Hanford Nuclear Reservation. In addition, Ecology contacted Clean Harbors about indefinitely storing AFFF at their facility in Aragonite, Utah. The Nuclear Waste Program and Clean Harbors rejected the possibility of storing state-collected AFFF at their facilities for liability, legal, and environmental reasons. No other public or private facilities have been identified as a potential central storage site as of the draft EIS publication date. Therefore, this alternative was eliminated.

Meanwhile, a separate supercritical water oxidation (SCWO) technology alternative was eliminated from further consideration for several reasons. First, under Washington State dangerous waste regulations, PFAS-containing AFFF designates as a state-only dangerous waste and must be disposed of at a federally permitted TSD facility. Currently, there are no SCWO facilities located at TSDs.

However, state regulations permit the disposal of state-only dangerous waste at non-TSDs if Ecology gets written permission from the receiving state’s responsible environmental regulatory agency. At the time that Ecology investigated SCWO for the draft EIS, there was a single commercially viable SCWO operation in the United States. That was a Battelle facility located in Wyoming, Michigan. Ecology reached out to Michigan’s Department of the Environment, Great Lakes, and Energy (EGLE) in the fall of 2022 about whether EGLE would authorize the shipping of Washington State’s PFAS-containing firefighting foam to the Wyoming facility. EGLE notified Ecology that they would not grant that permission.

In addition, at the time of EIS scoping and during the drafting of the EIS, Ecology had not yet received requested SCWO PFAS destruction data. As such, Ecology could not confirm the effectiveness of an SCWO alternative.

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4 Summaries of Comments and Responses

This section summarizes concerns by each resource area, as well as concerns about the EIS process, description of the program and alternatives, mitigation measures, and cumulative impacts. Environmental concerns were identified for each resource area based on public and stakeholder comments during the public comment period. Resource areas are identified in Chapter 3 of the EIS as follows:

- Air Quality
- Greenhouse Gas Emissions
- Earth and Water Resources
- Aquatic Resources
- Terrestrial Species and Habitats
- Vegetation
- Human Health and Safety
- Cultural, Historical, and Archeological Resources
- Tribal Resources
- Transportation and Truck Safety
- Environmental Justice
- Public Services and Utilities

4.1 SEPA EIS Process, Procedures, and Regulatory Context

The EIS State Environmental Policy Act (SEPA) process and regulatory context for the Washington Aqueous Film-Forming Foam (AFFF) Collection and Disposal Program are found in draft EIS Chapter 1: Introduction and Chapter 2: Project Description and Alternatives Analysis. The April 2022 *AFFF Collection and Disposal Comment Summary*[11] provides the scope of analysis in the EIS and the significant issues that are analyzed in depth in the EIS, including impacts to the environment and human health, potential alternative disposal methods, questions for Ecology, and recommended next steps.

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[11] Appendix A.1, Part 2: Scoping Comments Summary of the draft EIS, https://apps.ecology.wa.gov/publications/SummaryPages/2304064.html

4.1.1 Summary of Concerns

Several comments we received were focused on the EIS process and selected alternatives. Comments included questions about the selection of alternatives, conclusions on impacts, and the decision-making process.

Comments also expressed positions supporting or opposing particular AFFF program alternatives. Ecology used the public comments to review the draft EIS as it prepared the final EIS and to make transparent decisions about the disposal alternatives. The preferred alternative(s) will be selected after the final EIS is published and will guide the AFFF disposal program development and implementation.

Some commenters expressed support and guidance for industries managing per- and polyfluoroalkyl substances (PFAS) issues.

One commenter suggests that Ecology include AFFF as chemical waste under Washington's dangerous waste regulations (Chapter 173-303 WAC) — like chemicals such as polychlorinated biphenyls.

4.1.2 Summary of Responses

Ecology prepared the draft EIS to help the public better understand the environmental impacts and public health effects associated with each proposed disposal alternative. Given this information, the public could submit better-informed public comments. For a basic overview of SEPA, please visit Ecology's SEPA guidance website.[12]

4.1.3 Comment Codes

I-1-1-1
I-1-1-3
I-6-1-1
I-7-1-1
I-9-1-1
I-16-1-1
I-16-1-6
I-16-1-7
I-17-1-2
ORG-9-1-6
ORG-12-1-1
ORG-12-1-5
ORG-12-1-7

4.2 Program Description, Scope of Analysis, and Alternatives Support / Opposition

In 2019, the Washington State Legislature allocated funds authorizing Ecology to oversee the administration of a statewide program to collect, transport, and dispose of PFAS-containing firefighting foam currently owned by municipal fire departments and select state agencies. The EIS is to provide sufficient information on the best options for AFFF disposal that align with the protection of human health and the environment. Ecology will use this information to make an informed decision on which alternative or alternatives should be selected for implementation.

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[12] ecology.wa.gov/regulations-permits/sepa/environmental-review/sepa-guidance/basic-overview

The alternatives evaluated are listed below:

- Alternative 1: Approved Hold in Place
- Alternative 2: Incineration
- Alternative 3: Solidification and Landfilling
- Alternative 4: Class I Deep Well Injection
- Alternative 5: No Action

4.2.1 Summary of Concerns

Commenters express support for the program, although a few commenters recommend that it be expanded beyond fire stations.

Concerns about the approved hold in place alternative regard how long the AFFF would be held, and the ongoing risks of spills and releases. Some commenters support approved hold in place because it would allow time for emerging destruction technologies to develop and be available for consideration.

Concerns about the incineration alternative include human health and ecological risks of products of incomplete combustion, and uncertainty and lack of adequate studies about operational conditions, such as temperature and contact time to destroy PFAS. Some commenters support incineration because it is the only alternative considered in the EIS that can destroy PFAS, and commenters state that there are sufficient studies to support Ecology selecting this alternative. Some commenters referred Ecology to studies or publications that supported their comment.

Concerns about the solidification and landfilling alternative include risks of leaks to groundwater and air; the fact that landfilling is not a destructive technology; and that Ecology only considered hazardous waste landfills, excluding non-hazardous waste landfills and municipal solid waste landfills from the alternatives analysis. Some commenters support landfilling, stating that the engineering controls (solidification of AFFF, landfill liner and cap, leachate collection system) and monitoring are rigorous and sufficient to ensure against releases. Some commenters referred Ecology to studies or publications that supported their comment.

Concerns about the Class I deep well injection alternative include the fact that it is not a destructive technology and that there is a long-term risk to water supplies and changes with seismic activity. Some commenters support Class I deep well injection, stating that the injection locations are sufficiently deep and far from water supplies and seismically active areas.

Concerns about the no action alternative include ongoing risks of releases and human and ecological exposure to PFAS from the stored AFFF.

Commenters also requested that Ecology postpone AFFF Collection and Disposal implementation until impacts are thoroughly known and mitigated.

4.2.2 Summary of Responses

Ecology clarified that the current program is limited to municipal fire stations and similar entities, but future programs may include other entities. Ecology also clarified the anticipated timeline for selecting an alternative, which is expected to be late 2024.

Ecology acknowledged the risks associated with the approved hold in place, incineration, solidification and landfilling, and Class I deep well injection alternatives, and clarified that these risks are discussed in the EIS.

Ecology also acknowledged the comments supporting these alternatives and clarified that the engineering controls, monitoring, and operations are discussed in the EIS. If a commenter introduced a risk, engineering control, or publication/study that had not been cited and discussed in the EIS, Ecology added it, if relevant and appropriate. Ecology also referenced commenters to Master Responses 1 and 6 to clarify questions about, respectively, the scope and extent of the program and the reasoning behind eliminating certain alternatives from evaluation.

4.2.3 Comment Codes

GOV-1-1-1
GOV-1-1-2
GOV-2-1-1
GOV-2-1-2
I-11-1-1
I-11-1-2
I-11-1-3
I-11-1-4
I-12-1-1
I-12-1-2
I-12-1-3
I-12-1-4
I-13-1-2
I-13-1-3
I-13-1-4
I-14-1-1
I-15-1-1
I-16-1-2
I-16-1-3
I-16-1-4
I-16-1-5
I-18-1-1
I-19-1-1
I-20-1-1
I-2-1-1
I-3-1-1
I-3-1-2
I-4-1-1
I-4-1-2
I-8-1-1
I-8-1-2
IND-1-1-1
IND-1-1-1
IND-1-1-2
IND-1-1-3
IND-1-1-4
IND-1-1-5
IND-1-1-6
ORG-10-1-1
ORG-10-1-2
ORG-10-1-2
ORG-10-1-3
ORG-10-1-3
ORG-10-1-4
ORG-11-1
ORG-11-1-2
ORG-11-1-2
ORG-1-1-2
ORG-1-1-3
ORG-1-1-4
ORG-1-1-5
ORG-1-1-6
ORG-12-1-8
ORG-3-1-1
ORG-4-1-1
ORG-4-1-6
ORG-4-1-7
ORG-5-1-1
ORG-5-1-2
ORG-5-1-3
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ORG-6-1-3

ORG-6-1-4
ORG-6-1-5
ORG-6-1-6
ORG-6-1-6
ORG-7-1-10
ORG-7-1-2
ORG-7-1-5
ORG-7-1-6
ORG-7-1-7
ORG-7-1-9
ORG-8-1-1
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ORG-8-1-11
ORG-8-1-12
ORG-8-1-13
ORG-8-1-14
ORG-8-1-16
ORG-8-1-17
ORG-8-1-3
ORG-8-1-4
ORG-8-1-6
ORG-8-1-7
ORG-8-1-8
ORG-8-1-9
ORG-9-1-2
ORG-9-1-3
ORG-9-1-4
ORG-9-1-5
ORG-9-1-8

4.3 Air Quality

The EIS analyzed the effects on air quality from each of the alternatives. The affected environment included the ambient air at and near the participating fire stations, temporary storage facilities, potential treatment and disposal sites, and identified transportation routes. A combined qualitative and quantitative analysis was presented. For all alternatives, Ecology determined that there would be a low risk of a significant impact on air resources.

4.3.1 Summary of Concerns

Regarding incineration, commenters' concerns centered around products of incomplete combustion and uncertainty and lack of adequate studies about operational conditions, such as temperature and contact time to destroy PFAS. Commenters were concerned about the uncertainties and data gaps in the impact assessment presented in the EIS, which demonstrated minor PFAS release from incinerating the AFFF. Other commenters stated that data gaps are limited and that there are sufficient studies to show that incineration would have minor impact to air quality. One commenter stated that SCWO would have fewer air emissions than incineration.

Some commenters expressed concern about the solidification and landfilling alternative, citing studies that show that PFAS can be released through landfill gas or fugitive emissions.

4.3.2 Summary of Responses

Ecology acknowledged the data gaps associated with the impact assessment and release calculation, which are already included in the EIS in Section 3.1.4. Ecology clarified that the cited landfill study regarding PFAS emissions was focused on municipal solid waste landfills, which are not being considered under the EIS, and would not apply to hazardous waste landfills. If a commenter introduced a risk, engineering control, or publication/study that had not been cited and discussed in the EIS, Ecology added it, if relevant and appropriate. Ecology also referenced commenters to Master Response 6 to clarify the reasoning behind eliminating certain alternatives from evaluation, such as SCWO.

4.3.3 Comment Codes

ORG-3-1-1
ORG-3-1-2
ORG-4-1-1
ORG-4-1-4
ORG-4-1-7
I-18-1-1
IND-1-1-4
ORG-5-1-1
ORG-5-1-2
ORG-5-1-4
ORG-5-1-6
ORG-5-1-7
ORG-6-1-4
ORG-8-1-6
ORG-8-1-7
ORG-8-1-8
ORG-8-1-14
ORG-9-1-3
ORG-8-1-7
ORG-1-1-4

4.4 Ch 4.4 Greenhouse Gas Emissions

Emissions of PFAS are not classified as greenhouse gases and do not contribute to climate change. However, for Alternatives 2, 3, and 4, greenhouse gas emissions will result from the combustion of fossil fuels required to transport and dispose of AFFF, as well as combustion of AFFF for the incineration alternative. For all alternatives, Ecology determined that the greenhouse gas impacts would not be significant.

4.4.1 Summary of Concerns

Commenters express that the operating temperature needed to destroy PFAS for the Incineration option is not taken into account in the EIS when calculating greenhouse gas emissions. Commenters also express that limiting the landfill disposal options to two out-of-state landfills currently under contract with Ecology would result in higher greenhouse gas emissions than considering local, in-state landfills.

4.4.2 Summary of Responses

Ecology acknowledged the data gaps and limitations of the impact assessment for greenhouse gases, which are summarized in Sections 3.1.4 and 3.2.5 of the final EIS. Ecology also acknowledged the environmental impacts associated with transporting the AFFF while maintaining that these would be offset by potential final disposal at the two landfills considered. The landfills considered in the EIS are located in remote, arid regions that minimize leachate management requirements.

4.4.3 Comment Codes

I-16-1-5
IND-1-1-4
IND-1-1-6

4.5 Earth and Water Resources

The EIS analyzed the effects on earth and water resources from each of the collection and disposal alternatives. Earth and water resources analyzed included soil, surface water, and groundwater at and near the participating fire stations, temporary storage facilities, identified potential treatment and disposal sites, and identified transportation routes. For all alternatives, Ecology determined that there would be a low risk of a significant impact. The risk may be somewhat higher, though still low, for Alternatives 1 and 5, because fire stations may use PFAS-containing AFFF in emergencies.

4.5.1 Summary of Concerns

Concerns centered around the solidification and landfilling alternative and the Class I deep well injection alternative. Commenters expressed concern about the hazards of collection and transport, the risk of PFAS leaching even with solidification, the risk of PFAS migration polluting groundwater supplies, and the lack of recoverability from deep well injection for potential future treatment. Other commenters state that non-hazardous waste landfills, in addition to hazardous waste landfills, should be considered. Some commenters support Class I deep well injection, stating that this is a safe option due to careful siting in appropriate geologic areas and at depths far from water supplies. Some commenters also support solidification and landfilling, stating that the landfills under consideration in the EIS have zero water discharge and are RCRA permitted to prevent release to the environment.

4.5.2 Summary of Responses

Ecology acknowledged the concerns and, where appropriate, referred readers to Section 3.3.4 of the final EIS, which discusses the release mechanisms and risk of release. If a commenter introduced a risk, engineering control, or publication/study that had not been cited and discussed in the EIS, Ecology added it, if relevant and appropriate.

4.5.3 Comment Codes

I-8-1-3
I-9-1-2
I-11-1-2
I-11-1-3
I-11-1-4
I-12-1-3
I-17-1-2
I-19-1-2
ORG-1-1-1
ORG-1-1-2
ORG-1-1-3
ORG-4-1-7
ORG-7-1-4
ORG-7-1-6
ORG-8-1-12
ORG-8-1-13
ORG-9-1-4
ORG-9-1-5
ORG-12-1-1
ORG-12-1-4
ORG-12-1-5
ORG-12-1-6

4.6 Aquatic Resources

The EIS analyzed the effects on aquatic resources and their habitats from each of the collection and disposal alternatives. Sensitive aquatic resources include endangered or threatened aquatic life that live in water bodies, endangered or threatened aquatic-dependent wildlife that consume fish and other aquatic life, and sensitive aquatic habitats. These were analyzed at and near the participating fire stations, temporary storage facilities, potential treatment and disposal sites, and identified transportation routes. For all alternatives, Ecology determined that there would be a low risk of a significant impact. The risk may be somewhat higher, though still low, for Alternatives 1 and 5, because fire stations may use PFAS-containing AFFF in emergencies.

4.6.1 Summary of Concerns

Concerns centered around the solidification and landfilling alternative and the Class I deep well injection alternative. Commenters expressed concern about the hazards of collection and transport, the risk of PFAS leaching even with solidification, the risk of PFAS migration polluting groundwater supplies, and the lack of recoverability from deep well injection for potential future treatment. Other commenters stated that non-hazardous waste landfills, in addition to hazardous waste landfills, should be considered. Some commenters support Class I deep well injection, stating that this is a safe option due to careful siting in appropriate geologic areas and at depths far from water supplies. One commenter supports solidification and landfilling, stating that the landfills under consideration in the EIS have zero water discharge and are RCRA permitted to prevent release to the environment. One commenter stated that SCWO would have near-zero effect on aquatic resources.

4.6.2 Summary of Responses

Ecology acknowledged the concerns and, where appropriate, referred readers to Section 3.4.4, which discusses the release mechanisms and risk of release. If a commenter introduced a risk, engineering control, or publication/study that had not been cited and discussed in the EIS, Ecology added it, if relevant and appropriate. Ecology also referred commenters to Master Response 6 to clarify the reasoning behind eliminating certain alternatives from evaluation, such as SCWO.

4.6.3 Comment Codes

I-1-1-2
I-7-1-2
ORG-1-1-1
ORG-4-1-5
I-19-1-2
ORG-6-1-5
ORG-9-1-5

4.7 Terrestrial Species and Habitats

The EIS analyzed the effects on terrestrial species and habitats from each of the collection and disposal alternatives. Sensitive terrestrial species include endangered or threatened wildlife that live most of their life on land, and sensitive terrestrial habitats. These were analyzed at and near the participating fire stations, temporary storage facilities, potential treatment and disposal sites, and identified transportation routes. For all alternatives, Ecology determined that there would be a low risk of a significant impact. The risk may be somewhat higher, though still low, for Alternatives 1 and 5, because fire stations may use PFAS-containing AFFF in emergencies.

4.7.1 Summary of Concerns

Commenters are concerned about AFFF use on the land to put out wildfires. One commenter supports solidification and landfilling, stating that the landfills under consideration in the EIS have zero water discharge and are RCRA permitted to prevent release to the environment. One commenter stated that SCWO would have near-zero effect on terrestrial species and habitats.

4.7.2 Summary of Responses

Ecology acknowledged the concerns and, where appropriate, referred readers to Section 3.5.4, which discusses the release mechanisms and risk of release. Ecology also referenced commenters to Master Responses 1 and 6 to clarify questions about, respectively, the scope and extent of the program and the reasoning behind eliminating certain alternatives from evaluation, such as SCWO.

4.7.3 Comment Codes

I-1-1-2
I-9-1-1
ORG-4-1-5
ORG-6-1-5

4.8 Vegetation

The EIS analyzed the effects on vegetation from each of the collection and disposal alternatives. Sensitive vegetation includes endangered or threatened plant species, and vegetation alliances that have been identified as sensitive by the Washington Department of Fish and Wildlife. These were analyzed at and near the participating fire stations, temporary storage facilities, potential treatment and disposal sites, and identified transportation routes. For all alternatives, Ecology determined that there would be a low risk of a significant impact. The risk may be somewhat higher, though still low, for Alternatives 1 and 5, because fire stations may use PFAS-containing AFFF in emergencies.

4.8.1 Summary of Concerns

One commenter is concerned about AFFF use on the land to put out fires and recommends that the program be expanded beyond fire stations.

4.8.2 Summary of Responses

Ecology acknowledges the concerns and references the commenter to Master Response 1 to clarify questions about the scope and extent of the program.

4.8.3 Comment Codes

I-17-1-1
I-17-1-2

4.9 Human Health and Safety

The EIS analyzed the effects on human health and safety from each of the collection and disposal alternatives. The analysis focused on workers at the fire stations participating in Ecology's AFFF collection project, the temporary holding facilities, and the identified potential treatment and disposal sites for the collected AFFF. Impacts of PFAS on human health beyond the limits of the operational facilities were discussed in a general sense. Ecology determined that there would be a low risk of a significant impact to human health for all project alternatives.

4.9.1 Summary of Concerns

Commenters express general concern about the health effects of AFFF and PFAS, as well as specific concern for firefighters. Some commenters support incineration as the only alternative that provides for permanent destruction to protect human health. Other commenters express that incineration has too much potential for toxic releases and does not protect public health. Commenters also express concern that the analysis did not take into account data gaps and did not consider potential benefits of alternative destruction technologies, which have potential to be more protective of public health.

4.9.2 Summary of Responses

Ecology acknowledges the concerns and the expressions in support of or against incineration. Ecology references the commenters to Section 3.7.5 and other sections of the final EIS that list data gaps. Ecology also referenced commenters to Master Response 6 to clarify questions about the reasoning behind eliminating certain alternatives from evaluation.

4.9.3 Comment Codes

I-1-1-1
I-1-1-3
I-4-1-2
I-5-1-2
I-7-1-2
I-8-1-4
I-9-1-1
I-10-1-1
I-15-1-1
I-16-1-2
I-16-1-5
I-16-1-7
I-19-1-1
ORG-1-1-7
ORG-4-1-6
ORG-8-1-2
ORG-8-1-4
ORG-8-1-11
ORG-12-1-2

4.10 Cultural, Historical, and Archaeological Resources

4.10.1 Summary of Concerns

No comments concerning Cultural, Historical and Archeological Resources were submitted during the draft EIS public comment period.

4.11 Tribal Resources

Section 3.9 of the draft EIS describes the affected environment for cultural Tribal resources and effects on resources that would result from the proposed actions and alternatives. Historical and cultural resources specifically relate to archaeological sites and Tribal lands and activities discussed in Chapter 2: Project Description and Alternatives. Tribal lands in proximity to fire stations participating in the AFFF collection and disposal program would be subject to impacts of potential leaks or spills that cause accidental releases of AFFF.

4.11.1 Summary of Concerns

Ecology understates the impacts of PFAS disposal on environmental justice communities, focusing exclusively on communities in the immediate vicinity of disposal sites even though PFAS are highly mobile and are known to cause disproportionate harms to lower income communities, Indigenous communities, and communities of color nationwide.

4.11.2 Summary of Responses

The unique legal status of Tribes and the presence of treaty-reserved rights and cultural interests throughout the state create a special relationship between Tribes and state agencies responsible for managing and protecting the state's natural resources.

Under the 1989 State/Tribal Centennial Accord and the 2012 State/Tribal Relations Act (Chapter 122, Laws of 2012), Ecology works with Tribes in a government-to-government relationship to protect and manage shared natural resources and to cooperate across jurisdictions. Ecology is fully committed to the principals of government-to-government consultation and cooperation with Tribes, consistent with our mission to protect, preserve, and enhance Washington's environment, and promote the wise management of our land, air, and water for the benefit of current and future generations.

To respect this relationship, Ecology sought input from Tribes early and throughout the EIS process. Initial outreach included all 29 federally recognized Tribes in the state, and Ecology maintained communication with Tribes that expressed concerns or interest about the proposed project. Ecology offered government-to-government consultation and held Tribal-specific forums to share information about the EIS and receive feedback on the proposals.

Additionally, Master Response 5: Mitigation Measures outlines the regulatory oversight and expected development of a permit, rule, contract, or participation agreement which would include project-specific mitigation and protections as the AFFF program is selected and approved. In addition, Ecology will adhere to federal, state, and local regulations and guidelines protecting public safety and environmental health.

The risk of impacts to Tribes for any of the alternatives would be low, given that Tribal lands are not located close enough to fire stations, potential 10-day holding areas, potential transportation routes, or final destinations for AFFF or PFAS to reasonably impact them. However, Ecology would ensure that foam collection and transport is conducted on dates and times that minimize potential impacts upon Tribal operations and activities. Ecology would select routes, including modifying those presented in this EIS, if applicable, to minimize impacts upon Tribal issues, as well as avoid transporting, when possible, over sensitive resources.

Ecology would also implement regional spill response plans if a spill occurs on Tribal lands or traditional use areas. (This is not anticipated to be necessary, because routes do not traverse Tribal lands).

After the EIS is finalized, Ecology would develop and implement regional Tribal engagement plans. These plans would identify Ecology and Tribal AFFF points of contact through which information can be communicated about AFFF collection and transport. The plan would provide information such as the location and amount of foam to be collected. The plan would also include early notice regarding the foam's collection, allowing time for Tribal input on these activities.

4.11.3 Comment Codes

ORG-7-1-1

4.12 Transportation and Truck Safety

The draft EIS analyzed the transportation effects from each of the collection and disposal alternatives. The analysis focused on the risk of release of AFFF and PFAS to the environment from accidents or spills during truck transport. For all alternatives, Ecology determined that there would be a low risk of a significant impact because the AFFF would be transported using current U.S. Department of Transportation and state regulations, which include requiring approved containers, accurate labeling, appropriate handling, and appropriately implementing rapid spill response.

4.12.1 Summary of Concerns

Commenters express concerns about the hazards of collection and transportation for the landfilling and incinerator alternatives. One commenter stated that SCWO would reduce these potential hazards if deployed locally.

4.12.2 Summary of Responses

Ecology acknowledged the concerns and, where appropriate, referred readers to Sections 3.10.2 and 3.10.3, which discuss the release mechanisms, risk of release, and mitigations. Ecology also referenced commenters to Master Response 6 to clarify questions about the reasoning behind eliminating certain alternatives from evaluation, such as SCWO.

Ecology uses numerous tools and metrics to determine areas that have been subjected to environmental injustices and marginalization. We consider this a major factor in our analyses of each disposal option. Further, we use the most recent data available to identify sensitive waterways, watersheds, and other ecological impact areas. Identifying these areas in advance of AFFF transport will help ensure the hazardous waste transportation contractor is aware of these sites and takes all necessary safety precautions.

4.12.3 Comment Codes

ORG-1-1-2
ORG-1-1-5
IND-1-1-6
ORG-9-1-8
ORG-1-1-4
ORG-1-1-7
ORG-6-1-7

4.13 Environmental Justice

4.13.1 Summary of Concerns

Commenters expressed concern that activities at incineration, landfilling, and deep-well injection facilities will negatively impact low-income and at-risk communities.

Commenters recommended Ecology consider SCWO to safely treat AFFF with minimal harm to human health and safety.

One commenter thinks the draft EIS understates the harms associated with PFAS landfilling and incineration, declaring those impacts to be minimal due to faulty data while ignoring substantial evidence of data gaps and health risks.

The severity of health effects on environmental justice communities does not consider mobility of PFAS because the draft EIS analysis focuses only on communities located within the immediate vicinity of disposal sites.

4.13.2 Summary of Responses

Each disposal option has the potential to impact the environment and public health. In response to comments, Ecology reassessed the disposal program’s environmental justice impacts and replaced the draft EIS’s environmental justice chapter with a supplemental environmental justice report (see Appendix A.8). This new analysis still finds the disposal options aren't expected to have significant impacts on overburdened communities. For each disposal option, mitigation measures—including public outreach—can be implemented to moderate impacts on neighboring communities.

For example, if Ecology decides to incinerate the foam, we will select an incinerator that complies with state and federal law, is situated in a remote location, and requires scientifically accepted incineration temperatures, waste hold times, turbidity requirements, ash disposal measures, and leachate management to minimize impacts upon surrounding communities.

4.13.3 Comment Codes

ORG-6-1-8
ORG-8-1-2
ORG-8-1-15

4.14 Public Services and Utilities

The public services evaluated in this EIS include fire and emergency response, law enforcement, hospitals, emergency management, public schools, and recreation areas. The utilities evaluated in the EIS include electrical power, renewable energy (such as clean hydrogen), water, water supply, wastewater, natural gas, solid waste services, and telecommunications.

4.14.1 Summary of Concerns

Commenters requested Ecology provide timelines and benchmarks for disposal of AFFF and impacts to fire departments. The comments focus on support and guidance managing PFAS issues, which include both fire departments and businesses classified as LQGs.

Some comments focused on capacity shortfalls, especially for Alternative 2 incineration, and requested Ecology conduct further analysis, or focused on potential AFFF disposal sites not considered in the draft EIS, specifically, Subtitle D landfills.

Other comments expressed opposition to Alternatives 1 and 5 (hold in place and no action)

4.14.2 Summary of Responses

PFAS-containing foam could come in contact with and affect public health or the environment during collection and transport activities. However, should such a spill occur, Ecology will coordinate with local and regional emergency response teams and implement specific spill response initiatives described in the EIS's Chapter 4: Mitigation Measures. Because state law does not prohibit fire departments from using firefighting foam, it is unknown whether or how many fire departments would use their held foam under Alternative 5: No Action Alternative.

Commenters are referred to Master Response 1: Overview of Ecology's Product Replacement Program and Fire Department Participation and Master Response 5: Mitigation Measures.

Fire departments that currently have AFFF will be required to comply with the dangerous waste regulations as applicable to generators of dangerous waste once they have initiated disposal via the program.

4.14.3 Comment Codes

I-16-1-1
I-16-1-6
IND-1-13
ORG-10-1-4
ORG-11-1-2
GOV-2-1-2

4.15 Mitigation Measures

Mitigation refers to the process and measures taken to avoid, minimize, and/or offset adverse environmental and human health impacts. Ecology believes successful mitigation will require a wide variety of tools and options for decision-makers and project proponents, including wetland and multi-resource banks, in-lieu fee programs, advance mitigation, and traditional on- and off-site approaches. Consultation and coordination with Tribal and local governments are critical to mitigating environmental and public health impacts. Ecology's mitigation development includes expanded use of interagency agreements, multiagency permit review teams, programmatic agreements, and regional general permits to make mitigation decisions cost effective and more predictable.

Commenters asked about the effectiveness of the proposed measures intended to minimize and avoid the risk of spills during collection and transport of AFFF foam. Commenters also asked for additional mitigation measures to be added, to further reduce potentially significant impacts to the environmental and human health, given that complete destruction of PFAS is unknown.

4.15.1 Summary of Concerns

Commenters supported a general ban of PFAS-containing AFFF. Several commenters requested additional analysis and understanding of data gaps before selecting an alternative. Several commenters encouraged Ecology to consider all proven technologies so that disposal managers can select viable disposal method(s) without uncertainties.

4.15.2 Summary of Responses

Because the AFFF program alternatives are still being developed, some mitigation measures lack specific details. Ultimately, to be enforced, those mitigation measures must be identified and included as part of a permit, rule, contract, or participation agreement. Program-specific mitigation and protections would occur after the final EIS is published and the preferred AFFF disposal option is selected. SEPA allows for broad consideration of potential environmental impacts and yields important information about project alternatives and mitigation measures that would reduce environmental impacts. To the extent that information is known about aspects of the AFFF Collection and Disposal program, that information was incorporated into the EIS. Chapter 4 of the draft EIS describes state and regional programs, such as Washington's robust Geographic Spill Response Plans, that would minimize the risk of accidental releases. Ecology acknowledges that potentially significant impacts may become known during the initial program implementation. Ongoing monitoring and data collection would help determine if mitigation measures need updating. Drainage from surfaces where AFFF is applied for firefighting must be retained as far as possible, with a retainment capacity large enough for firefighting water from a large fire.

4.15.3 Comment Codes

I-3-1-2
I-8-1-2
I-8-1-3

ORG 1-1-5
IND-1-1-5
IND-1-1-8

4.16 Cumulative Impacts

Chapter 5 of the draft EIS evaluates the potential cumulative impacts on environmental resources topics analyzed in the EIS. This analysis discusses the potential impacts from the proposed AFFF Collection and Disposal Program that could result in significant adverse impacts and could contribute to cumulative impacts. A comparison of program alternatives was also made to identify vulnerabilities, allowing Ecology to modify or replace alternatives and associated mitigation and avoidance measures as needed.

4.16.1 Summary of Concerns

Commenters expressed concerns about accidental spills while transporting AFFF to disposal sites, either from vehicle accidents or other accidental release. Commenters either supported or opposed the alternatives presented in the draft EIS because of perceived threats to human health and the environment.

Commenters urged Ecology to implement testing and monitoring protocols to detect residual traces of PFAS. A requirement for testing residuals prior to disposal may also be included to confirm PFAS destruction.

Some commenters concluded that none of the proposed action alternatives would completely destroy PFAS-containing AFFF.

4.16.2 Summary of Responses

The draft EIS does not recommend adoption of any of the five AFFF program alternatives. The SEPA process is intended to ensure that environmental values are considered during decision-making actions by state and local agencies. The process helps agency decision-makers, applicants, and the public understand how the proposed project will affect the environment. The environmental review process in SEPA is intended to work with other regulations and documents to provide a comprehensive review of a proposal. Thus, the draft EIS analysis and conclusions, in accordance with SEPA requirements, must be considered by Ecology and any other relevant agency in decisions regarding selection and implementation of a proposed action on the AFFF program.

4.16.3 Comment Codes

I-3-1-2
I-4-1-2
I-8-1-1
IND-1-1-8

4.17 Additional Comments Received on the Draft EIS

This subsection captures editorial comments, philosophical matters, opinions, and unrelated comments.

4.17.1 Summary of Concerns

Commenters requested that different or more alternatives be analyzed in the EIS, including emerging technologies and other geographic locations, storage technologies, or other program improvements. Commenters also asked whether alternatives with less environmental impact are required for analysis, such as storing AFFF stockpiles in a centralized location. Further, commenters questioned the objectivity of Ecology's contractor, asking for clarification on their relationship with industry, the agency's hiring process, and Ecology's input on the final EIS.

4.17.2 Summary of Responses

Commenters are referred to Master Response 6: Alternatives Considered and Eliminated, for discussion on storage at a centralized location.

As noted in the EIS's Section 2.2.6.1 Collection and Storage of AFFF at a Centralized Location, we considered collecting and transporting the AFFF to a storage facility that Ecology would construct and operate in Washington. The facility would collect and store the AFFF stockpiles in one repository until acceptable advanced treatment technology becomes available. On pages 5-55 through 5-57 of this report, Ecology details the vetting process used to hire its contractor, the contractor's relationship with industry, and the agency's editorial control of the EIS.

4.17.3 Comment Codes

I-5-1-1
ORG-2-1-1
ORG-4-1-3
I-17-1-1
IND-1-1-8
ORG-6-1-9
ORG-7-1-4
ORG-8-1-5
ORG-8-1-19
ORG-9-1-7
ORG-12-1-2
ORG-12-1-6

I-9-1-2
ORG-3-1-2
ORG-4-1-4
IND-1-1-2
ORG-6-1-7
ORG-7-1-1
ORG-7-1-8
ORG-8-1-15
ORG-8-1-20
ORG-9-1-9
ORG-12-1-3
GOV-2-1-1
I-13-1-1
ORG-4-1-2
ORG-4-1-5
IND-1-1-7
ORG-6-1-8
ORG-7-1-3
ORG-8-1-2
ORG-8-1-18
ORG-8-1-21
ORG-11-1-3
ORG-12-1-4

5 Comment Record

The following table includes a complete record of all comments received during the draft EIS comment period, along with our responses. Comments appear in the order received and include public meeting transcripts.

See Attachment 1 to view all comments in their original format. To aid in locating responses to particular comments, we added reference ID numbers to the page margins of the comments in Attachment 1.

Commenter	Comment Code	Comment	Ecology Response	Attachment 1 Commenter Reference ID
Christy Pruitt	I-1-1-1	It is imperative this firefighting foam is removed ASAP from ALL WA stocks. It isn't a matter of "can" cause cancer; it WILL cause cancer to people who are exposed to it. It is absolutely unacceptable that WA government has not budgeted to have this completed before now- this has been a known issue for many years. The fact that the state hasn't remedied this situation shows a complete lack of concern for our firefighters, their families, the individuals who have had tragic fires & their families, pets, as well as the communities the foam is released in.	Ecology appreciates the time and attention that the commenter committed to reviewing the draft EIS and for expressing their thoughts in support or opposition to the proposed program. Ecology will continue to review the comments and use them to inform future decisions as appropriate.	I-1-1
Christy Pruitt	I-1-1-2	Washington State prides itself on being forward thinking in its environmental protection and justice. Yet, these chemicals kill fish in whatever community waterways this leaks into (drains in every neighborhood and every highway system around the state). Not to mention the harm that comes to the forests, prairies, and wildlife that this is dumped on during all wildfires across the entire state. This all runs off into the Puget Sound, where our fish species and even beloved orca whale populations are sickening, washing up dead, wasted away due to various factors- all due to pollutants, of which I'm sure fire fighting foam is part of; Washington admits to holding & using large stores - I cannot imagine port fires are exempt.	Ecology appreciates the time and attention that the commenter committed to reviewing the draft EIS and for expressing their thoughts in support or opposition to the proposed program. Ecology will continue to review the comments and use them to inform future decisions as appropriate.	I-1-1

Commenter	Comment Code	Comment	Ecology Response	Attachment 1 Commenter Reference ID
Ryan Dailey	I-2-1-1	I have no major comments on the draft itself, but would like to share a promising technology myself and peers have been following regarding PFA's cleanup. I am in no manner affiliated with this company, I simply have an environmental engineering background and am very impressed with BioLargo's PFA's cleanup technology: https://www.biolargoengineering.com/biolargo-aec/ BioLargo Aqueous Electrostatic Concentrator (AEC) is designed to provide rapid, effective, and affordable concentration of per- and polyfluoroalkyl substances (PFAS) in water. It works by separating PFAS compounds in an electrostatic field and forcing them through a proprietary membrane system. The result ? the AEC removes >99% PFAS from water in continuous flow, at energy costs as low as 30 cents per 1,000 gallons. Advantages over other technologies: - More energy-efficient - More affordable on per-gallon basis - Much less PFAS-laden waste produced - Less activated carbon required in PFAS life cycle - Higher purity of final water - Compact; small footprint - Development and commercialization of the AEC is supported in part by a grant provided by the US EPA SBIR. I highly encourage relevant stakeholders to consider utilizing the AEC technology as the state continues to pick up PFAS cleanup contracts over the coming years.	Thank you for your suggestion to Ecology regarding the AEC technology. Ecology completed its evaluation of potential disposal alternatives during the EIS's scoping phase in 2021 and 2022. During scoping, Ecology recognized that some removal, disposal, or destruction technologies were proven and commercially available, while other technologies were still experimental/unproven, or not yet widely commercially available. Ecology recognizes that new alternatives are becoming commercially available every year. The AEC technology is included in the draft EIS in Section 2.2.7, Emerging Technologies for Commercial PFAS Treatment. If this technology is further developed and becomes technically and commercially viable, the technology could be implemented under Alternative 1 in the future.	I-2-1

Commenter	Comment Code	Comment	Ecology Response	Attachment 1 Commenter Reference ID
Erick McWayne	I-3-1-1	Thank you for the opportunity to provide comments on the AFFF disposal guidelines. I recommend presenting the disposal options as "destructive" and "non-destructive" options. In addition to incineration, other destructive PFAS treatment technologies applicable to AFFF include electrochemical oxidation, plasma treatment, supercritical water oxidation, alkaline hydrothermal liquefaction, and sonochemical methods. A generic placeholder for new destructive technologies could also be included as "other destructive treatment technologies applicable to AFFF".	Thank you for your suggestion to Ecology to clarify the disposal options as "destructive" or "nondestructive." Ecology concurs that this language would add clarity, and we will consider this revision for the final EIS. Regarding the suggestion for a generic placeholder for new technologies, Ecology has included such a placeholder in the draft EIS in Section 2.2.7, Emerging Technologies for Commercial PFAS Treatment. If these technologies are further developed and become technically and commercially viable, they could be implemented under Alternative 1 in the future.	I-3-1
Erick McWayne	I-3-1-2	Ecology may wish to specify that all residuals from destructive treatment be disposed of at a permitted and lined landfill with leachate collection system. A requirement for testing residuals prior to disposal may also be included to confirm PFAS destruction. Testing treatment residuals for ultra-shortchain PFAS including carbon tetrafluoride and trifluoroacetate to confirm complete PFAS destruction, or other similar confirmation is recommended. Thank you!	Thank you for your suggestions. The two incineration facilities under consideration in the EIS are Clean Harbors' Aragonite, Utah, and Kimball, Nebraska, locations. The residuals from these incinerators are disposed of by Clean Harbors into their permitted hazardous waste landfills, which include liners and leachate collection per federal regulation. Ecology will ensure that this is clarified in the final EIS. Testing of treatment residuals is under the purview of Clean Harbors. If Ecology selects to incinerate the collected AFFF, leachate testing may be required as part of the work order.	I-3-1

Commenter	Comment Code	Comment	Ecology Response	Attachment 1 Commenter Reference ID
Peter Storch	I-4-1-1	I am an environmental/chemical engineer working for Arcadis and I have been involved in the development and execution of foam transition projects in Australia, including disposal of AFFF, since 2017. I have lead foam transition programs in the aviation, emergency response, chemical manufacturing, and petroleum industries. My experience and engineering assessments have taught me that effective disposal of the AFFF concentrate is one of the greatest risk reducing steps in the program. My experience working with regulators in Australia has also showed that strong regulatory leadership in the disposal of this highly-concentrated PFAS waste is critical to reduce the risk of releasing PFAS to the environment. The disposal option that is most sustainable, risk reducing, and protective of human health and the environment is destruction of AFFF concentrate by engineered incineration. Incineration in a controlled, monitored process at a licensed facility is the accepted, preferred and required method of disposal for AFFF in Australia, and is recommended in the Australian and New Zealand PFAS National Environmental Management Plan, Heads of EPA, V2 2020. PFAS, and as a concerned professional engineer and citizen of the world, I believe the alternative disposal options for AFFF concentrate short of destruction, represents unreasonable risk to human health and the environment.	Ecology appreciates the time and attention that the commenter committed to reviewing the draft EIS and for expressing their thoughts in support or opposition to the proposed program alternatives. Ecology will continue to review the comments and use them to inform future decisions as appropriate.	I-4-1
Lance Safley	I-5-1-1	One option is to burn. That puts this in a risk vs reward situation when using it to actually put out a fire. Local fire departments don't put out an actual house fire but every 25 years and unless the home has neighbors go ahead and let it burn. I suppose the 1 in a million that putting out the fire is to save lives in the home then that falls into the risk vs reward and use the spray.	Ecology appreciates the time and attention that the commenter committed to reviewing the draft EIS and for expressing their thoughts in support or opposition to the proposed program. Ecology will continue to review the comments and use them to inform future decisions as appropriate.	I-5-1

Commenter	Comment Code	Comment	Ecology Response	Attachment 1 Commenter Reference ID
Lance Safley	I-5-1-2	How many gallons are they using on practice fires and such? That's a criminal act unless they had no MSDS chart and that also is criminal act. On MSDS sheet, how do they load this into their pump trucks or is this delivered to them in concealed fire extinguishers? How has firefighters handled this product to stay safe? And everything loses pressure over time, these things are poisoning and contaminating its surroundings every day. Then this stuff in our schools and not added to their MSDS sheet? No wonder child cancer is at epidemic raise. Why use it on car fires when once again by the time fire department get there is no lives to save. Or is this just a money grab as someone clearly didn't care about environment for many years.	Ecology appreciates the time and attention that the commenter committed to reviewing the draft EIS and for expressing their thoughts in support or opposition to the proposed program. Ecology will continue to review the comments and use them to inform future decisions as appropriate.	I-5-1
John Worthington	I-6-1-1	Please Pay for disposal by creating a nautical mile tax on China/Asia firefighting products. An additional nautical mile tax should be applied to American ingredients sent to China/Asia to make said firefighting products. In other words double down on world economy taxes and make those sneaky corporate greed pay to pollute for once.	Ecology appreciates the time and attention that the commenter committed to reviewing the draft EIS and for expressing their thoughts in support or opposition to the proposed program. Ecology will continue to review the comments and use them to inform future decisions as appropriate.	I-6-1
Patrice Murphy	I-7-1-1	I believe these types of chemicals should be banned and better, safer alternatives to the environment found and used. My son was highly allergic and had multiple issues due to these chemicals. I am not sure what the lasting effects on his health will be. Also the effects on the marine life must be addressed.	Ecology appreciates the time and attention that the commenter committed to reviewing the draft EIS and for expressing their thoughts in support or opposition to the proposed program. Ecology will continue to review the comments and use them to inform future decisions as appropriate.	I-7-1

Commenter	Comment Code	Comment	Ecology Response	Attachment 1 Commenter Reference ID
Petr Pospisil	I-8-1-1	For treatment of AFFF (unused or from drainage), all of the proposed options cannot avoid release of PFAS into the environment with time. See e.g., https://www.sciencedirect.com/science/article/abs/pii/S0045653520318543 Therefore, any method should be first diligently tested on a small scale with evaluation of long term effects, and different methods must be adapted to local conditions.	The comments note that PFAS would be released from fire department storage or firefighting operations. Draft EIS Chapter 1: Introduction and Background, Section 1.1 Statement of Purpose and Need states that the AFFF Collection and Disposal Program responds to Washington legislation that restricts AFFF manufacture, sale, and use for training. This leaves municipal fire departments and other first responders with on-site stockpiles of AFFF that they may never use. The program is intended to help fire departments safely dispose of stockpiles of AFFF. Chapter 2: Project Description and Alternatives, Section 2.1.2 Washington Fire Department AFFF Storage Inventory and Spill and Release Reporting presents information on current fire department storage and use of AFFF. The AFFF Collection and Disposal Program was established to avoid the environmental risks noted in the comment.	I-8-1
Petr Pospisil	I-8-1-2	AFFF gets most likely into the environment in case if fire fighting operations. Drainage from surfaces where AFFF is applied for fire fighting must be retained as far as possible, with a retainment capacity large enough for fire fighting water from a large fire. (e.g. roads, ports and airports, industrial facilities etc.) It is not acceptable that overflow is spilled into the environment, as it is e.g. in current road projects. Drainage must be adequately treated. Alternatively, to adsorption on charcoal or incineration, modern treatment methods should be evaluated. See e.g., https://www.umsicht.fraunhofer.de/de/projekte/pfas-perfluorAd.html	The comments note that PFAS would be released from fire department storage or firefighting operations. Draft EIS Chapter 1: Introduction and Background, Section 1.1 Statement of Purpose and Need states that the AFFF Collection and Disposal Program responds to Washington legislation that restricts AFFF manufacture, sale, and use for training. This leaves municipal fire departments and other first responders with on-site stockpiles of AFFF that they may never use. The program is intended to help fire departments safely dispose of stockpiles of AFFF. Chapter 2: Project Description and Alternatives, Section 2.1.2 Washington Fire Department AFFF Storage Inventory and Spill and Release Reporting presents information on current fire department storage and use of AFFF. The AFFF	I-8-1

Commenter	Comment Code	Comment	Ecology Response	Attachment 1 Commenter Reference ID
			Collection and Disposal Program was established to avoid the environmental risks noted in the comment.	
Todd Bauernfeind	I-9-1-1	I have limited knowledge and yield to those that do, such as the many great comments I read. I support complete ban on these chemicals until the future development of other measures. I do work in health care and understand the impact on everyone human and animal in natural eco-system.	Ecology appreciates the time and attention that the commenter committed to reviewing the draft EIS and for expressing their thoughts in support or opposition to the proposed program. Ecology will continue to review the comments and use them to inform future decisions as appropriate.	I-9-1
Todd Bauernfeind	I-9-1-2	I live within eye sight of both airports in the West Plains of Spokane, no action has been taken to test my wells, nor have been able to find how to have my wells tested.	The Department of Ecology's AFFF draft EIS investigates the environmental and public health impacts associated with the collection, transport, and disposal of firefighting foam containing PFAS at the state's municipal fire departments. This investigation does not include the foam at Washington's commercial airports or military bases. Testing drinking water wells potentially contaminated with PFAS by airport operations is beyond the scope of this plan. However, Ecology's Toxics Cleanup Program is working with the Spokane International Airport (SIA) on a remedial investigation and feasibility study to determine the extent and locations of PFAS contamination at the site and evaluate cleanup options. Please visit Ecology's SIA PFAS cleanup site page[13] more information. Fairchild Air Force Base is also conducting a remedial investigation, testing wells inside their monitoring area, and providing bottled water or filtration systems to homes with PFAS levels above 70 parts per trillion in their drinking water. Please	I-9-1

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[13] apps.ecology.wa.gov/cleanupsearch/site/16774

Commenter	Comment Code	Comment	Ecology Response	Attachment 1 Commenter Reference ID
			visit the Fairchild Restoration Program webpage[14] for more information. To ensure people are drinking clean water, Ecology, the U.S. Environmental Protection Agency (EPA), the Washington State Department of Health, the Spokane Regional Health District, and Eastern Washington University are studying groundwater quality in the northeast West Plains to better understand the extent and severity of PFAS contamination. Ecology and the EPA are coordinating to sample private drinking water wells in the northeast West Plains at no cost to residents. For more information, please visit Ecology's PFAS in West Plains private wells webpage[15] and join the West Plains PFAS updates email list. Ecology also awarded the City of Medical Lake an area-wide groundwater investigation grant, which will develop a model of PFAS contamination in groundwater in the West Plains. The project includes public outreach, groundwater sampling and analysis, and identification of PFAS sources using geochemical fingerprinting. Sampling began in the spring of 2024. If you have questions about the SIA PFAS site, drinking water sampling in the West Plains, or the area-wide groundwater study, please contact Erika Beresovoy at erika.beresovoy@ecy.wa.gov or 509-385-2290.	

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[14] www.fairchild.af.mil/Information/Restoration/
[15] ecology.wa.gov/west-plains

Commenter	Comment Code	Comment	Ecology Response	Attachment 1 Commenter Reference ID
Nathan	I-10-1-1	Are we so stupid as to allow UNSTABLE CHEMICALS - who we've been lulled into thinking are stable (they are ACIDS!!!!!) UNSTABLE, HARMFUL, COROSIVE ACIDS HAVE NO ROOM IN AGRICULTURE OR SOCIETY. perfluorooctanoic acid (PFOA) and perfluorooctane sulfonic acid (PFOS) Perfluorohexane sulfonic acid (PFHxS) and Perfluorononanoic acid (PFNA) Hexavalent chromium - Cr(VI) is known to cause cancer. In addition, it targets the respiratory system, kidneys, liver, skin and eyes. Hexavalent chromium — known more commonly as chromium-6 or "the Erin Brockovich chemical" — gained international notoriety in the 1990s, after Brockovich discovered that it was contaminating drinking water and making people sick in the San Bernardino County town of Hinkley, Calif.Mar 24, 2022. FORD. FORD. FORD. FORD. FORD . .. $$$$$$$ GET THE $ OUT OF OUR LIVES FORD. TRIBAR. Twelve chemical companies are responsible for the majority of the global PFAS production: AGC, Arkema, Chemours, Daikin, 3M, Solvay, Dongyue, Archroma, Merck, Bayer, BASF and Honeywell.	Ecology appreciates the time and attention that the commenter committed to reviewing the draft EIS and for expressing their thoughts in support or opposition to the proposed program. Ecology will continue to review the comments and use them to inform future decisions as appropriate.	I-10-1
Caroline Armon	I-11-1-1	After reading the information and 5 alternatives, I support alternative 2- incineration. It seems to have the least potential impacts.	Ecology appreciates the time and attention that the commenter committed to reviewing the draft EIS and for expressing their thoughts in support or opposition to the proposed program. Ecology will continue to review the comments and use them to inform future decisions as appropriate.	I-11-1
Caroline Armon	I-11-1-2	I do not support alternative 1- approved leave in place, nor no action alternative, as that has been the status quo and impacts are happening: https://www.sanjuanjournal.com/news/hannah-heights-water-system-highly-contaminated/	Ecology appreciates the time and attention that the commenter committed to reviewing the draft EIS and for expressing their thoughts in support or opposition to the proposed program. Ecology will continue to review the comments and use them to inform future decisions as appropriate.	I-11-1

Commenter	Comment Code	Comment	Ecology Response	Attachment 1 Commenter Reference ID
Caroline Armon	I-11-1-3	I do not support alternative 4- class 1 deep well injection, with flooding and sea levels rising there is still potential contamination.	Ecology appreciates the time and attention that the commenter committed to reviewing the draft EIS and for expressing their thoughts in support or opposition to the proposed program. Ecology will continue to review the comments and use them to inform future decisions as appropriate.	I-11-1
City of Vancouver Fire Dept. (Tom O'Connor)	GOV-1-1-2	While I understand the draft EIS requirement and process, it is concerning to see two of the five "disposal options" aren't disposal options at all and would require firefighting agencies to maintain storage of PFAS containing foam. I do not have the required expertise to take a position on disposal methods, but respectfully request that an actual disposal method is selected and implemented.	The comment expresses a position supporting implementation of Alternative 2: Incineration, Alternative 3: Solidification and Landfilling, or Alternative 4: Deep Well Injection for disposal of AFFF foam. Please see Master Response 4 for additional information regarding the no action alternative. While SEPA requires discussion of a no action alternative, Ecology does not consider this a viable option. The intent of the EIS is to inform decision-makers of the best options for disposal that align with the protection of human health and the environment.	GOV-1-1
City of Vancouver Fire Dept. (Tom O'Connor)	GOV-1-1-1	My fire department, like many others, no longer uses AFFF and has switched over to fluorine free foam for firefighting use. We've put all our AFFF in temporary storage and have been waiting for Ecology to implement a disposal program as previously communicated.	Ecology values your participation in Ecology's Product Replacement Program. We anticipate launching the disposal program in fall of 2024.	GOV-1-1
Kat Krohn	I-12-1-4	The research on the effectiveness of incineration in incomplete according to the EPA (https://www.epa.gov/sites/default/files/2019-09/documents/technical_brief_pfas_incineration_ioaa_approved_final_july_2019.pdf). Using the approved hold in place alternative would provide a stop gap measure while further research is being done on incineration.	Ecology appreciates the time and attention that the commenter committed to reviewing the draft EIS and for expressing their thoughts in support or opposition to the proposed program. Ecology will continue to review the comments and use them to inform future decisions as appropriate. As discussed in draft EIS Section 3.1.2.3, Alternative 2: Incineration, incinerator operators were required to apply for and obtain air permits to construct and operate. As part of the permitting process, the applicants submitted air quality analyses to demonstrate that the incinerators would not cause	I-12-1

Commenter	Comment Code	Comment	Ecology Response	Attachment 1 Commenter Reference ID
			or contribute to a violation of any applicable National Ambient Air Quality Standard. Ecology acknowledges the commenter's note regarding the effectiveness of incineration on PFAS compounds. The uncertainties associated with the incineration option are included in the draft EIS in Section 3.1.4, Data Gaps.	
Kat Krohn	I-12-1-3	The mention of potential leachate from solidification and landfilling also makes this a least preferred disposal method. My greatest concern with AFFF disposal is groundwater contamination.	Ecology appreciates the time and attention that the commenter committed to reviewing the draft EIS and for expressing their thoughts in support or opposition to the proposed program. Ecology will continue to review the comments and use them to inform future decisions as appropriate. Ecology is considering landfilling at only two locations - US Ecology Nevada and US Ecology Idaho. Both are federally permitted hazardous waste landfills with rigorous engineered liners and leachate capture systems which mitigate migration of contaminants to groundwater. Groundwater monitoring around the landfill is required as well. Groundwater in both locations is deep, providing for additional natural mitigation (see EIS Section 3.3.2, Earth and Water Resources, Environmental Setting).	I-12-1
Kat Krohn	I-12-1-2	The inability to monitor class 1 deep well injection as stated in 2.2.4.2 makes this my least preferred disposal method.	The comment expresses opposition to Alternative 4, Class I Deep Well Injection. Ecology appreciates the time and attention that the commenter committed to reviewing the draft EIS and for expressing their thoughts in support or opposition to the proposed program. Ecology will continue to review the comments and use them to inform future decisions as appropriate.	I-12-1

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Kat Krohn	I-12-1-1	My preferred disposal option is approved hold in place. This allows Ecology to continue to monitor evolving technologies for disposal as stated in 2.2.1.1.	Ecology appreciates the time and attention that the commenter committed to reviewing the draft EIS and for expressing their thoughts in support or opposition to the proposed program. Ecology will continue to review the comments and use them to inform future decisions as appropriate.	I-12-1
Julie Shumway	I-13-1-1	While I strongly believe the compounds needs to be phased out of every day life use as lubricants. I'm not necessarily anti-AFFF. Currently there is a strong argument showing Best Management Practices in case of oil based emergencies. A clean up utilizing a double gac system and disposal has worked.	Ecology appreciates the time and attention that the commenter committed to reviewing the draft EIS and for expressing their thoughts in support or opposition to the proposed program. Ecology will continue to review the comments and use them to inform future decisions as appropriate.	I-13-1
Julie Shumway	I-13-1-3	Injection is the worst idea!	The comment expresses opposition to Alternative 4, Class I Deep Well Injection. Ecology appreciates the time and attention that the commenter committed to reviewing the draft EIS and for expressing their thoughts in support or opposition to the proposed program. Ecology will continue to review the comments and use them to inform future decisions as appropriate.	I-13-1
Julie Shumway	I-13-1-4	Thermal destruction would be the second choice.	Ecology appreciates the time and attention that the commenter committed to reviewing the draft EIS and for expressing their thoughts in support or opposition to the proposed program. Ecology will continue to review the comments and use them to inform future decisions as appropriate.	I-13-1
Julie Shumway	I-13-1-2	As far as how to dispose of AFFF it is not listed in RCRA but should still be solidified and shipped to a non- hazardous waste landfill which accepts this types of waste.	Ecology appreciates the time and attention that the commenter committed to reviewing the draft EIS and for expressing their thoughts in support or opposition to the proposed program. Ecology will continue to review the comments and use them to inform future decisions as appropriate. While PFAS is not currently listed under the Resource Conservation and Recovery Act (RCRA) as a federal	I-13-1

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			hazardous waste, under Washington State law, PFAS-containing firefighting foam is designated as a state-only dangerous waste. As such, PFAS-containing foam must be disposed of at a federally permitted treatment, storage, or disposal (TSD) facility. Non-hazardous waste landfills do not qualify as a TSD. If Ecology selects landfilling as the disposal option for the state's collected firefighting foam, it will be solidified in a medium that minimizes PFAS escaping into the leachate and buried at a hazardous waste landfill in either Idaho or Nevada.	
Liora Llewellyn	I-14-1-1	For the store-in-place option: in the spirit of pollution prevention, could the storage area be a (only one) central location where all AFFF foam can be stored in one place, overseen by Ecology, with proper BMPs in place for longer term storage of hazardous materials? This would centralize the possible pollution, and avoid the possibility of accidental use or release, improper storage, and ease the burden of longer-term storage on volunteer firefighting communities. It would be particularly beneficial to provide transportation/shipping for this effort. This would be a great first step for any of the proposed actions (except do nothing).	Ecology appreciates the time and attention that the commenter committed to reviewing the draft EIS and for expressing their thoughts in support or opposition to the proposed program. Ecology will continue to review the comments and use them to inform future decisions as appropriate. Please refer to Master Response 6 - Alternatives Considered and Eliminated, for discussion on storage at a centralized location. As noted in Section 2.2.6.1 Collection and Storage of AFFF at a Centralized Location, we considered collecting and transporting the AFFF to a storage facility that Ecology would construct and operate in Washington. The facility would collect and store the AFFF stockpiles in one repository until acceptable advanced treatment technology became available. Ecology investigated the collection and transport of AFFF to either a private or government-operated Transport, Storage, and Disposal (TSD) facility capable of storing, managing, and monitoring AFFF indefinitely in an indoor environment. Ecology contacted its Nuclear Waste Program about the	I-14-1

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			possibility of indefinitely storing AFFF at the Hanford Nuclear Reservation. In addition, Ecology contacted Clean Harbors about indefinitely storing AFFF at their facility in Aragonite, Utah. The Nuclear Waste Program and Clean Harbors rejected the possibility of storing state-collected AFFF at their facilities. As of the draft EIS publication date, no other public or private facility has been identified as a potential central storage site. Therefore, it was eliminated.	
Chuck Danner	I-15-1-1	Of the five options listed, I believe incineration to make the most sense. My understanding is that if incinerated above certain temperatures the chemicals are broken down and rendered to be completely harmless. Completely harmless should be the desired goal/outcome. If incineration attains that goal the rest is basically a No-Brainer! I don’t believe any of the other four options have any merit!	Ecology appreciates the time and attention that the commenter committed to reviewing the draft EIS and for expressing their thoughts in support or opposition to the proposed program. Ecology will continue to review the comments and use them to inform future decisions as appropriate.	I-15-1
Marli Heininger	I-16-1-5	A one and done solution should be prioritized for workers, the general public, carbon emissions, and permanent destruction of a chemical that won't be destroyed by any other natural elements. The fact that these TSCA chemicals like PCBs and PFAs are remarkably resistant to any sort of chemical degradation and cannot be effectively removed from drinking water is a very important element to consider to actually protect public health for multiple generations to come. More novel treatment methods could develop in time, but that also includes spreading the material around and spending more carbon from our finite resources.	Ecology appreciates the time and attention that the commenter committed to reviewing the draft EIS and for expressing their thoughts in support or opposition to the proposed program. Ecology will continue to review the comments and use them to inform future decisions as appropriate.	I-16-1
Marli Heininger	I-16-1-1	From the perspective of an electric utility that operates in generation, transmission, and distribution within WA, management options that are highly compatible with Polychlorinated Biphenyls that are incidental in electric equipment is very desirable. A plan for general industry to be able to hold small quantities safely until disposal would be very useful. Aside from bagging product and staging it	Ecology appreciates the time and attention that the commentor committed to reviewing the draft EIS and for expressing their thoughts on it. Polychlorinated biphenyls (PCBs) and their management and disposal are beyond the scope of this EIS. However, Ecology finalized a chemical action plan that details Ecology’s approach to	I-16-1

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		near other regulated chemicals/waste, there's not much else to do. I have encountered a situation where there is brand new, unadulterated, unused product in its original container, yet waste profiling is a pain. All efforts to get more details from the manufacturer have gone nowhere, and I do not have much confidence in lab analysis in addition to the unnecessary costs to identify something that has known hazards. Guidance for that would be helpful.	managing these chemicals. Visit our website to read the PCB Chemical Action Plan.[16]	
Marli Heininger	I-16-1-6	A good road map with benchmarks for the timeline on how the state might collectively work to dispose of this chemical would be very helpful for industries that have contact with this chemical but aren't necessarily experts with regards to its performance. A specific set of waste profiles with prescribed treatment methods would also be helpful.	Please see Master Response 1: Overview of Ecology's Product Replacement Program and Fire Department Participation, which describes the specific scope of this EIS. In addition to this EIS to address AFFF at fire stations, Ecology published a PFAS Chemical Action Plan[17] (September 2022) to guide the development of environmental testing programs throughout the state. For additional information regarding Ecology's progress to address PFAS in Washington, please visit Ecology's PFAS webpage.[18] Ecology appreciates the time and attention that the commenter committed to reviewing the draft EIS and for expressing their thoughts in support or opposition to the proposed program.	I-16-1
Marli Heininger	I-16-1-7	If companies will refuse to share "proprietary" information, I think the regulatory agencies should hold them accountable, and in the interest of efficient disposal that isn't hindered with excessive red tape, having categorical or concentration based profiles would be very helpful. It makes no sense to sample unused product when *someone* in the industry knows what it is. It isn't fair to	Ecology appreciates the time and attention that the commenter committed to reviewing the draft EIS and for expressing their thoughts in support or opposition to the proposed program. Ecology will continue to review the comments and use them to inform future decisions as appropriate. The intent of this EIS is to inform decision-makers of the best	I-16-1

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[16] apps.ecology.wa.gov/publications/SummaryPages/1507002.html
[17] apps.ecology.wa.gov/publications/SummaryPages/2104048.html
[18] ecology.wa.gov/pfas

Commenter	Comment Code	Comment	Ecology Response	Attachment 1 Commenter Reference ID
		all the waste workers, lab techs, and field crews to have to expose themselves to collect samples over an arbitrary threshold. If the PFAs are there, they're there. For AFFF specifically, it's obviously not flammable or corrosive, but it doesn't neatly fall under a toxic character either.	options for AFFF disposal that align with the protection of human health and the environment. Ecology concurs with the commenter that AFFF is known to contain PFAS. Sampling the AFFF is not a specific element of any of the options.	
Marli Heininger	I-16-1-2	Considering how PCBs are either buried or incinerated, I am inclined to follow those practices. However, landfilling a forever chemical still poses ongoing risk. Since hormone interference is among the health effects, solidification in concrete sounds extremely insufficient and is certainly not secure against any sort of natural disaster. [...] If ever a landfill of any kind needs to be remediated - such as the Pasco Landfill, a nasty intensive project - the long term costs will be so much greater and continue to spread around potential exposure or spills.	The comment expresses opposition to Alternative 3, Solidification and Landfilling. Ecology appreciates the time and attention that the commenter committed to reviewing the draft EIS and for expressing their thoughts in support or opposition to the proposed program. Ecology will continue to review the comments and use them to inform future decisions as appropriate.	I-16-1
Marli Heininger	I-16-1-3	The same goes for deep well injection - that sounds like the most dangerous and expensive of all the options. That is an entire industry that doesn't exist, creates more exposure, and will leave more natural spaces poisoned for years and years. Human error is the biggest factor here.	The comment expresses opposition to Alternative 4, Class I Deep Well Injection. Ecology appreciates the time and attention that the commenter committed to reviewing the draft EIS and for expressing their thoughts in support or opposition to the proposed program. Ecology will continue to review the comments and use them to inform future decisions as appropriate.	I-16-1
Marli Heininger	I-16-1-4	Incineration is an ideal treatment method since that infrastructure and process stream already exists. Plus, we can scientifically determine what needs to be done to burn the material hot enough for cleaner emissions.	Ecology appreciates the time and attention that the commenter committed to reviewing the draft EIS and for expressing their thoughts in support or opposition to the proposed program. Ecology will continue to review the comments and use them to inform future decisions as appropriate.	I-16-1

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Washington Association of Sewer & Water Districts (Judi Gladstone)	ORG-1-1-1	Clean water is a major concern to both our membership and the clients they serve. The potential for contamination is always a concern, especially since, beyond our wellheads and collection points, we have no control over what is sprayed, injected, discharged or built near our facilities. The situation with PFAS over the entire country is especially alarming given the longevity and ease of travel of these compounds. We appreciate Ecology's efforts to develop the best solutions for disposal of AFFF. Our focus will always be to keep contaminants out of water supplies, as it is more difficult and expensive to remove them than to keep them out in the first place.	Ecology appreciates the time and attention that the commenter committed to reviewing the draft EIS and for expressing their thoughts in support or opposition to the proposed program. Ecology will continue to review the comments and use them to inform future decisions as appropriate.	ORG-1-1
Washington Association of Sewer & Water Districts (Judi Gladstone)	ORG-1-1-2	1. Solidification and Landfilling We would not support this option. There will be the hazards of collection and transport, and the resulting solids when buried, still carry the possibility of leaching into the environment. There is also no way to recover this material and treat the PFAS compounds when technology becomes available.	Ecology appreciates the time and attention that the commenter committed to reviewing the draft EIS and for expressing their thoughts in support or opposition to the proposed program. Ecology will continue to review the comments and use them to inform future decisions as appropriate. Draft EIS Chapter 4: Mitigation Measures explains Ecology's approach to analysis, significance criteria, and identifying mitigation and best practices designed to reduce potentially significant environmental impacts from implementation of one or more of the alternatives. Section 4.4 Impacts and Mitigation Measures, Table 4-1: Comparison of Program Impacts by Alternative summarizes the potential adverse impacts of each program alternative. Table 4-1 notes that three disposal alternatives — Alternative 2: Incineration, Alternative 3: Solidification and Landfilling, and Alternative 4: Deep Well Injection — would have no impacts or less than significant impacts on all resource topics analyzed, except Tribal resources. For Tribal	ORG-1-1

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			resources, Alternatives 2, 3, and 4 would have less than significant impacts with mitigation. The comment expresses a position opposing implementation of Alternative 3: Solidification and Landfilling. The draft EIS analysis and conclusions, in accordance with SEPA requirements, must be considered by Ecology and any other relevant agency in decisions regarding selection and implementation of a proposed action on the AFFF program. Also please see Master Response 5 for additional discussion on mitigation measures.	
Washington Association of Sewer & Water Districts (Judi Gladstone)	ORG-1-1-3	2. Deep Well Injection We would not support this option. Again, hazards of collection and transport exist, plus the possibility of polluting the environment and groundwater supplies, and lack of recoverability for future treatment.	Ecology appreciates the time and attention that the commenter committed to reviewing the draft EIS and for expressing their thoughts in support or opposition to the proposed program. Ecology will continue to review the comments and use them to inform future decisions as appropriate. Draft EIS Chapter 4: Mitigation Measures explains Ecology's approach to analysis, significance criteria, and identifying mitigation and best practices designed to reduce potentially significant environmental impacts from implementation of one or more of the alternatives identified in the draft EIS. Section 4.4 Impacts and Mitigation Measures, Table 4-1: Comparison of Program Impacts by Alternative summarizes the potential adverse impacts of each program alternative. Table 4-1 notes that three disposal alternatives — Alternative 2: Incineration, Alternative 3: Solidification and Landfilling, and Alternative 4: Deep Well Injection — would have no impacts or less than significant impacts on all resource topics analyzed, except for Tribal resources. For Tribal resources, alternatives 2, 3, and 4 would have less than significant impacts with mitigation.	ORG-1-1

Commenter	Comment Code	Comment	Ecology Response	Attachment 1 Commenter Reference ID
			The comment expresses a position opposing implementation of Alternative 4: Deep Well Injection. The draft EIS analysis and conclusions, in accordance with SEPA requirements, must be considered by Ecology and any other relevant agency in decisions regarding selection and implementation of a proposed action on the AFFF program. Also please see Master Response 5 for additional discussion on mitigation measures.	
Washington Association of Sewer & Water Districts (Judi Gladstone)	ORG-1-1-4	3 . Incineration This may be an option. While collection and transport hazards are present, at the endpoint the compounds are destroyed and residuals are dealt with in a safe manner. This is, of course, predicated on proper safeguards at the incineration facility that do not allow pollutants to go airborne.	Ecology appreciates the time and attention that the commenter committed to reviewing the draft EIS and for expressing their thoughts in support or opposition to the proposed program. Ecology will continue to review the comments and use them to inform future decisions as appropriate. Draft EIS Chapter 4: Mitigation Measures explains Ecology's approach to analysis, significance criteria, and identifying mitigation and best practices designed to reduce potentially significant environmental impacts from implementation of one or more of the alternatives identified in the draft EIS. Section 4.4 Impacts and Mitigation Measures, Table 4-1: Comparison of Program Impacts by Alternative summarizes the potential adverse impacts of each program alternative. Table 4-1 notes that three disposal alternatives — Alternative 2: Incineration, Alternative 3: Solidification and Landfilling, and Alternative 4: Deep Well Injection — would have no impacts or less than significant impacts on all resource topics analyzed, except for Tribal resources. For Tribal resources, alternatives 2, 3, and 4 would have less than significant impacts with mitigation.	ORG-1-1

Commenter	Comment Code	Comment	Ecology Response	Attachment 1 Commenter Reference ID
Washington Association of Sewer & Water Districts (Judi Gladstone)	ORG-1-1-5	4. Approved Hold in Place This may be the best option of the 5 outlined. Collection and transport hazards are eliminated for the short term. As indicated, approved containment would be required. There may be an issue of how safe the containment is from vandalism, accident or natural disaster. There may also be an issue of space availability for smaller facilities. The AFFF remains available in the future for destruction as technologies develop.	The comment expresses support of Alternative 1: Approved Hold in Place and outlines certain concerns. Ecology appreciates the time and attention that the commenter committed to reviewing the draft EIS and for expressing their thoughts in support or opposition to the proposed program. Ecology will continue to review the comments and use them to inform future decisions as appropriate. Please see Master Response 5 for discussion on mitigation measures for the alternatives evaluated. If Ecology selects Alternative 1: Approved Hold in Place, the agency will provide participating fire departments with guidance and resources to safely store its AFFF until additional analysis is completed, new destruction technologies prove viable, or Ecology decides to send the foam to a federally permitted TSD for disposal.	ORG-1-1

Commenter	Comment Code	Comment	Ecology Response	Attachment 1 Commenter Reference ID
Washington Association of Sewer & Water Districts (Judi Gladstone)	ORG-1-1-6	5. No Action Not an option. Regulators must know where it is kept, and that it is safe from contaminating the environment, as well as plan for future remediation of these compounds.	Ecology appreciates the time and attention that the commenter committed to reviewing the draft EIS and for expressing their thoughts in support or opposition to the proposed program. Ecology will continue to review the comments and use them to inform future decisions as appropriate. The comment expresses a position opposing implementation of Alternative 5: No Action. Chapter 2: Project Description and Alternatives, Section 2.2.5 Alternative 5: No Action states that under this alternative, fire departments would continue to use, store, and dispose of their supply of commercial-use AFFF in their individually selected manner without Ecology support. Because the intent of this EIS is to inform decision-makers of the best options for disposal that align with the protection of human health and the environment, no action is not being considered a viable option. Please also see Master Response 4 for additional discussion on the no action alternative.	ORG-1-1
Washington Association of Sewer & Water Districts (Judi Gladstone)	ORG-1-1-7	We would like to reopen a 6th option that was closed by Ecology, and that is the collection of AFFF into one site. Collection and transport hazards would exist, but robust containment could be designed, and it would not be scattered across the state in smaller containment units that would be in population centers. When the time came, destruction technologies could be set up at just one site, reducing costs and dangers of release near people.	Ecology appreciates the time and attention that the commenter committed to reviewing the draft EIS and for expressing their thoughts in support or opposition to the proposed program. Ecology will continue to review the comments and use them to inform future decisions as appropriate. Please refer to Master Response 6 - Alternatives Considered and Eliminated, for discussion on storage at a centralized location. As noted in Section 2.2.6.1 Collection and Storage of AFFF at a Centralized Location, we considered collecting and transporting the AFFF to a storage facility that Ecology would construct and operate in Washington. The facility would collect and store the AFFF stockpiles in one repository until acceptable	ORG-1-1

Commenter	Comment Code	Comment	Ecology Response	Attachment 1 Commenter Reference ID
			advanced treatment technology became available. Ecology investigated the collection and transport of AFFF to either a private or government-operated Transport, Storage, and Disposal (TSD) facility capable of storing, managing, and monitoring AFFF indefinitely in an indoor environment. Ecology reached out to its Nuclear Waste Program about the possibility of indefinitely storing AFFF at the Hanford Nuclear Reservation. In addition, Ecology contacted Clean Harbors about indefinitely storing AFFF at their facility in Aragonite, Utah. The Nuclear Waste Program and Clean Harbors rejected the possibility of storing state-collected AFFF at their facilities. As of the draft EIS publication date, no other public or private facility has been identified as a potential central storage site. Therefore, it was eliminated.	
Tumwater Fire Department (Brad Ridgeway)	ORG-2-1-1	We at Tumwater Fire have AFFF stored in 5-gallon pails and in the onboard foam tanks on our engines. We can surmise from the draft plan how we will go about disposing of the AFFF that resides in stored pails. We are concerned with how we will properly dispose of AFFF that resides right now in onboard 30-gallon tanks on each fire engine. We can drain these tanks into empty 5-gallon pails and re-label them accordingly. Would this be acceptable? Then we could flush the foam systems including the tanks. This will require a large volume of water flow and result in diluted contaminant from our discharge to be released. Is the flushing acceptable and if so, where should this take place? There is an interest here to transition to new foam so we can get the Legacy AFFF off the engines. We have not yet	We value your participation in Ecology's Product Replacement Program. We anticipate launching the program in fall of 2024. When an alternative is selected, additional guidance will be provided. Depending on the disposal option Ecology selects, fire departments will be provided direction and guidance on how to prepare their AFFF for disposal. In the meantime, Ecology provides the following guidance for firefighting organizations[19] on how to safely store their AFFF until the foam is picked up. If a fire department needs to transfer its foam into new containers to store it safely, Ecology is providing resources[19] to make this transfer. Ecology understands that as fire departments switch to fluorine-free foam (FFF) alternatives, they are requesting guidance on how to safely deep clean their engines and other apparatus contaminated	ORG-2-1

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[19] https://apps.ecology.wa.gov/publications/SummaryPages/2104031.html

Commenter	Comment Code	Comment	Ecology Response	Attachment 1 Commenter Reference ID
		purchased any replacement for our legacy AFFF but we will as soon as we have a plan to transition.	with PFAS-containing firefighting foam. Ecology, other state governments, and the Interstate Technology Regulatory Council (ITRC) are developing deep cleaning guidance. Ecology expects to release its guidance shortly. Further, Ecology understands that fire departments are looking for direction on which FFF to use. Ecology has not verified the effectiveness and PFAS content of FFF on the market and cannot make a recommendation. However, the Department of Defense certifies several FFF as meeting military specifications for use at military bases and airports. In addition, Clean Production Action certifies several dozen foams as fluorine-free.	
Missouri University of Science & Technology (Meisam Vajdi)	ORG-3-1-1	What air pollution control devices are best for PFAS? No facilities currently have air pollution control devices that were installed specifically to address PFAS emissions. Some have installed controls for PFAS emissions including thermal oxidizers, carbon absorption and wet scrubbers with packed bed fiber filters. The appropriate control strategy will likely vary based on the specific PFAS chemicals involved. More research is necessary to determine if the PFAS is permanently captured and not simply transferred to other media, such as wastewater or sludge.	Ecology appreciates the time and attention that the commenter committed to reviewing the draft EIS and for expressing their thoughts in support or opposition to the proposed program. Ecology will continue to review the comments and use them to inform future decisions as appropriate. As discussed in draft EIS Section 3.1.2.3, Alternative 2: Incineration, incinerator operators were required to apply for and obtain air permits to construct and operate. As part of the permitting process, the applicants submitted air quality analyses to demonstrate that the incinerators would not cause or contribute to a violation of any applicable National Ambient Air Quality Standard. Ecology acknowledges the commenter's note regarding the effectiveness of incineration on PFAS compounds and the ongoing evaluation of pollution control devices. The uncertainties associated with the incineration option are included in the draft EIS in Section 3.1.4, Data Gaps.	ORG-3-1

Commenter	Comment Code	Comment	Ecology Response	Attachment 1 Commenter Reference ID
Missouri University of Science & Technology (Meisam Vajdi)	ORG-3-1-2	“Electronic nose or E-nose” and “open ended hollow coaxial cable resonator sensors” are two technologies that sniff out gases throughout the ports. 1000 electronic noses and resonator sensors distributed through Washington ports and residential areas, register all changes in the air immediately enabling businesses, municipal authorities, and environmental agency to respond to unpleasing gases before they pose a problem to anyone. Some substances are toxic, dangerous, or unpleasant. The sensors in the E-nose and resonator sensors take measurements of odorous and odorless gas compounds in the vicinity. The measured gas compound is compared with the chemical fingerprints of known compounds recorded in a central cloud database. These are flagged up in the environmental agency’s control rooms and at the businesses in the vicinity. the agency investigates the report, which may mean visiting the site. if necessary, an environmental report is issued to inform residents. Companies also have their own e-noses on sites. This enables them to take measures early on, such as adapting production processes. The mobile E-nose is ideal for investigating gases in a specific area by car or in a harbor patrol boat. Deployment of 1000 electronic noses and resonator sensors in the ports creates a unique partnership involving Washington environmental authorities, businesses, and residents. Hence the name “we-nose network”. Mission: Developing health-based screening levels for PFAS compounds, as needed. Learning about how PFAS is used and estimating potential air releases. As the uses of PFAS chemicals by industry are identified through air permit applications the AQD will screen allowed emissions for any potential adverse health effects as required in the air toxics rules. Appropriate air permitting measures for PFAS (such as material limits, material substitution, control	Ecology appreciates the time and attention that the commenter committed to reviewing the draft EIS and for expressing their thoughts in support or opposition to the proposed program. Ecology will continue to review the comments and use them to inform future decisions as appropriate.	ORG-3-1

Commenter	Comment Code	Comment	Ecology Response	Attachment 1 Commenter Reference ID
		requirements, emission limits and/or stack dispersion requirements) will be included in future air permits, as necessary.		
Clean Harbors (Michael Crisenbery)	ORG-4-1-1	Products of Incomplete Combustion The draft EIS did not include reference to a recent test EPA performed at the Raleigh NC facility "rainbow furnace". AFFF was injected into the furnace at multiple temperatures and stack gas samples were analyzed using an OTM-50 methodology. EPA was able to confirm > 99.999% destruction but also confirmed that products of incomplete combustion was virtually zero when temperatures above 1090 ° C were used.	Ecology appreciates the time and attention that the commenter committed to reviewing the draft EIS and for expressing their thoughts in support or opposition to the proposed program. Ecology will continue to review the comments and use them to inform future decisions as appropriate. Ecology will review the cited reference and add discussion into the final EIS, if appropriate.	ORG-4-1
Clean Harbors (Michael Crisenbery)	ORG-4-1-6	Table 3.11-4 – Relative Risk Associated with Alternative 2 by Resource The human health & safety impacts column does not mention the risk assessment modeling performed. This confirmed stack emissions are protective of human health.	Ecology appreciates the time and attention that the commenter committed to reviewing the draft EIS and for expressing their thoughts in support or opposition to the proposed program. Ecology will continue to review the comments and use them to inform future decisions as appropriate. Ecology will review the cited risk assessment modeling and add discussion into the final EIS, if appropriate.	ORG-4-1
Clean Harbors (Michael Crisenbery)	ORG-4-1-7	Clean Harbors Environmental Services (CHES) elected to conduct its first full-scale testing of PFAS destruction at its HWC in Aragonite, Utah. The Team of EA Engineering, Science, and Technology, Inc. and Montrose Environmental Group, Inc. was retained by CHES to develop a comprehensive program for PFAS destruction testing at Aragonite, to conduct the testing and to report the results, under technical oversight by Focus Environmental, Inc. The testing was conducted June 2021 and included sampling and analysis for forty-nine target PFAS analytes in HWC process waste feed streams, treatment chemical feed streams, solid and liquid process residue streams, and HWC stack gases. Three sets of waste feed conditions were evaluated by running triplicate tests under each condition.	Ecology appreciates the time and attention that the commenter committed to reviewing the draft EIS and for expressing their thoughts in support or opposition to the proposed program. Ecology will continue to review the comments and use them to inform future decisions as appropriate. Ecology acknowledges Clean Harbor's PFAS destruction testing at the Aragonite facility. The test and a high-level summary of the results are mentioned in Section 2.1.5, Dangerous Waste Handling, Treatment, and Disposal, and in several places within Section 3.1, Air Quality, Section 3.2, Greenhouse Gas Emissions, and Section 3.11, Environmental Justice. Ecology will re-review the test report and the commenter's information and decide	ORG-4-1

Commenter	Comment Code	Comment	Ecology Response	Attachment 1 Commenter Reference ID
		1. Test Condition 1 was intended to establish a baseline, by feeding a typical waste profile, without adding additional PFAS spiking compounds to the waste feed (Test Runs 1 - 3). 2. During Test Condition 2 (Test Runs 4 - 6), the feed rates of perfluorooctanoic acid (PFOA) (CAS# 335-67-1), perfluorooctanesulfonic acid (PFOS) (CAS# 1763-23-1), perfluorohexane sulfonic acid (PFHxS) (CAS# 355-46-4), and hexafluoropropylene oxide – dimer acid (HFPO-DA or GenX) (CAS# 13252-13-6) were augmented by spiking to facilitate calculation of destruction and removal efficiency (DRE) values for these compounds. 3. During Test Condition 3 (Test Runs 7 - 9), aqueous film forming foam (AFFF) concentrate was also fed to the HWC. U.S. Environmental Protection Agency Other Test Method 45 (OTM-45) was employed for sampling stack gas during the testing. The PFAS analytical method employed for this test program was Liquid Chromatography/Tandem Mass Spectrometry (LC/MS/MS) with Department of Defense Isotope Dilution for the forty-nine targeted PFAS analytes. U.S. Environmental Protection Agency Method 26A was employed for determination of hydrogen fluoride (HF) concentration in stack gas. The results of the June 2021 testing demonstrate that common legacy PFAS (perfluorooctanoic acid (PFOA), perfluorooctanesulfonic acid (PFOS), perfluorohexane sulfonic acid (PFHxS), and hexafluoropropylene oxide – dimer acid (HFPO-DA or GenX are effectively destroyed in the Aragonite incineration system at levels exceeding 99.9999 percent (%) DRE. This was demonstrated during all three test runs (Test Runs 4–6) when spiking was conducted. It should be noted that RCRA and TSCA regulations require a 99.9999% DRE be demonstrated to destroy dioxins and polychlorinated biphenyls (PCB's). In all cases DRE values were calculated using the most conservative approach. Analytes that were not detected in	whether additional technical detail is appropriate for the EIS. If appropriate, such detail will be added to the final EIS.	

Commenter	Comment Code	Comment	Ecology Response	Attachment 1 Commenter Reference ID
		the feed materials were included as zero values in the waste feed material mass balance. PFAS contributions from treatment chemicals were not included in the DRE calculations (per Resource Conservation and Recovery Act (RCRA) regulations). Analytes that were not detected in the stack gas samples were assumed to be present at the method detection limit (MDL) in the mass balance. Because of these various conservative assumptions, it is likely that all the actual DREs are greater than the values presented in this report. Stack gas concentrations for all forty-nine target PFAS analytes were either not detectable, or if detectable results were near the limit of quantitation. The individual PFAS stack gas mass emission rates were extremely low, ranging from 10¯9 to 10¯7 pounds per hour (lb./hr.), with an aggregate stack emission rate for all target PFAS on the order of 10¯6 lb./hr. Stack gas emissions were modeled using EPA's AERMOD program and were 5 to 8 orders of magnitude lower than any state or federal ambient air quality guideline if effect. The Aragonite HWC is a zero-water discharge facility and all solids generated are sent to a RCRA hazardous waste landfill for secure disposal. In summary, the test data supports RCRA permitted high temperature thermal destruction units can effectively destroy PFAS chemicals. Stack gas emissions were modeled using EPA methodology and are 5-8 orders of magnitude below any state or federal ambient air quality guideline if effect.		
Clean Harbors (Michael Crisenbery)	ORG-4-1-2	Section 1.5.1.3 – National Defense Authorization Act The Clean Harbors PFAS Destruction test at the Aragonite UT facility was shared with both EPA and DoD. EPA did not have that data when the initial PFAS disposal guidance was developed but both agencies got it shortly after that publication.	Ecology appreciates the time and attention that the commenter committed to reviewing the draft EIS and for expressing their thoughts in support or opposition to the proposed program. Ecology will continue to review the comments and use them to inform future decisions as appropriate. In the final	ORG-4-1

Commenter	Comment Code	Comment	Ecology Response	Attachment 1 Commenter Reference ID
			EIS, Ecology will update Section 1.5, Environmental Policy and Regulatory Setting.	
Clean Harbors (Michael Crisenbery)	ORG-4-1-3	Section 2..1.5.10 Dangerous Waste Transport, Treatment and Disposal Facilities Contracted with Washington Department of Ecology The Clean Harbors section includes information from a PFAS Destruction Test performed in 2021. That report was shared with several state and federal agencies including EPA, DoD, and the Department of Ecology. In addition to determining destruction removal efficiency, stack emissions were sampled and analyzed using EPA OTM-45. That data was run through EPA risk modeling and the results were 5-8 orders of magnitude below any state or federal air ambient limit/guideline in effect at the time. This risk assessment is the same required under RCRA for hazardous waste combustors. The report and data were peer reviewed by Dr. Phil Taylor, a recognized incineration expert who has worked on PFAS destruction for decades. Dr. Taylor confirmed the destruction study was professionally designed and executed.	Ecology appreciates the time and attention that the commenter committed to reviewing the draft EIS and for expressing their thoughts in support or opposition to the proposed program. Ecology will continue to review the comments and use them to inform future decisions as appropriate. Ecology will review the cited risk assessment modeling and add discussion into the final EIS, if appropriate.	ORG-4-1
Clean Harbors (Michael Crisenbery)	ORG-4-1-4	Section 3.1.4 – Data Gaps As noted above, the PFAS destruction test was peer reviewed by Dr. Phil Taylor.	Ecology appreciates the time and attention that the commenter committed to reviewing the draft EIS and for expressing their thoughts in support or opposition to the proposed program. Ecology will continue to review the comments and use them to inform future decisions as appropriate. Ecology will review the cited risk assessment modeling and peer review information and add discussion into the final EIS, if appropriate.	ORG-4-1
Clean Harbors (Michael Crisenbery)	ORG-4-1-5	Page 3.3.10 Both the Aragonite UT and Kimball NE facilities have zero water discharge operations. All waste is managed in RCRA permitted containment to prevent any release to the environment.	Ecology appreciates the time and attention that the commenter committed to reviewing the draft EIS and for expressing their thoughts in support or opposition to the proposed program. Ecology will review the comments and use them to inform future	ORG-4-1

Commenter	Comment Code	Comment	Ecology Response	Attachment 1 Commenter Reference ID
			decisions as appropriate. We will incorporate the commenter's clarification into the final EIS.	
Nancy Lust	I-17-1-1	I want to commend the Dept of Ecology for recognizing the dangers associated with PFAS getting into the groundwater, but I think they need to broaden their scope. This draft EIS focuses on what to do with existing supplies of firefighting foam contaminated with PFAS, but my concern is how soils contaminated with petroleum and PFAS have already been disposed of in Yakima County. Right now, all levels of government are working to figure out a way to get clean water to residents in East Selah, who have the misfortune of living near the US Army Training Center, where the Army trained soldiers to put out gas fires with PFAS foam. Their wells are contaminated now. The Army has stopped this practice, but much of the contaminated soils generated for years at the US Army Training Center were disposed at the Anderson limited purpose landfill, now owned by DTG Recycle. These soils were put into an UNLINED LANDFILL. I live near this landfill and very little exploratory work has been done to determine if the groundwater has been contaminated.	The comments focus on broadening the scope of the draft EIS to consider past disposal practices for contaminated soil and water. Please see Master Response 1: Overview of Ecology's Product Replacement Program and Fire Department Participation, which describes the scope of this draft EIS to help fire departments and other first responders in Washington collect, remove, and dispose of stockpiles of AFFF. Ecology cannot expand the draft EIS scope. However, Ecology has published a PFAS Chemical Action Plan[20] (September 2022) to guide the development of environmental testing programs. For more information, please visit Ecology's PFAS webpage.[21] Ecology appreciates the time and attention that the commenter committed to reviewing the draft EIS and for expressing their thoughts in support or opposition to the proposed program.	I-17-1
Nancy Lust	I-17-1-2	At a minimum, I would like Ecology to determine where other PFAS-contaminated soils may have been disposed of in Washington State, and develop a protocol for testing the groundwaters around these sites. As of now, it is my understanding that DTG will be adding PFAS to the list of chemicals it tests when it does routine groundwater sampling, but there are no plans to my knowledge for testing neighboring wells. I would support such testing of neighboring wells to make sure PFAS has not seeped into our water supply.	The comments focus on broadening the scope of the draft EIS to test soils and groundwater. Please see Master Response 1: Overview of Ecology's Product Replacement Program which describe the scope of work and eligibility requirements. Ecology's AFFF collection and disposal program goal is to assist fire departments and other first responders in Washington collect, remove, and dispose of stockpiles of AFFF. Ecology cannot expand the draft EIS scope. However, Ecology has published a PFAS	I-17-1

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[20] apps.ecology.wa.gov/publications/SummaryPages/2104048.html

[21] ecology.wa.gov/pfas

Commenter	Comment Code	Comment	Ecology Response	Attachment 1 Commenter Reference ID
			Chemical Action Plan[22] (September 2022) to guide the development of environmental testing programs. For more information, visit Ecology's PFAS webpage.[23] Ecology appreciates the time and attention that the commenter committed to reviewing the draft EIS and for expressing their thoughts in support or opposition to the proposed program.	
Meisam Vajjdi	I-18-1-1	So, is there a detector for PFAS materials? Are you seeking, or is that important to have detectors, for example, in the incinerator facilities? I think that it's necessary to have detectors to detect and monitor the air and environment in that facility, to understand if the process is accurately done or not. So, I'm curious to know what the importance is of having detectors, especially in the air, for PFAS materials. Thank you.	The comment focuses on air monitoring for PFAS at incinerator facilities. As discussed in draft EIS Section 2.1.5.10, Dangerous Waste Transport, Treatment, and Disposal Facilities Contracted with Washington Department of Ecology, the two incineration facilities under consideration are Clean Harbors in Aragonite, Utah, and Kimball, Nebraska. Both facilities are federally permitted and operate under multiple environmental permits, including air permits. The facilities monitor for a number of pollutants, including EPA Criteria Pollutants (Section 3.1.2, Significance Criteria). PFAS compounds are not currently listed by EPA as Criteria Pollutants. Under current operating conditions, the Clean Harbors Aragonite incinerator has shown destruction of "99.9999 percent of common legacy PFAS compounds" (for example, PFOS, PFOA, PFHxS, and GenX). Also please see Master Response 5, which describes the use of mitigation measures to reduce potentially significant, adverse environmental impacts. Ecology appreciates the time and attention that the commenter committed to reviewing the draft EIS and for expressing their thoughts in support or opposition to the proposed program.	I-18-1

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[22] apps.ecology.wa.gov/publications/SummaryPages/2104048.html
[23] ecology.wa.gov/pfas

Commenter	Comment Code	Comment	Ecology Response	Attachment 1 Commenter Reference ID
Green Party of Washington (Alice Green)	I-19-1-1	My concern is for first responders and firefighters and their exposure to PFAS, which has increased their cancer rates and some health hazard to them. I would like to know: is incineration the only means for which it can actually chemically change the molecule from PFAS? [...] So, first of all, if you could just let me know – is incineration really the only way that the actual molecule can be altered? Thank you	Supercritical Water Oxidation (SCWO) is an existing technology has been demonstrated to destroy PFAS molecules. During draft EIS development, a separate alternative considering SCWO technology was eliminated for several reasons. First, under Washington State Dangerous Waste Regulations, PFAS-containing foam must be disposed of at a RCRA-permitted treatment, storage, and disposal facility (TSD). Currently, there are no SCWO facilities at a TSD. However, state regulations permit the disposal of state-only dangerous waste at non-TSDs, if the Department of Ecology receives written permission from the receiving state. Ecology received notice from a receiving state that they would not grant that permission. Please also see Master Response 6 for a discussion of other alternatives considered and eliminated. Ecology appreciates the time and attention that the commenter committed to reviewing the draft EIS and for expressing their thoughts in support or opposition to the proposed program.	I-19-1
Green Party of Washington (Alice Green)	I-19-1-2	Also, our concern is for any water seepage and water contamination.	Ecology appreciates the time and attention that the commenter committed to reviewing the draft EIS and for expressing their thoughts in support or opposition to the proposed program. Throughout the draft EIS, mitigation measures are identified to reduce potentially significant, adverse environmental impacts from implementation of one or more of the alternatives. Examples under various alternatives include, but are not limited to, proper storage of AFFF stockpiles, adherence to Department of Transportation regulations during transportation, and groundwater monitoring at landfill disposal sites. The AFFF Collection and Disposal Program was established to avoid	I-19-1

Commenter	Comment Code	Comment	Ecology Response	Attachment 1 Commenter Reference ID
			environmental risks such as seepage and water contamination. Also please see Master Response 5 for additional information on mitigation measures.	
John Lovie	I-20-1-1	I've read that there are some other technologies in the works, such as lower temperature hydrolysis in non-aqueous solvents, that might work adequately for removing PFAS in fairly concentrated solutions, like returned firefighting foam concentrate. So, I'm hoping that, in consideration of these alternatives, that you take a look out on the horizon and see what might be coming down the pike in terms of alternative destruction technologies. The picture in 2 or 3 years might look quite different than the way it does right now, and it would be a shame to go down an irreversible path that doesn't give us the option to take advantage of those newer technologies.	Ecology appreciates the time and attention that the commenter committed to reviewing the draft EIS and for expressing their thoughts in support or opposition to the proposed program. Ecology completed its evaluation of potential disposal alternatives during the EIS's scoping phase in 2021 and 2022. During scoping, Ecology recognized that some removal, disposal, or destruction technologies were proven and commercially available, while other technologies were still experimental/unproven, or not yet widely commercially available. Ecology recognizes that new alternatives are becoming commercially available every year. Several emerging technologies are included in the draft EIS in Section 2.2.7, Emerging Technologies for Commercial PFAS Treatment. If these technologies are further developed and become technically and commercially viable, they could be implemented under Alternative 1 in the future. Also please see Master Response 3: Development of Alternatives.	I-20-1
Waste Management (James Denson)	IND-1-1-1	APPROVED HOLD-IN-PLACE / NO ACTION WM believes the Hold-In-Place and No Action alternatives are unsuitable because these alternatives do not solve the problem of proper management and place an undue burden on Washington facilities, some of which may have limited resources, to safely store unused AFFF and prevent releases of these materials to the environment. The Hold-In-Place alternative is slightly favorable, because the Department commits to providing suitable containment for use by facilities storing the material. However, WM believes neither alternative directly addresses the problem and unreasonably delays pursuit of existing alternative solutions.	Ecology appreciates the time and attention that WM committed to reviewing the draft EIS and for expressing their thoughts in support or opposition to the proposed program. Please see Master Comment 4, which describes the regulatory requirement to include a no action alternative. Please also see Master Response 3, which describes the development of the alternatives, including Alternative 1, Approved Hold in Place.	IND-1-1

Commenter	Comment Code	Comment	Ecology Response	Attachment 1 Commenter Reference ID
Waste Management (James Denson)	IND-1-1-2	CLASS I DEEP WELL INJECTION WM largely agrees with the Department's assessment of the Class I Deep Well Injection alternative. However, we respectfully disagree with some of the discussed disadvantages. For example, the PEIS states that deep well injection means the "disposed AFFF concentrate mass remains in place with no method for verifying PFAS destruction". Deep well injection, by definition, is not a destruction technology, but rather a disposal technology that ensures a waste is injected into a geologically isolated injection zone bounded by confining layers of rock that prevent migration of wastes into underground sources of drinking water (USDWs). Class I deep wells are carefully located and constructed in geological zones specifically designed to make waste mobility/migration impossible due to the imperviousness of the confining layers. So even though deep well injected wastes are not destroyed, they are confined and isolated so that they are forever trapped inside the injection zone, effectively rendering them harmless to USDWs. The PEIS also states that "deep well injection facilities are generally operated under limited compliance monitoring; therefore, the long-term stability of injected wastes is undocumented." WM strongly disagrees with this assertion as Class I deep well injection wells are regulatorily required to meet rigorous environmental standards to ensure environmentally safe disposal of wastes they are permitted to accept. Deep well facilities are required to conduct numerous monitoring activities, including groundwater, air, mechanical integrity as well as monitoring of the confining structure to ensure wastes are properly injected into the confining geologic zone. Deep well operations must periodically perform extensive testing and evaluation to prove there is no migration occurring and that the injection zone is geologically stable and sufficiently free of faults or fractures to prevent fluid movement.	Ecology appreciates the time and attention that WM committed to reviewing the draft EIS and for expressing their thoughts in support or opposition to the proposed program. Ecology concurs with WM's comment that deep well injection is not a destructive approach, and we will correct this in the final EIS. Additionally, for the final EIS, Ecology will request monitoring information and requirements from the Advantek and US Ecology facilities under consideration for AFFF disposal, and we will modify the discussion in the final EIS, if appropriate.	IND-1-1

Commenter	Comment Code	Comment	Ecology Response	Attachment 1 Commenter Reference ID
Waste Management (James Denson)	IND-1-1-3	INCINERATION WM believes the Department must consider the incineration capacity shortfall that is currently impacting waste disposal via incineration, as this capacity shortfall is expected to continue for several years in the future. Currently scheduling non-bulk, containerized wastes into these facilities is highly limited and many months out. This issue would certainly present a challenge to the disposal of AFFF inventories, which are largely containerized wastes. This could exacerbate the already challenging issue of transporting AFFF over large distances to the incineration facilities highlighted by the Department, as these less than bulk loads may have to be placed in temporary storage at transfer stations until an incineration facility is willing to accept them. In addition, the Department needs to re-analyze this alternative based on the Significance Criteria in Section 3.12.2.2. Specifically, the Significance Criteria in this section states that the Approved Hold in Place alternative would not be consistent with the program objectives and legislative code, and then concludes that there would be less than significant impacts on police, fire departments, and emergency services. This analysis does not consider that, when viewed in light of the incineration capacity shortfall, the Incineration alternative necessarily includes an indeterminate period of the impacts associated with the Approved Hold in Place alternative. Fire departments that currently have AFFF will be required to implement many of the administrative and engineering controls listed in Section 3.1.3. for an unspecified period, in addition to other administrative and engineering controls associated with storing and managing hazardous substances. The PEIR does not acknowledge the demands implementing these controls for an indeterminate period will have on fire department resources, as well as whether the concomitant delay in permanently disposing of AFFF waste is consistent with the program objectives and	Ecology appreciates the time and attention that WM committed to reviewing the draft EIS and for expressing their thoughts in support or opposition to the proposed program. Ecology is aware of the national incineration capacity shortfall, and we appreciate WM's observation that, if Alternative 2 is selected, undue delay in implementation could impact fire departments as well as program objectives. Communications with Clean Harbors indicates they have been able to work through the "national backlog" with minimal disruption and are bringing a new incinerator online at Kimball, Nebraska. Ecology will consider incineration capacity when making a disposal decision and will modify the discussion in the final EIS, if appropriate. Please also see Master Response 5 regarding mitigation measures. Mitigation measures are outlined in the EIS with varying levels of detail. Project-specific mitigation and protections would be developed after the final EIS is published and the Ecology AFFF program is selected and approved.	IND-1-1

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		legislative code, as noted in Section 3.12.2.2.		
Waste Management (James Denson)	IND-1-1-4	The PEIR also does not analyze the criteria and hazardous air pollutants, and Greenhouse Gas Emissions associated with combustion of fuel to heat the incinerator. The PEIR seems to assume that hazardous waste incinerators are continuously operated at a temperature capable of destroying PFAS. U.S. EPA's 2020 Interim Guidance on the Destruction and Disposal of PFAS and PFAS Containing Materials states that breaking the carbon-flourine bond requires 1.5 times more energy compared to the thermal energy required to break carbon-chlorine bonds. An incineration facility that is operated to minimize costs and emissions is unlikely to consume additional energy and generate additional combustion emissions by always operating at the higher temperatures and times required to destroy PFAS. The PEIR should be revised to evaluate whether hazardous waste incinerators use additional energy to reach the higher operating temperatures necessary to destroy PFAS, any resulting impacts to the various resource areas, including air quality and Greenhouse Gas Emissions, and energy demands, as well as any mitigation measures that might reduce these impacts. The Department should also compare these additional impacts to other legal alternatives for the permanent management and disposal of AFFF wastes.	Ecology appreciates the time and attention that WM committed to reviewing the draft EIS and for expressing their thoughts in support or opposition to the proposed program. The comment focuses on the operating temperature needed to destroy PFAS, specifically, that this temperature requires higher energy than incinerators may normally operate at. Throughout Sections 3.1 and 3.2, the limitations of the impact assessment for criteria pollutants and greenhouse gases are stated, and the data gaps associated with the impact assessments are summarized in Sections 3.1.4 and 3.2.6. Ecology will evaluate WM's comment and augment discussion in the Data Gaps sections, if appropriate. Also please refer to Master Response 3, Development of Alternatives. The selected alternative would require compliance with permits and approvals under local, state, and federal rules for hazardous waste collection, transport, and disposal, including, in the case of Alternative 2, EPA operating permits for incinerators.	IND-1-1

Commenter	Comment Code	Comment	Ecology Response	Attachment 1 Commenter Reference ID
Waste Management (James Denson)	IND-1-1-5	SOLIDIFICATION AND LANDFILLING - Subtitle C Landfills WM agrees with the Department's assessment that permitted hazardous waste landfills are required by RCRA Subtitle C to be designed with "…rigorous liner and cap systems that limit the risk of releases." In addition, WM also agrees with the Department's assessment that landfill leachate is collected and properly treated or disposed, and that federal and state regulatory requirements also require landfills to monitor groundwater in the landfill area. It is important to note that the PEIR correctly references U.S. EPA's 2020 Interim Guidance on the Destruction and Disposal of PFAS and PFAS-Containing Materials, including that EPA found permitted hazardous waste landfills carry a lower level of uncertainty in their ability to control the migration of PFAS to the environment. Nevertheless, the Department's AFFF collection and disposal program lists incineration as the planned disposal method for AFFF wastes.	The comments focus on the AFFF product replacement program alternatives, including environmental impact conclusions, and the decision-making process regarding Alternative 3: Solidification and Landfilling. The draft EIS does not recommend adoption of any of the alternatives. The draft EIS analysis and conclusions, in accordance with SEPA requirements, will be considered by Ecology and any other relevant agency in decisions regarding selection and implementation of a proposed action on the AFFF program.	IND-1-1
Waste Management (James Denson)	IND-1-1-6	WM notes that the Department constrains its analysis of potential disposal facilities to sites that are currently under contract with the Department for waste disposal services. WM believes the Department should expand the PEIR's analysis to include any properly permitted waste disposal facility, regardless of whether that facility is currently under contract with the Department to provide waste disposal services. By restricting the population of facilities to only those with existing contracts, the PEIR prioritizes administrative convenience over environmental protection, and does not consider the potential to reduce numerous environmental impacts, including air quality, Greenhouse Gas Emissions, Human Health and Safety, Transportation and Truck Safety, and Public Services and Utilities that would result from disposing of AFFF wastes at the closest, properly permitted disposal facility that also carries the least uncertainty in preventing PFAS migration into the	Thank you for your input. Ecology appreciates the time and attention you've dedicated to reviewing the draft EIS. In considering the disposal of collected PFAS-containing firefighting foam, Ecology is evaluating various options. For incineration, Ecology is considering two Clean Harbors, federally permitted incinerators. However, other disposal avenues, such as solidification and landfilling, deep-well injection, and approved hold in place methods, are also under consideration. These options are offered by companies not presently under contract with Ecology. Should solidification and landfilling or deep-well injection be selected, Ecology will initiate a Request for Quotes and Qualifications (RFQQ) from hazardous waste haulers. Ecology regards PFAS-containing firefighting foam as	IND-1-1

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		environment. For example, by expanding the population of facilities that could be used for disposal, WM's Chemical Waste Management of the Northwest (CWMNW) Subtitle C facility in Arlington OR would be a potential disposal location, as it is a suitable alternative for AFFF disposal. The CWMNW facility has been safely solidifying and disposing of these PFAS containing waste (Including AFFF) from across the country for several years. The facility is located in a very protective environmental setting with regard to safety for air, climate, groundwater, and exceeds Subtitle C landfill design standards. Notability the CWMNW facility is rail served with regular service from Seattle. As noted in sections 3.1.2.1, 3.2.1.2, and 3.10.1, travel distance is a key variable affecting criteria pollutant emissions, Greenhouse Gas Emissions, as well as Transportation and Truck Safety impacts. By transporting AFFF wastes a shorter distance to the CWMNW facility, there would be a reduction in each of these impacts compared to transporting the wastes to more remote locations. At the same time, the PEIR does not analyze the increased risks to Transportation and Truck Safety, as well as other resource areas such as Public Services and Utilities, associated with having AFFF wastes in transit over longer distances and longer periods. Because the PEIR assumes that the transportation risks are the same regardless of whether AFFF waste travels one mile or 1,000 miles, the PEIR does not consider that each additional mile traveled extends the risks of collisions, equipment failure, or various human errors that might occur, resulting in an increased risk of releasing PFAS into the environment. It is again worth noting here that the Arlington facility is rail served and significantly reduces GHG emissions and the risks associated with over the road transportation. A PEIR that properly considers these risks would discuss the advantages of permanently managing AFFF wastes near its current location and take into account the benefits of rail transportation.	a state-only dangerous waste. Consequently, its disposal necessitates compliance with state regulations at a permitted hazardous waste Treatment, Storage, and Disposal (TSD) facility. In the absence of such a facility, Ecology must seek approval from the environmental regulatory authority of the receiving state for foam disposal. The current draft EIS assesses two Subtitle C hazardous waste landfills, one near Grand View, ID, and the other near Beatty, NV. These facilities have experience in solidifying and landfilling PFAS firefighting foam. Moreover, their locations in remote, arid regions with minimal annual precipitation—approximately 6 inches per year for Beatty and 8 inches for Grand View—minimize leachate management requirements. Ecology acknowledges the safety concerns and environmental impacts associated with transporting PFAS-containing foam. The Grand View site sits roughly 400 miles from the Puget Sound area, while Beatty is approximately 770 miles distant. Despite recognizing the increased spill risk and air quality impacts with greater distances traveled, we maintain that engaging a qualified hazardous waste hauler to consolidate foam loads will mitigate these risks. Additionally, the rationale behind transporting the foam to sites with minimal need for leachate management justifies the associated transport risks and impacts.	

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Waste Management (James Denson)	IND-1-1-7	Subtitle D landfills Subtitle D landfills are also subject to extensive federal, state, and local environmental, health and safety requirements including detailed design criteria, location restrictions, financial assurance capability, corrective action standards and requirements for closure and post-closure periods. Therefore, Subtitle D landfills in the proper environmental setting are well suited for safe disposal of AFFF and should be considered by the Department as a viable alternative for disposal. Expanding the list of alternatives to include Subtitle D landfills may result in closer locations for disposal, thus minimizing the risk of transporting AFFF over long distances to a final destruction or disposal destination. Most Subtitle C facilities, and many Subtitle D facilities like the Arlington facilities, have closed-loop systems that manage leachate within the facility rather than discharging their leachate for offsite treatment. PFAS waste streams that are disposed in landfills that produce minimal leachate volumes, especially those facilities that employ stabilization or solidification technologies and are located in dry climates, afford heightened levels of environmental protection.	Ecology appreciates the time and attention that WM committed to reviewing the draft EIS and for expressing their thoughts in support or opposition to the proposed program. In Washington State, PFAS-containing AFFF typically designates as state-only persistent dangerous waste. According to the Dangerous Waste Regulations in Chapter 173-303 WAC, dangerous waste must be disposed of at an approved Subtitle C landfill designed to treat or manage persistent dangerous waste.	IND-1-1
Waste Management (James Denson)	IND-1-1-8	Finally, as stated throughout our comments, WM encourages the Department to keep all proven technologies on the table as it works to finalize this Draft. As noted above, the PEIR needs revision and additional analysis to properly inform AFFF disposal managers of the environmental impacts and mitigation measures associated with all legal methods of disposal of AFFF wastes, enabling the managers to make the choice with the least environmental impacts, and the least uncertainty with preventing PFAS migration into the environment, unconstrained by the administrative conveniences associated with government contracting.	The EIS does not recommend adoption of any of the five AFFF program alternatives. The SEPA process is intended to ensure that environmental values are considered during decision-making actions by state and local agencies. The process helps agency decision-makers, applicants, and the public understand how the proposed project will affect the environment. The environmental review process in SEPA is intended to work with other regulations and documents to provide a comprehensive review of a proposal. Thus, the draft EIS analysis and conclusions, in accordance with SEPA requirements,	IND-1-1

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			must be considered by Ecology and any other relevant agency in decisions regarding selection and implementation of a proposed action on the AFFF program.	
Coalition for Responsible Waste Incineration (Melvin Keener)	ORG-5-1-1	1. Products of incomplete combustion The draft repeats the following statement several times (in various forms). "PFAS destruction with these treatment devices remains uncertain due to concerns about products of incomplete combustion (PICs) and release of non-PFAS pollution." The draft acknowledges that EPA is continuing research in this area. CRWI would like to point the State to a recent publication (Footnote 1) that directly addresses this issue. Here the Agency reports experimental work using their Rainbow Furnace to destroy legacy aqueous film-forming foam (AFFF). The paper shows greater than 99.99% destruction for all of the PFAS components of this AFFF sample except for PFBA when fed directly into the flame. We suspect that this one example is an artifact since their results show 99.99% destruction at a slightly lower temperature (1090 °C). In fact, these results show greater than 99.999% destruction for a large number of the component PFAS compounds some as low as 970 °C. These results are consistent with those shown at Clean Harbors Aragonite and Chemours Fayetteville (discussion below). But more important, this paper shows the levels of PICs produced at various temperatures (see Table 3 in the publication, duplicated below with totals for each column added). Table 3. Volatile PFAS and Other Gases Quantified in the Emissions from AFFF Incineration [...] When closely examined, this data shows that AFFF when subjected to injection into the flame, 1180 °C, and 1090 °C have virtually no PICs measured when using current methods. When subjected to temperatures of 970 °C, the	Ecology appreciates the time and attention that the commenter committed to reviewing the draft EIS and for expressing their thoughts in support or opposition to the proposed program. Ecology will continue to review the comments and use them to inform future decisions as appropriate. Ecology will review the cited reference and add discussion into the final EIS, if appropriate.	ORG-5-1

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		number goes up. This is primarily due to one compound, octafluoropropane, which accounts for approximately 90% of the PIC emissions at that temperature. It is also interesting to note that carbon monoxide (CO) seems to be a good indicator of PIC emissions. This is exactly what EPA discovered in the 1980's when trying to measure PIC emissions during the destruction of organic compounds (Footnote 2). At that time, the Agency was focused on organic chemicals and chlorinated organic chemicals. Based on the evidence in the Table above, it appears that fluorinated organic compounds behave in a similar manner as all other organic chemicals. While the conditions needed for destruction may vary based on the chemistry of the materials being destroyed, the concepts developed to show destruction and continued compliance under RCRA (Footnote 3) and carried over into the Clean Air Act requirements (Footnote 4) apply for fluorinated organics as well. CRWI believes there are data showing that under certain conditions, few fluorinated PICs are emitted. At destruction temperatures above 1000 °C, the highest concentration is 4 ppb. The vast majority were non-detects. We believe that the final EIS should include the same conclusions.		
Coalition for Responsible Waste Incineration (Melvin Keener)	ORG-5-1-2	The draft environmental impact statement also lists advantages and disadvantages of using hazardous waste incinerators to destroy AFFF. The draft states that incineration is "one of only a few technologies that can potentially destroy PFAS, thus reducing future risks to public health and adverse effects on the environment." CRWI agrees with that assessment but would take it one step further. It is the only commercially available technology that can handle the volumes of materials that need destruction. Tests at Clean Harbors Aragonite and Chemours Fayetteville for 2020 (Footnote 5) and 2022 (Footnote 6) have shown at least 99.99% reductions for	Thank you for your comment. Regarding the advantages of incineration, we will look closely and incorporate updates to better clarify that incineration is one of only a few commercially available and permitted technologies that can potentially destroy persistent dangerous waste. Ecology will consider clarifying more specifically what the data gaps are, which includes better understanding of a facility's ability to effectively maintain destruction temperatures and treatment times, stack gas analysis, incomplete combustion, and other risk factors associated with incomplete combustion.	ORG-5-1

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		the PFAS compounds fed. Under disadvantages, the draft states that “EPA research on incineration continues to evaluate effective destruction temperatures and treatment time, the potential to generate products of incomplete combustion, stack gas analyses, deposition onto land, and other risk factors.” Given the release of the 2023 paper (footnote 1), CRWI contends that the destruction temperature and residence time window is sufficiently defined. The research data from EPA used a variant of OTM-50 to sample and analyze PICs from the Rainbow Furnace. This method (Footnote 7) was released by EPA on January 18, 2024. Now that it is available, facilities can start developing emissions data for the 30 PFAS compounds currently included in the method. These 30 compounds closely mirror the analysis done in the 2023 EPA paper (footnote1).		
Coalition for Responsible Waste Incineration (Melvin Keener)	ORG-5-1-3	“Clean Harbors reports that testing demonstrates that the Aragonite Incinerator destruction and removal efficiencies (DREs) exceed 99.9999 percent for common PFAS compounds (EA, 2021). It is not reported if these results have been subjected to peer review or scrutiny by regulatory agencies.” While the Aragonite report was not peer-reviewed in the traditional sense, it was reviewed by Dr. Philip Taylor, one of the pre-eminent researchers in the field of combustion chemistry. EPA scientists at the Office of Research and development have a copy of this data and are presumably using it in the next draft of their disposal and destruction guidance document. The report has also been reviewed by the Department of Defense and the Utah Department of Environmental Quality.	Ecology appreciates the time and attention that the commenter committed to reviewing the draft EIS and for expressing their thoughts in support or opposition to the proposed program. Ecology will continue to review the comments and use them to inform future decisions as appropriate. Ecology will review the cited risk peer review information and add discussion into the final EIS, if appropriate.	ORG-5-1
Coalition for Responsible Waste Incineration	ORG-5-1-4	“PFAS are difficult to destroy due to the strength of the carbon-fluorine bond. Incomplete destruction or recombination of reactive intermediates can potentially result in the formation of new PFAS or other PICs of	Ecology appreciates the time and attention that the commenter committed to reviewing the draft EIS and for expressing their thoughts in support or opposition to the proposed program. Ecology will	ORG-5-1

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(Melvin Keener)		concern (EPA 2020c). Information regarding the emissions of PICs from PFAS incineration and their control is lacking." The carbon-fluoride bond is one of the strongest chemical bonds. However, it can be broken using the proper combustion fundamentals. This has been demonstrated numerous times in the laboratory and the field (see discussions above). EPA and the combustion industry have recognized this since the 1980's and developed a method to show destruction and continuous compliance with the conditions that guarantee destruction. This is accomplished by requiring hazardous waste combustion facilities to select one or more compounds that is more difficult to destroy than the compounds that they would normally combust and show at least 99.99% destruction removal efficiency (DRE) for those compounds. This concept was developed early in the regulation of hazardous waste incinerators under Subpart O of the RCRA regulations. In the guidance document for hazardous waste incinerators (Footnote 8), EPA discusses the concepts for demonstrating DRE for organic hazardous waste. In the opening paragraphs of this guidance document, EPA explains this concept.[...] The guidance gives detailed instructions on selecting POHCs and the entire process of demonstrating DRE. Hazardous waste facilities have used this guidance since 1989 to demonstrate the ability to meet these criteria. Appendix VIII of the guidance contains a list of organic compounds ranked on how difficult they are to destroy (incinertibility index). This idea was initially suggested by the researchers at the University of Dayton (Footnote 9). Class 1 chemicals on this list are the most difficult to destroy. For example, chlorobenzene is a Class 1 chemical. When a facility demonstrates a minimum DRE of 99.99% for chlorobenzene, it can be inferred that the facility can destroy a similar or greater percentage of any organic chemical ranked lower in Class 1 or any chemical in	continue to review the comments and use them to inform future decisions as appropriate.	

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		Classes 2, 3, or 4. In a recent paper, Blotevogel, et, al., (Footnote 10) concluded that perfluorooctanoic acid would fit into Class 3 of the incinerability index and hexafluoropropylene oxide dimer acid would fit into Class 5. This shows that the initial destruction of the original compounds is relatively easy. The PIC question has been addressed by EPA research (discussed above).		
Coalition for Responsible Waste Incineration (Melvin Keener)	ORG-5-1-5	“PFAS chemicals are not specifically addressed in incinerator RCRA permits. The optimal conditions for PFAS destruction, allowable feed rates, and emissions have not been characterized.” The draft environmental impact statement is correct that PFAS chemicals are not currently addressed in RCRA permits. This is because no PFAS compound has been designated as a hazardous waste. However, the optimal conditions for destruction has been demonstrated from by the data developed by Clean Harbors, Chemours, and EPA’s Office of Research and Development.	Ecology appreciates the time and attention that the commenter committed to reviewing the draft EIS and for expressing their thoughts in support or opposition to the proposed program. Ecology will continue to review the comments and use them to inform future decisions as appropriate. Ecology will review the cited publications and add discussion into the final EIS, if appropriate.	ORG-5-1
Coalition for Responsible Waste Incineration (Melvin Keener)	ORG-5-1-6	“Standardized methods for testing levels of PFAS emissions from stationary sources remain under development.” While this may have been partially correct when the draft was released (OTM-45 has been available since 2021), OTM-50 was released early in 2024. These two test methods do not cover all the potential PFAS emissions but will give facilities and regulators the tools they need to determine if the original compounds are destroyed and whether there are significant PICs produced in the process.	Ecology appreciates the time and attention that the commenter committed to reviewing the draft EIS and for expressing their thoughts in support or opposition to the proposed program. Ecology will continue to review the comments and use them to inform future decisions as appropriate. Ecology is aware of the new test method, which was released after publication of the draft EIS. Ecology will incorporate information about the new test method in the final EIS.	ORG-5-1
Coalition for Responsible Waste Incineration (Melvin Keener)	ORG-5-1-7	4. The relative risk associated with incineration is low. The conclusions of the draft environmental impact statement states: “Human Health & Safety Impacts – Incomplete incineration of AFFF may deposit residual PFAS in the surrounding soils and nearby surface waterbodies if thermal treatment does not adequately control fluorinated	Ecology appreciates the time and attention that the commenter committed to reviewing the draft EIS and for expressing their thoughts in support or opposition to the proposed program. Ecology will continue to review the comments and use them to inform future decisions as appropriate.	ORG-5-1

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		products of incomplete combustion. Discharge from the incineration of AFFF from the project would not affect water resources. Deposition onto soils could occur in trace or very low measurable quantities. Therefore, the risk to these resources from incineration is low." EPA's data shown in the table above supports this conclusion. For combustion temperatures above 1000 °C, the total PIC concentrations are less than 4 ppb. Ony when the combustion temperature falls below 1000 °C does the total PIC concentration show an increase and majority of this is from one compound, octafluoropropane. Toxicity information does not exist for this compound but according to the safety data sheets, octafluoropropane is relatively inert, nonflammable, and nontoxic (Footnote 11) CRWI believes that based on EPA data, this conclusion is correct.		
Revive Environmental Technology, LLC (Matthew Massey)	ORG-6-1-1	As detailed further below, Revive respectfully submits that supercritical water oxidation ("SCWO"), one of the listed emerging technologies, has been technically ready and commercially available since May 2023 and should be given additional and further consideration as one of the listed Alternatives. Pending that addition, we believe Alternative #1 ("Approved Hold in Place") in the EIS to be the only responsible action for DoE (Footnote 3).	During the development of the draft EIS, an alternative utilizing SCWO technology was evaluated. It was ultimately eliminated because under Washington State Dangerous Waste Regulations, PFAS-containing foam designates as a persistent state-only dangerous waste and must be disposed of at a RCRA-permitted treatment, storage, and disposal facility. Currently, there are no RCRA-permitted facilities that implement SCWO technology. State regulations permit the disposal of state-only dangerous waste at non-TSDs, if the Department of Ecology receives written permission from the receiving state. Ecology has reached out to one other state that employed this technology in 2022and was not granted that permission. Because of this, Ecology did not consider SCWO as a separately listed alternative. We appreciate your feedback related to Alternative 1 as the only responsible action and will consider it when updating the final EIS.	ORG-6-1

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Revive Environmental Technology, LLC (Matthew Massey)	ORG-6-1-2	SUPERCRITICAL WATER OXIDATION AND PER- AND POLYFLUOROALKYL SUBSTANCES SCWO is an advanced technology which destroys PFAS by leveraging the distinctive attributes of supercritical water to mineralize PFAS compounds. This "special phase" is achieved at temperatures above 374°C and pressures surpassing 22.1 MPa. These elevated pressures and temperatures allow for the broad and complete mineralization of PFAS within seconds. That has two implications: - SCWO completely destroys all types of PFAS (long and short chain compounds), often to nondetect levels. - SCWO only produces non-toxic byproducts - carbon dioxide, water, and brine. - SCWO treats all types of PFAS waste, including AFFF, landfill leachate, industrial wastewater, and contaminated groundwater. There are multiple companies (Footnote 4), in various stages of development, currently using SCWO-based technology systems to destroy PFAS compounds.	SCWO and other emerging technologies are being considered under Alternative 1, Approved Leave in Place. This alternative would require AFFF to be stored at participating fire departments under Ecology-approved conditions while new technologies are investigated by the EPA and brought online. When we published the draft EIS, we had not received requested SCWO PFAS destruction data. As such, we could not determine the effectiveness of the technology. Ecology will review SCWO information that has been published since the publication of the draft EIS, and we will update discussion as appropriate. Also please see Master Responses 3 and 6.	ORG-6-1

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Revive Environmental Technology, LLC (Matthew Massey)	ORG-6-1-3	Revive became the first commercially available, fully permitted, complete PFAS destruction solution available in the U.S. Revive has successfully partnered with multiple state and local regulators to secure the necessary air and water discharge permits (Footnote 5). Revive rapidly scaled its capability and has seven operational PFAS Annihilators®, which have a combined ability to treat 700,000,000 gallons of PFAS-laden waste annually, when combined with other pre-treatment technologies. [...] Importantly, because SCWO (and the PFAS Annihilator®) is a chemical process, its efficacy can be measured and verified to a far greater extent than landfilling, incineration, or deep well injection ("Incumbent Disposal Options"). Revive can produce batch-by-batch analytical evidence of the complete PFAS destruction and zero harmful byproducts, thus providing a higher level of transparency and certainty. To date, all deployments of the PFAS Annihilator® have destroyed PFAS molecules below the U.S. EPA's proposed 4 parts per trillion drinking water standards. Finally, and perhaps most significantly, Revive is already assisting multiple states organize and conduct AFFF Takeback programs. Revive has been working with New Hampshire (Footnote 6) and Ohio (Footnote 7) on their respective takeback programs, which are scheduled for 2024. In addition to destroying their respective AFFF stockpiles, we are providing program infrastructure support, including arranging for collection, tracking, storage, destruction, and disposal. Thus, we have real world experience at every stage of the collection and disposal process.	Ecology recognizes the contributions Revive has made in assisting states with AFFF treatment and disposal. Under Washington State Dangerous Waste Regulations, PFAS-containing foam must be disposed of at a RCRA-permitted treatment, storage, and disposal (TSD) facility. Currently, there are no SCWO facilities at a TSD. However, state regulations permit the disposal of state-only dangerous waste at non-TSDs if the Department of Ecology receives written permission from the receiving state. At the time Ecology was investigating SCWO, there was a single commercially viable SCWO operation in the United States. That was a Battelle facility located in Wyoming, Michigan. Ecology reached out in the fall of 2022 to Michigan's Department of the Environment, Great Lakes, and Energy (EGLE) seeking permission to ship Washington State's collected PFAS containing firefighting foam to the state's Wyoming facility. EGLE notified Ecology they would not grant permission. Also please see Master Responses 3 and 6.	ORG-6-1

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Revive Environmental Technology, LLC (Matthew Massey)	ORG-6-1-4	When compared to the Incumbent Disposal Options, the PFAS Annihilator® presents the same or less potential adverse environmental impacts (Footnote 10). Its air emissions are demonstrably cleaner than those from an incinerator, consisting of only carbon dioxide and no PFAS molecules.	Ecology appreciates the time and attention that the commenter committed in reviewing the draft EIS. Ecology recognizes the contributions Revive has made in assisting states with AFFF treatment and disposal. Under Washington State Dangerous Waste Regulations, PFAS-containing foam must be disposed of at a RCRA-permitted treatment, storage, and disposal (TSD) facility. Currently, there are no SCWO facilities at a TSD. However, state regulations permit the disposal of state-only dangerous waste at non-TSDs, if the Department of Ecology receives written permission from the receiving state. Ecology received notice from a receiving state that they would not grant that permission. Ecology will follow up with Revive to confirm the air emissions data. Also please see Master Responses 3 and 4.	ORG-6-1
Revive Environmental Technology, LLC (Matthew Massey)	ORG-6-1-5	Likewise, the impact on aquatic resources and terrestrial habitats is near zero due to the destruction of the PFAS molecules.	Ecology recognizes the contributions Revive has made in assisting states with AFFF treatment and disposal. Under Washington State Dangerous Waste Regulations, PFAS-containing foam must be disposed of at a RCRA-permitted treatment, storage, and disposal (TSD) facility. Currently, there are no SCWO facilities at a TSD. However, state regulations permit the disposal of state-only dangerous waste at non-TSDs, if the Department of Ecology receives written permission from the receiving state. Ecology received notice from a receiving state that they would not grant that permission.	ORG-6-1
Revive Environmental Technology, LLC (Matthew Massey)	ORG-6-1-6	Landfilling and deep well injection only move PFAS around without addressing the core problem.	Ecology appreciates the time and attention that the commenter committed to reviewing the draft EIS and for expressing their thoughts in support or opposition to the proposed program. Ecology will continue to review the comments and use them to inform future decisions as appropriate.	ORG-6-1

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Revive Environmental Technology, LLC (Matthew Massey)	ORG-6-1-7	Concerns about spills from vehicle accidents or other handling mishaps can be greatly reduced due to PFAS Annihilator's® ability to be deployed on site, significantly decreasing the cumulative transport miles needed to destroy the AFFF.	Ecology recognizes the contributions Revive has made in assisting states with AFFF treatment and disposal. Under Washington State Dangerous Waste Regulations, PFAS-containing foam must be disposed of at a RCRA-permitted TSD facility. These facilities are typically established in a permanent location. Currently, there are no SCWO facilities at a TSD. Also please see Master Responses 3 and 6.	ORG-6-1
Revive Environmental Technology, LLC (Matthew Massey)	ORG-6-1-8	Unlike the Incumbent Disposal Options, the PFAS Annihilator® does not have environmental justice concerns. Landfills and incinerators are frequently located in or near environmental justice communities, with harmful effects disproportionately impacting disadvantaged low income, overburdened communities.	Ecology recognizes the contributions Revive has made in assisting states with AFFF treatment and disposal. Under Washington State Dangerous Waste Regulations, PFAS-containing foam must be disposed of at a RCRA-permitted treatment, storage, and disposal (TSD) facility. Currently, there are no Supercritical Water Oxidation (SCWO) facilities at a TSD. However, state regulations permit the disposal of state-only dangerous waste at non-TSDs, if Ecology receives written permission from the receiving state. Ecology received notice from a receiving state that they would not grant that permission. Environmental justice concerns at the Michigan locations were part of the rationale for this denial. Also please see Master Responses 3 and 6. Environmental justice concerns, specifically the proximity of disposal locations to low-income populations and communities of color, and potential impacts arising from that proximity, are considered in the environmental justice portion of the final EIS, Section 3.11, and Appendix A.8: Environmental Justice Report. As part of the draft EIS, Ecology analyzed each alternative to determine if there were environmental justice concerns. After reviewing public comments and considering federal guidance, Ecology	ORG-6-1

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			determined that additional analysis and different methodology should be completed. For the final EIS, the environmental justice analysis used U.S. Census Bureau data to determine if communities of color or low-income communities near treatment locations (including hold in place) were disproportionately impacted by any of the alternatives. Further, any emerging technology that proves viable would require a similar environmental justice analysis.	
Revive Environmental Technology, LLC (Matthew Massey)	ORG-6-1-9	Revive strongly recommends the Washington Department of Ecology reconsider the exclusion of SCWO as an approved disposal method in its upcoming AFFF disposal program. SCWO technology not only aligns with the DoE's commitment to protect human health and the environment but also offers a more sustainable and transparent solution compared to Incumbent Disposal Options. By including SCWO, the DoE will benefit from a proven, commercially viable technology that guarantees complete destruction of PFAS with minimal environmental impact. We urge the Department to prioritize innovative, effective solutions like ours in its final decision, ensuring a safer and cleaner future for Washington's communities and natural resources.	Ecology appreciates the time and attention that the commenter committed to reviewing the draft EIS and for expressing their thoughts in support or opposition to the proposed program. Ecology will continue to review the comments and use them to inform future decisions as appropriate. During public scoping for the draft EIS, the Department of Ecology identified seven disposal options. Those included the five currently in the draft EIS, as well as SCWO and collect and hold. SCWO was dropped as a stand-alone alternative for several reasons. Under Washington State Dangerous Waste Regulations (Chapter 173-303 WAC), PFAS-containing foam designates as a persistent state-only dangerous waste and must be disposed of at a RCRA-permitted TSD facility. Currently, there are no RCRA permitted facilities that implement SCWO technologies. State regulations permit the disposal of state-only dangerous waste at non-TSDs, if the Department of Ecology receives written permission from the receiving state. During development of the draft EIS, SCWO was being utilized at a facility in Wyoming, Michigan. Ecology reached out to Michigan's Department of Environment, Great Lakes, and Energy in 2022 about Ecology shipping Washington	ORG-6-1

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			State's collected foam to the Michigan facility. Washington was not granted that permission. Because of this, Ecology dropped SCWO as a separately listed alternative. Ecology appreciates Revive's and other companies' efforts to develop innovative destruction technologies. While Ecology believes SCWO and other innovative PFAS destruction technologies show promise, the technology is not yet RCRA-permitted and we have not received permission from another state to receive our PFAS dangerous waste.	
Revive Environmental Technology, LLC (Matthew Massey)	ORG-6-1-10	Until such time as DoE has completed the additional review needed to include SCWO as a listed Alternative, DoE should proceed with Alternative #1 ("Approved Hold in Place").	Ecology appreciates the time and attention that the commenter committed to reviewing the draft EIS and for expressing their thoughts in support or opposition to the proposed program. Ecology will continue to review the comments and use them to inform future decisions as appropriate.	ORG-6-1
Environmental Technology Council (James Williams)	ORG-7-1-1	For hazardous waste combustion units EPA requires a minimum DRE of 99.99%. ETC member company Clean Harbors recently conducted tests which demonstrated a DRE of 99.9999% (test results can be requested at https://www.cleanharbors.com/PFAS-Study). Additionally, the U.S. Department of Defense lists 140 research projects on the destruction of materials containing PFAS compounds that can be found at https://serdp-estcp.org/focusareas/deb5c156-f647-4934-8313-fa00364ff55e/treatment-of-pfas-impacted-matrices.	Ecology appreciates the time and attention that the commenter committed to reviewing the draft EIS and for expressing their thoughts in support or opposition to the proposed program. Ecology will continue to review the comments and use them to inform future decisions as appropriate.	ORG-7-1
Environmental Technology Council (James Williams)	ORG-7-1-2	Additionally, we stress the position that RCRA and CAA permitting requirements that provide additional regulatory oversight and include operating requirements and emission limitations to safely and effectively treat hazardous and non-hazardous contaminants cannot be overlooked. RCRA hazardous waste facilities are subject to CAA Title V permitting	Please see Master Response 5: Mitigation Measures. The response outlines the regulatory oversight and expected development of a permit, rule, contract, or participation agreement which would include project specific mitigation and protections as the AFFF program is selected and approved. In addition, Ecology will adhere to federal,	ORG-7-1

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		requirements and to maximum achievable control technology standards pursuant to § 112 of the CAA that include, emission limitations for metals, dioxin/furans, particulate matter, hydrogen chloride and chlorine gas, and carbon monoxide or hydrocarbons, as well as limits on minimum organic DRE. Also, under the authority of RCRA's "omnibus" clause (§ 3005(c)(3); and 40 CFR 270.32 (b)(2)), RCRA permit writers may impose additional terms and conditions on a site-specific basis as may be necessary to protect human health and the environment. Due to these additional safeguards, we believe RCRA regulated commercial incinerators are well suited to safely and properly destroy materials containing PFAS compounds such as AFFF. While the Draft considers incineration as a viable destruction option, it also considers landfills and deep well injections as viable disposal options. Keeping all options in the toolbox is important given the environmental and human health harms that can be caused by PFAS compounds found in AFFF.	state, and local regulations and guidelines protecting public safety and environmental health. Ecology appreciates the commenter's support of the alternatives developed.	
Environmental Technology Council (James Williams)	ORG-7-1-3	Subtitle D landfills are also subject to extensive federal, state, and local environmental, health and safety requirements including detailed design criteria, location restrictions, financial assurance capability, corrective action standards and requirements for closure and post-closure periods. Therefore, Subtitle D landfills should also be considered a viable option for disposal.	Ecology appreciates the time and attention that ETC committed to reviewing the draft EIS and for expressing their thoughts in support or opposition to the proposed program. In Washington State, PFAS-containing AFFF typically designates as state-only persistent dangerous waste. According to the Dangerous Waste Regulations in Chapter 173-303 WAC, dangerous waste must be disposed of at a RCRA-permitted TSD designed to treat or manage persistent dangerous waste. If solidification and landfilling were selected as the disposal option, Ecology would dispose of the foam at a federally permitted Subtitle C landfill.	ORG-7-1

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Environmental Technology Council (James Williams)	ORG-7-1-4	ETC encourages the Department to include Subtitle C and Subtitle D facilities in the mix of viable technologies to address AFFF treatment and disposal as they are very well suited to manage highly concentrated PFAS compounds in waste streams. For example, treatment methods used to stabilize wastes are applied to minimize the mobilization and migration of PFAS out of these disposed wastes. Most Subtitle C facilities, and many Subtitle D facilities, have closed-loop systems that manage leachate within the facility rather than discharging leachate for offsite treatment. PFAS compounds in waste streams that are disposed in landfills that produce minimal leachate volumes, especially those facilities that employ stabilization or solidification technologies and are in dry climates, afford heightened levels of environmental protection. Accordingly, ETC recommends that the Department recognize that these facilities offer a reduced risk of PFAS compound migration into the environment and should be considered a viable disposal option for AFFF. Again, it is important to keep all proven technologies in the mix of destruction and disposal options.	The comments focus on potential AFFF disposal sites such as Subtitle C and Subtitle D landfills. AFFF designates as a state-only dangerous waste and must be disposed of at a RCRA-permitted TSD. As such if AFFF is disposed of by solidification and landfilling it must be sent to a Subtitle C facility. Subtitle D landfills are not considered in the draft EIS. In draft EIS Section 2.2.3.2, Ecology lists relative general disadvantages of AFFF landfilling overall, including the uncertainty as to whether certain PFAS may be designated as hazardous substances in the future. As such, Ecology recognizes potential long-term legal and environmental liabilities associated with disposal in Subtitle D landfills. RCRA-permitted Subtitle C landfills are already included as a potential alternative under Alternative 3.	ORG-7-1
Environmental Technology Council (James Williams)	ORG-7-1-5	In addition to high temperature incineration and landfilling, ETC also views underground injection as a viable option for the disposal of AFFF. […] Understanding that this technology may not be available everywhere, ETC supports its use where appropriate. Underground injection to Class I waste wells can reduce the potential risks of human exposure to injected materials, assist in avoiding discharge to surface and shallow groundwater and virtually eliminate air emissions. Since Class I wells are only sited in geological areas conducive to injection operations, we agree with the Department's assessment that this may be a limited technology. However, due to the benefits of this technology it must be kept in the mix of options for destruction and disposal.	The comments focus on the AFFF product replacement program alternatives, including environmental impact conclusions, and the decision-making process regarding Alternative 4: Class I Deep Well Injection. Ecology recognizes Deep well injection is a viable alternative and is considering it among potential disposal options. Deep Well injections impacts upon the environment and public health, along with potential mitigation measures, are included in EIS Chapters 2, 3, and 4.	ORG-7-1

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Environmental Technology Council (James Williams)	ORG-7-1-6	The Draft indicates that a disadvantage of Class I deep well injection is that deep well injection facilities are generally operated under limited compliance monitoring; therefore, the long-term stability of injected wastes is undocumented. To the contrary, waste disposal via Class I injection wells is only permitted if the operator can demonstrate the waste will remain in place where it has been injected. To demonstrate this an operator must receive approval of a “no-migration petition” from EPA. A no-migration petition is used to give EPA information and modeling results using data on local and regional geology, waste characteristics, geochemical conditions of the well site, injection history, and many other factors EPA uses to determine whether the operator has adequately demonstrated that the waste will not migrate from the disposal site. These strict requirements and oversight coupled with the fact that Class I waste disposal wells are designed to dispose of and isolate liquid wastes below the land surface and beneath USDW, make these wells a viable option for the disposal of certain PFAS compounds.	Ecology appreciates the time and attention that ETC committed to reviewing the draft EIS and for expressing their thoughts in support or opposition to the proposed program. For the final EIS, Ecology will request monitoring information and requirements from the Advantek and US Ecology facilities under consideration for AFFF disposal, and we will modify the discussion in the final EIS, if appropriate. Ecology recognizes Deep well injection is a viable disposal option and is considering it along with four others. Please see Master Response 5: Mitigation Measures. The response outlines the regulatory oversight and expected development of a permit, rule, contract, or participation agreement which would include project-specific mitigation and protections as the AFFF program is selected and approved. In addition, Ecology will adhere to federal, state, and local regulations and guidelines protecting public safety and environmental health.	ORG-7-1
Environmental Technology Council (James Williams)	ORG-7-1-7	The alternative option “approved hold in place” is essentially storage. While storage of AFFF is not a destruction or disposal technology, the Draft does note that extended interim storage may be an appropriate strategy until identified uncertainties are addressed and appropriate destruction and disposal technologies can be recommended. ETC does not support storage in lieu of disposal. Allowing for storage of certain AFFF would create the risks of spills and accidental releases which we believe are unacceptable. Also, the presence of certain PFAS compounds when deemed a hazardous substance under the Comprehensive Environmental Response Compensation and Liability Act and supported as such under the current Administration, creates long- term liability risk to property owners, operators, parties handling	Ecology appreciates the time and attention that the commenter committed to reviewing the draft EIS and for expressing their thoughts in support or opposition to the proposed program. Ecology will continue to review the comments and use them to inform future decisions as appropriate.	ORG-7-1

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		waste and others that encounter material managed from a site where PFAS was identified.		
Environmental Technology Council (James Williams)	ORG-7-1-8	Regarding the collection and storage of AFFF at a centralized location and the non-vehicle transport (i.e., air and maritime) of AFFF materials, ETC agrees with the Department that these options should not be considered. As noted previously, allowing storage of certain PFAS and AFFF would create the risks of spills and accidental releases. In the case of non-vehicle transport, the Department points out that the releases could be to air and water, thus the elimination of this option.	Ecology appreciates the time and attention that the commenter committed to reviewing the draft EIS and for expressing their thoughts in support or opposition to the proposed program. Ecology will continue to review the comments and use them to inform future decisions as appropriate.	ORG-7-1
Environmental Technology Council (James Williams)	ORG-7-1-9	ETC understands that there is much uncertainty as to when many emerging PFAS compound treatment technologies will become available for commercial use. However, we encourage the Department to closely monitor the research and development conducted in this area. ETC member companies are constantly engaging in such efforts to bring about innovative technologies to address PFAS treatment and disposal.	Ecology appreciates the time and attention that the commenter committed to reviewing the draft EIS and for expressing their thoughts in support or opposition to the proposed program. Ecology will continue to review the comments and use them to inform future decisions as appropriate. Please see Master Response 6, which discusses alternatives considered and eliminated. Emerging technologies will remain under consideration for Alternative 1, Approved Hold in Place, if they become technically and commercially viable.	ORG-7-1
Environmental Technology Council (James Williams)	ORG-7-1-10	Finally, as stated throughout our comments, ETC encourages the Department to keep all proven technologies in the mix of destruction and disposal options as it works to finalize this Draft.	Ecology appreciates the time and attention that the commenter committed to reviewing the draft EIS and for expressing their thoughts in support or opposition to the proposed program. Ecology will continue to review the comments and use them to inform future decisions as appropriate. Please see Master Response 6, which discusses alternatives considered and eliminated. Emerging technologies will remain under consideration for Alternative 1, Approved Hold in Place, if they become technically and commercially viable.	ORG-7-1

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Sierra Club and Earthjustice (Sonya Lunder)	ORG-8-1-1	To begin, we support the state's AFFF collection and disposal efforts. [...] Moreover, because of PFAS' "extreme persistence ... [and] mobility,"(Footnote 1) many treatment and disposal technologies fail to destroy or permanently contain PFAS, but rather continue the cycle of contamination by releasing additional PFAS to the air and water. Washington's AFFF collection and disposal program allows the state to make coordinated and informed decisions about the best methods of PFAS disposal, while relieving individual fire departments of the logistical and financial burdens associated with such disposal. We also strongly support Ecology's decision to prepare an EIS for its AFFF disposal program. As the Environmental Protection Agency has acknowledged, "significant uncertainties remain" with respect to the effectiveness and environmental impact of traditional waste disposal methods – landfilling, incineration, and deep-well injection – when applied to PFAS-containing wastes. (Footnote 2) AFFF disposal presents substantial environmental and health risks, and the EIS process offers an opportunity to carefully evaluate those impacts and to identify the safest and most effective disposal option.	Ecology appreciates the time and attention that the commenter committed to reviewing the draft EIS and for expressing their thoughts in support or opposition to the proposed program. Ecology will continue to review the comments and use them to inform future decisions as appropriate.	ORG-8-1
Sierra Club and Earthjustice (Sonya Lunder)	ORG-8-1-2	However, Ecology's draft EIS fails to provide the "impartial discussion of significant environmental impacts and ... reasonable alternatives" that the State Environmental Policy Act ("SEPA") requires (Footnote 3). Ecology selected a private contractor with close ties to the hazardous waste incineration industry to prepare the EIS, a conflict that raises serious questions about the objectivity of the underlying analysis. The draft EIS understates the harms associated with PFAS landfilling and incineration, declaring those impacts to be minimal based on a misapplication of industry test data while ignoring substantial evidence of data gaps and health risks. Ecology also understates the impacts of PFAS disposal on environmental justice	Ecology's determination that a contractor was necessary for the completion of the AFFF draft EIS research, investigation, and drafting was guided by a commitment to thoroughness and professionalism. In adherence with state law and regulations, Ecology followed procedures outlined for the notification of a Request for Quotes and Qualifications (RFQQ), ensuring transparency and fairness in the solicitation of a qualified contractor. Subsequently, after a review process in accordance with established protocols, TRC Inc. received the AFFF draft EIS contract. Ecology's RFQQ application requires bidders to	ORG-8-1

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		communities, focusing exclusively on communities in the immediate vicinity of disposal sites even though PFAS are highly mobile and are known to cause disproportionate harms to lower income communities, Indigenous communities, and communities of color nationwide.	disclose any interest, direct or indirect, that might be construed as prejudicial in any way to the professional judgment of the bidder in rendering service to Ecology under the resulting contract. In addition, the bidder must describe the internal policies and procedures for handling conflicts of interest and client confidentiality. TRC's submitted proposal did not include reference to membership in the Coalition for Responsible Incineration (CRWI). When Ecology learned of the association between TRC Inc. and CRWI, TRC reported that the staff who worked on the RFQQ — and subsequently worked on the draft EIS — were unaware of the company's association with the coalition. As subsequently reported to Ecology, none of the staff members who are or were involved in CRWI worked on any aspect of the RFQQ or the draft EIS. Prior to hiring TRC, Ecology conducted draft EIS scoping to gather public input on a number of issues, including a list of potential disposal options. This scoping led to the identification of seven disposal alternatives originally included in the draft EIS. Those were 1. Approved Hold in Place, 2. Incineration, 3. Solidification and Landfilling, 4. Deep Well Injection. 5. Super Critical Water Oxidation, 6. Collect and Hold, and 7. No Action. Ecology entered into the draft EIS work with TRC Inc. with this list of options to analyze. After hiring TRC and for reasons laid out in Master Response 6, Ecology eliminated alternative 5. Super Critical Water Oxidation and 6. Collect and Hold from consideration. Throughout the draft EIS development Ecology maintained rigorous oversight and retained editorial control of the document. Expert input and feedback	

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			from Ecology's subject matter specialists were integral to shaping the positions and conclusions presented in the draft EIS, ensuring the comprehensive review of the complexities regarding AFFF disposal reflect Ecology's understanding of the matter. The draft EIS relies on current scientific literature, encompassing hundreds of references, studies, reports, and documents, to assess the environmental and public health impacts of foam collected for disposal from Washington's municipal fire departments. Ecology conducted a thorough review of the current PFAS destruction literature, examined data sets, and engaged with research labs, universities, private industry, non-profits, and state and federal entities to evaluate the effectiveness of available destruction technology. However, Ecology acknowledges existing data gaps concerning the efficiency and effectiveness of all PFAS destruction technologies, as outlined in Chapter 3.1.4. If new destruction information emerges, Ecology commits to considering it before making any decision. Ecology is also cognizant of the environmental justice issues associated with PFAS-containing foam disposal. The disposal options were selected to minimize potential impacts on low-income and overburdened communities. In response to this comment and others received during the draft EIS comments period, Ecology revised the analysis to look more closely at impacts to low-income populations and communities of color. For the final EIS, new analyses were conducted to determine the best evaluation criteria to identify low-income populations and communities of color, rooted in Promising Practices for EJ Methodologies	

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			in NEPA Reviews by the U.S. EPA. Further, Ecology replaced the draft EIS environmental justice chapter with a new analysis contained in the supplemental Appendix A.8: Environmental Justice Report. Additionally, because the different technologies presented as disposal options in this EIS (landfilling, deep well-injection, incineration, etc.) have different release mechanisms and routes of exposure, the study area for each alternative and its potential impact on environmental justice communities is determined according to best practices and available data. Due to the mobile nature of air pollution, the environmental justice study area for incineration options is 10 miles, whereas the study area for the other options is 0.25 miles. We acknowledge that air pollution is a global phenomenon and can potentially travel great distances. However, keeping the study area at 10 miles maximizes identifying potential disproportionate impacts to low-income populations and communities of color in proximity to the source and therefore most at risk, without diluting the data with a much larger radius. Section 2.1 of Appendix A.8 to the final EIS outlines the study areas for each alternative.	
Sierra Club and Earthjustice (Sonya Lunder)	ORG-8-1-3	Finally, Ecology fails to seriously consider several advanced PFAS destruction alternatives that have the potential to eliminate or reduce the impacts associated with traditional disposal technologies, such as super critical water oxidation ("SCWO") – which has been used to treat AFFF in other locations – and closed-loop Hydrothermal Alkaline Treatment ("HALT") technology developed by Washington based Aquagga, the winner of EPA's Innovative Ways to Destroy PFAS Challenge. (Footnote 4)	Ecology acknowledges that SCWO is an existing technology that has been demonstrated to destroy PFAS molecules. During the EIS scoping phase, a separate alternative considering SCWO technology was eliminated for several reasons. First, under Washington State Dangerous Waste Regulations, PFAS-containing foam must be disposed of at a RCRA-permitted treatment, storage, and disposal facility (TSD). Currently, there are no SCWO facilities at a TSD. However, state regulations permit the	ORG-8-1

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			disposal of state-only dangerous waste at non-TSDs, if the Department of Ecology receives written permission from the receiving state. During the drafting of the EIS, there was a single facility utilizing SCWO technology to treat AFFF. Ecology received notice from the receiving state's environmental authority that it would not grant permission. Please also see Master Response 6 for a discussion of other alternatives considered and eliminated. Ecology appreciates the time and attention that the commenter committed to reviewing the draft EIS and for expressing their thoughts in support or opposition to the proposed program.	
Sierra Club and Earthjustice (Sonya Lunder)	ORG-8-1-4	The impacts of Ecology's PFAS disposal decisions extend far beyond the 59,000 gallons of AFFF covered by the current collection and disposal program. In addition to fire stations, AFFF is also stored at ferry terminals, airports, refineries, and other industrial facilities across the state, and Ecology has acknowledged the potential for expanded collection and disposal efforts in the future. More broadly, other states, municipalities, and private parties are struggling with similar issues concerning PFAS disposal and are searching for better solutions. Ecology has a statutory obligation to carefully evaluate the environmental and health impacts of its PFAS disposal program, and its analysis and selection of alternatives has the potential to inform future decisions and move the nation towards more protective PFAS disposal technologies. In its final EIS, we urge Ecology to fully account for the risks associated with PFAS incineration as well as the potential benefits of alternative destruction technologies.	Ecology appreciates the time and attention that the commenter committed to reviewing the draft EIS and for expressing their thoughts in support or opposition to the proposed program. Ecology will continue to review the comments and use them to inform future decisions as appropriate.	ORG-8-1
Sierra Club and Earthjustice (Sonya	ORG-8-1-5	Ecology Must Investigate and Disclose the Potential Conflicts Involving the Contractor It Selected to Prepare the EIS To prepare the DEIS, Ecology retained TRC Companies	Ecology's determination that a contractor was necessary for the completion of the AFFF draft EIS research, investigation, and drafting was guided by a commitment to thoroughness and professionalism.	ORG-8-1

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Lunder)		(“TRC”), a private consultant with longstanding ties to the hazardous waste incineration industry. (Footnote 17) By its own account, TRC represents and “produce[s] bottom-line results for our commercial, solid and hazardous waste clients.” (Footnote 18) For years, TRC has also been an associate member of the Coalition for Responsible Waste Incineration (“CRWI”), a trade association created in the 1980s by Dow, 3M, Monsanto and other hazardous waste generators to promote hazardous waste incineration. (Footnote 19) CRWI members currently include hazardous waste incineration companies such as Clean Harbors Environmental Services, Heritage Thermal Services, Ross Incineration Services, and Veolia ES Technical Solutions, as well as numerous chemical and pesticide manufacturers. (Footnote 20) TRC is listed as an “associate member,” a membership tier designed for “companies that provide goods and services to the hazardous waste combustion industry.” (Footnote 21) TRC’s close ties to the incineration industry raise serious concerns about the objectivity of the DEIS, and in particular Ecology’s assessment of the impacts of incinerating AFFF. The mission statement of CRWI states that “high temperature combustion is an integral part of the solution to the waste management challenge facing hazardous waste generators today” and that “for many wastes ... combustion remains the safest, most appropriate treatment method.” (Footnote 22) CRWI has openly lobbied the White House Office of Science and Technology Policy to endorse PFAS incineration, which CRWI erroneously claimed to be the “only ... commercially available method for destroying PFAS compounds.” (Footnote 23) TRC’s membership in a trade organization that exists to encourage hazardous waste incineration, and that declared has incineration to be the “only” viable option for PFAS destruction, raises serious questions about whether TRC can even-handedly assess the environmental	In adherence with state law and regulations, Ecology followed procedures outlined for the notification of a Request for Quotes and Qualifications (RFQQ), ensuring transparency and fairness in the solicitation of a qualified contractor. Subsequently, after a review process in accordance with established protocols, TRC was awarded the AFFF draft EIS contract. The RFQQ application requires contractors to disclose any potential conflicts of interest that could impact their work. Specifically, the application requires “a bidder to disclose to Ecology any interest, direct or indirect, that might be construed as prejudicial in any way to the professional judgment of the bidder in rendering service to Ecology under the resulting contract.” TRC’s submitted proposal did not include reference to membership in the Coalition for Responsible Incineration (CRWI). When Ecology learned of the association between TRC and CRWI, TRC Inc. staff reported that the staff who worked on the RFQQ – and subsequently worked on the draft EIS - were unaware of the firm’s association with the coalition. As subsequently reported to Ecology, none of the staff members who are or were involved in CRWI worked on any aspect of the RFQQ or the draft EIS. TRC has reported that their CRWI membership ended in December 2022. TRC is a company of more than 8,000 employees that works nationwide with thousands of clients in many market sectors, including environmental remediation. Due to contractual requirements, TRC is not at liberty to disclose its past or current association with any potential clients. Prior to hiring TRC, Ecology conducted draft EIS scoping to gather public input on a number of	

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		and health impacts of PFAS incineration and other disposal methods, as SEPA requires. Ecology must immediately disclose the extent of TRC's role in the preparation of the DEIS, as well as any screening that Ecology conducted to evaluate potential conflicts of interest before retaining TRC to work on the EIS. While SEPA authorizes Ecology to use outside consultants to prepare an EIS, Ecology remains responsible for assuring that the EIS is prepared in a professional manner." (Footnote 24) Here, Ecology failed to perform that required oversight. As described in greater detail below, the DEIS's assessment of the risks from PFAS incineration rely heavily on a single test conducted by Clean Harbors, a hazardous waste incinerator and CRWI member. The DEIS also identifies two Clean Harbors incinerators as potential disposal locations, without any discussion of the substantial gaps in Clean Harbors' testing or Clean Harbors' relationship to TRC. The public has the right to know whether TRC has any current or past contractual relationship with Clean Harbors or any other hazardous waste management company, and Ecology must ensure the "impartiality of the EIS by more closely scrutinizing TRC's analysis of incineration and other disposal methods, as set forth in greater detail below. (Footnote 25).	issues, including a list of potential disposal options. This scoping led to the identification of seven disposal alternatives, originally included in the draft EIS. Those were 1. Approved Hold in Place, 2. Incineration, 3. Solidification and Landfilling, 4. Deep Well Injection. 5. Super Critical Water Oxidation, 6. Collect and Hold, and 7. No Action. Ecology entered into the draft EIS work with TRC Inc. with this list of options to analyze. After hiring TRC Inc. and for reasons laid out in Master Response 6, Ecology eliminated option 5. Super Critical Water Oxidation and 6. Collect and Hold from consideration. Throughout the process of drafting the EIS Ecology maintained rigorous oversight. Ecology retained editorial control of the document. Expert input and feedback from Ecology's subject matter specialists were integral to shaping the positions and conclusions presented in the draft EIS, ensuring that the comprehensive review of the complexities regarding AFFF disposal reflect Ecology's understanding of the matter. Ecology also recognizes that there are data gaps regarding the efficiency and effectiveness of all PFAS destruction technologies. Ecology reviewed the current PFAS destruction literature, reviewed data sets, and spoke with research labs, universities, private industry, non-profits, and state and federal entities about the effectiveness of available destruction technology. Those data gaps are described in Chapters 3 and 5 of the final EIS. If new destruction information becomes available, Ecology will consider it before making a decision.	

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Sierra Club and Earthjustice (Sonya Lunder)	ORG-8-1-6	Ecology Overlooks Significant Environmental and Health Risks Associated With PFAS Incineration The DEIS badly understates the concerns regarding the safety of incineration as a disposal option for PFAS. Ecology fails to critically assess industry data effectiveness of PFAS incineration, overlooks potentially harmful byproducts of incineration, and presents an unrealistic view of the ability of compliance-plagued hazardous waste incinerators to operate at ideal conditions when incinerating PFAS stockpiles. Ecology erroneously asserts that incineration is one of only a few technologies that can potentially destroy PFAS … reducing future risks to public health and adverse effects on the environment.” (Footnote 26) The only cited support for that claim is a study conducted by a hazardous waste incinerator, without any government oversight, that purportedly found “destruction of 99.9999 percent of common legacy PFAS compounds.”(Footnote 27) But that study did not, and could not, establish the safety of PFAS incineration, since it did not measure the PFAS and other byproducts that are most likely to be produced during the incineration process. Destruction and removal efficiency (“DRE”) compares the levels of certain target PFAS in the feedstock waste with the levels of those chemicals in stack emissions following incineration. But it doesn’t account for the formation of harmful byproducts that may be generated as result. The incineration of PFAS releases highly reactive fluorine molecules that can form a variety of harmful fluorinated compounds, including but not limited to new PFAS. As the Department of Energy and U.S. Environmental Protection have acknowledged, “incineration can result in the formation of other PFAS compounds in [stack] emissions,” as well as other harmful products of incomplete combustion (“PICs”) “which may become problematic in	Ecology appreciates the time and attention that the commenter committed to reviewing the draft EIS and for expressing their thoughts in support or opposition to the proposed program. The comment focuses on data gaps associated with PFAS incineration. Throughout Section 3.1, the limitations of the impact assessment for air quality are stated, and the data gaps associated with the impact assessments, including for incineration, are summarized in Sections 3.1.4. Ecology will evaluate this comment and augment discussion in the Data Gaps sections, if appropriate. Also please refer to Master Response 3, Development of Alternatives. The selected alternative would require compliance with permits and approvals under local, state, and federal rules for hazardous waste collection, transport, and disposal, including, in the case of Alternative 2, EPA operating permits for incinerators.	ORG-8-1

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		their own right.” (Footnote 28) A “destruction” method that merely converts one PFAS to another or generates toxic PICs does not “reduce] future risks to public health and adverse effects on the environment.” (Footnote 29)		
Sierra Club and Earthjustice (Sonya Lunder)	ORG-8-1-7	The EIS Relies Exclusively on an Industry-Funded Study That Didn’t Examine Harmful Byproducts of Incineration The incineration destruction figure cited by Ecology comes from a single test conducted at Clean Harbors’ Aragonite, Utah incinerator in July 2021. (Footnote 30) This study measured PFAS emissions using EPA Other Test Method 45 (“OTM-45”) for air, which is capable of detecting approximately 50 semi-volatile and polar PFAS, less than 1% of the PFAS class. (Footnote 31) But PFAS incineration is also expected to produce a variety of volatile, nonpolar PFAS, which are not detected by OTM-45. (Footnote 32) Clean Harbors thus cannot say whether its alleged destruction of PFOA and PFOS is actually creating new PFAS that it failed to measure its pilot study. (Footnote 33) Notably, while Washington presents the data on PFAS incineration as clear cut, a PFAS incineration scientist commissioned by Clean Harbors to review its study data raised concerns about the formation of breakdown products and the low recovery of fluorine in the form of hydrofluoric acid. (Footnote 34) The challenges of documenting the ultimate fate of the fluorine molecules released during incineration led the scientist to conclude, “[i]n summary, development of better analysis methods organic and inorganic fluoride are needed to support PFAS-performance testing at the full scale.” (Footnote 35) EPA recently released a new draft test method for air, OTM-50, which will capture up to 30 highly volatile, nonpolar PFAS, the very type of breakdown products expected to be produced by PFAS incineration. This method will allow future experimental and observational studies to more fully report products of incomplete combustion of PFAS	Ecology appreciates the time and attention that the commenter committed to reviewing the draft EIS and for expressing their thoughts in support or opposition to the proposed program. The comment focuses on byproducts of PFAS incineration. Throughout Section 3.1, the limitations of the impact assessment for air quality are stated, and the data gaps associated with the impact assessments, including for incineration, are summarized in Sections 3.1.4. Chapter 2 Project Description and Alternatives includes descriptions of treatment and disposal facilities, required permits and legal authority for each alternative evaluated in the draft EIS. Ecology will evaluate this comment and augment discussion in the Data Gaps sections, if appropriate. Ecology is aware of the new test method, released after the draft EIS publication. Ecology will incorporate information about the new test method in the final EIS. Also please refer to Master Response 3, Development of Alternatives. The selected alternative would require compliance with permits and approvals under local, state, and federal rules for hazardous waste collection, transport, and disposal, including, in the case of Alternative 2, EPA operating permits for incinerators.	ORG-8-1

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		materials. (Footnote 36) But it was not used by Clean Harbors or in any of the studies referenced in the DEIS, precluding a full assessment of the effectiveness and impacts of PFAS incineration.		
Sierra Club and Earthjustice (Sonya Lunder)	ORG-8-1-8	A Recent Study by EPA Scientists Confirms the Potential Generation of PFAS and Toxic Byproducts During PFAS Incineration In July 2023, a publication by EPA scientists ("Shields et al.") reviewed the safety and efficacy of PFAS incineration in a trial study at EPA's Rainbow research combustor. (Footnote 37) This study also used EPA method OTM-45 to measure the destruction of PFAS from AFFF compounds, while using but nontarget analysis of OTM-45 cannisters to identify about 10 fluorochemicals as breakdown products. These include fluoroform, pentafluoroethane, 1H-hepafluoropropane, and 1H perflouroheptane, which are greenhouse gases with long residency times in the atmosphere. Of particular importance was the observation that PFAS breakdown and byproduct formation is highly temperature dependent, with notable performance declines below experimental temperatures of 1000° C. At 970° C less than 99.99% of two shorter chain PFAS chemicals (PFBA and PFPeA) were destroyed. At 870° C cannisters included at least 15 measurable breakdown products at concentrations ranging from 0.4 to 903 mg/m3. The authors conclude: "These results suggest that [destruction efficiency] alone may not be the best indication of total PFAS destruction, and additional PIC characterization may be warranted." (Footnote 38) The Shields study also focused on steady-state combustor operations, noting that the realworld operating conditions of a hazardous waste incinerator will inevitably include temporary disruptions to oxygen and temperature depressions. (Footnote 39) The authors state the "time dependent behavior of PFAS in [hazardous waste	Ecology appreciates the time and attention that the commenter committed to reviewing the draft EIS and for expressing their thoughts in support or opposition to the proposed program. Ecology will continue to review the comments and use them to inform future decisions as appropriate. The cited reference was published while Ecology was finalizing the draft EIS. Ecology will review the cited reference and add discussion into the final EIS, if appropriate.	ORG-8-1

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		incinerators] and other batch fed systems will depend on the system's ability to smooth these transients and maintain high temperatures," concluding, "[m]ore research into rotary kiln systems and full-scale incinerators is needed." (Footnote 40) Multiple studies have detected elevated PFAS concentrations in the vicinity of operating incinerators or thermal oxidizers designed to destroy gaseous PFAS waste, raising further concerns about the impacts of PFAS incineration. (Footnote 41) Ecology failed to consider those studies or address those potential impacts in its DEIS.		
Sierra Club and Earthjustice (Sonya Lunder)	ORG-8-1-9	Thermal breakdown is dependent on proper residency time, temperature and turbulence inside the incinerator chamber. But neither Shields nor Clean Harbors tested incinerators during their real world, commercial operations. Instead, those tests were conducted under carefully controlled conditions [...] Notably, both of the Clean Harbors incinerators referenced in the EIS – in Aragonite, Utah and Kimball, Nebraska – have already received and incinerated large volumes of AFFF and other PFAS-containing waste, but they did not measure their releases of PFAS during those operations. (Footnote 42)	Ecology appreciates the time and attention that the commenter committed to reviewing the draft EIS and for expressing their thoughts in support or opposition to the proposed program. The comment focuses on the incinerator operating conditions needed to destroy PFAS and questions whether the results of PFAS incineration testing are representative of typical operating conditions. If Ecology selects incineration as the disposal method, we will require as part of any work order the following condition: Segregation and metering of collected PFAS foam into the incinerator while it operates at maximum operating temperatures. Throughout Sections 3.1 and 3.2, the limitations of the impact assessment for air quality, including incineration, are stated. The data gaps associated with the impact assessments are summarized in Sections 3.1.4 and 3.2.6 of the draft EIS. Ecology will evaluate this comment and augment discussion in the Data Gaps sections, if appropriate. Also please refer to Master Response 3, Development of Alternatives. The selected alternative would require compliance with permits and approvals under local, state, and federal rules for hazardous waste	ORG-8-1

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			collection, transport, and disposal, including, in the case of Alternative 2, EPA operating permits for incinerators.	
Sierra Club and Earthjustice (Sonya Lunder)	ORG-8-1-10	Ecology states that hazardous waste incinerators have administrative controls like permit conditions, operating and maintenance procedure and trained personnel to ensure incineration happens under carefully controlled conditions. (Footnote 43) In reality, however, incinerators like Clean Harbors' Aragonite facility routinely violate permit requirements. The Aragonite facility has a long history of environmental non-compliance, including "incinerating mercury-containing wastes that are prohibited from incineration," "incinerating lead-containing wastes that are prohibited from incineration," "failing to properly categorize wastes and/or document the categorization of wastes," "failing to calibrate monitoring instruments," and dozens of other violations. (Footnote 44) The other Clean Harbors incinerator considered by Ecology, in Kimball, Nebraska, has a similarly checkered compliance history, as documented in the accompanying analysis of several hazardous waste incinerators' environmental violations. (Footnote 45) In 2020, EPA and Clean Harbors reached a settlement agreement resolving alleged violations related to emissions limits and reporting, including "failure to manage and contain hazardous wastes; failure to comply with air emission limits; failure to comply with chemical accident prevention safety requirements; and failure to timely report use of certain toxic chemicals. (Footnote 46) Our analysis of publicly available records also indicated the facility had at least 105 total violations of emission limits, operating permit limit ("OPLs"), or other permit terms. (Footnote 47) The facility reported at least 57 instances where it exceeded the emissions standard for total hydrocarbon content	Ecology appreciates the time and attention that the commenter committed to reviewing the draft EIS and for expressing their thoughts in support or opposition to the proposed program. Ecology will continue to review the comments and use them to inform future decisions as appropriate.	ORG-8-1

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		("THC"). (Footnote 48) Of these, two were expressly linked in the facility's reports to problems maintaining adequate minimum temperature for the combustor. (Footnote 49) There was one additional reported violation during this span where the facility violated its minimum temperature requirement. (Footnote 50) The facility also documented ten exceedances of the particulate matter standard. (Footnote 51) Those reports may actually underrepresent the facility's compliance problems. A separate report related to leak-detection also included reporting of startup/shutdown events, revealing incidents that are not reflected in the list of OPL and emission limit violations reported for 2019. [...] EPA has characterized the Kimball, NE incinerator as a "significant noncomplier" with the Resource Conservation and Recovery Act ("RCRA") in every quarter since 2021. (Footnote 52)		
Sierra Club and Earthjustice (Sonya Lunder)	ORG-8-1-11	Those violations are not unique to Clean Harbors; other hazardous waste incinerators have similar number and types of permit violations, including explosions and major malfunctions. (Footnote 53) It is common for air permits to exempt pollutant limits during periods of Startup, Shut-down, and Malfunction ("SSM" events. (Footnote 54) Given the gaps in the available test data, the potential releases of PFAS and other toxic byproducts from hazardous waste incinerators, and the long history of permit violations by Clean Harbors and others, Ecology cannot reasonably conclude that PFAS incineration presents "minimal" impacts on public health and the environment.	Ecology appreciates the time and attention that the commenter committed to reviewing the draft EIS and for expressing their thoughts in support or opposition to the proposed program. Regarding data gaps: Throughout Sections 3.1 and 3.2, the limitations of the impact assessment for air quality, including incineration, are stated, and the data gaps associated with the impact assessments are summarized in Section 3.1.4. Regarding Ecology's conclusion that incineration presents a low risk of a significant impact on air resources: We clarify that this specifically regards Washington State's 59,000 gallons of AFFF stockpiles, as detailed in Section 3.1.3.2. Ecology acknowledges the data gaps associated with PFAS incineration.	ORG-8-1
Sierra Club and Earthjustice	ORG-8-1-12	Ecology Overlooks Significant Environmental and Health Risks Associated With Landfill Disposal of PFAS Ecology also understates the impacts associated with the	Ecology appreciates the time and attention that the commenter committed to reviewing the draft EIS and for expressing their thoughts in support or	ORG-8-1

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(Sonya Lunder)		disposal of AFFF at hazardous waste landfills in Idaho and Nevada. Without considering the latest research on potential PFAS releases from landfills, Ecology asserts that “[t]he risk of PFAS release [from landfills] is very low” and “[t]he consequences [of such releases] would be insignificant.”(Footnote 55) These conclusions are not supported by the record. Due to their volatility and mobility in water, substantial volumes of PFAS are projected to be lost from landfills each year. A recent review paper authored by EPA scientists (“Tolaymat et al”) estimated that 1,233 kg of landfills are released annually via leachate and landfill gas, or approximately 15 percent of the quantity of PFAS shipped to U.S. landfills on a given year. (Footnote 56) More than 130 kg of those PFAS releases are projected to be uncontained and released directly to environment. (Footnote 57) While Ecology has considered solidifying AFFF before sending it to a hazardous waste landfill, evidence suggests that PFAS solidification doesn’t fully immobilize the chemicals. One study reports that the “[o]verall immobilization of PFAS analytes that were detectable in the leachate from two PFAS contaminated soils ranged from 87.1% to 99.9%”(Footnote 58) Ecology must evaluate the possibility that some PFAS escape from the solidified AFFF and enter the air, soil, or groundwater.	opposition to the proposed program. Ecology notes that the Tolaymat study focuses on municipal solid waste landfills (Subtitle D), whereas the draft EIS is only considering hazardous waste landfills (Subtitle C). Ecology will review recent studies on PFAS in landfill gas and incorporate information into the final EIS, if appropriate. Ecology will also review recent data regarding PFAS solidification effectiveness, although we note that both the Idaho and Nevada hazardous waste landfills are zero-discharge facilities.	

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Sierra Club and Earthjustice (Sonya Lunder)	ORG-8-1-13	But studies have estimated a significant amount of uncaptured PFAS leachate, and landfills often fail to destroy or permanently contain the PFAS in the leachate that they do capture. PFAS are commonly detected in landfill leachate, across many different geographic locations and landfill types. One paper in particular measured PFAS in leachate from a landfill housing only municipal solid waste incinerator ash. The ash was residues of materials that were burned at 950° C, yet the landfill leachate contained more than 2000 ng/L of PFAS. (Footnote 61) This indicates both that notable amounts of PFAS remained after incineration and were soluble in landfill liquids. PFAS also leach from hazardous waste landfills. An analysis of 29 leachate samples from two California hazardous waste landfills measured average PFAS concentrations of 68,000 ng/L, with a maximum measured value of 377,000 ng/L. (Footnote 62) Given this evidence that PFAS will leach from even solidified AFFF waste, Washington must more carefully consider the management and fate of leachate generated from any landfill accepting PFAS waste. […] We are only aware of one instance in which a landfill is exploring the use of on-site advanced destruction technology to destroy PFAS in leachate liquids (Footnote 64). Ecology did not consider that leachate treatment option in the DEIS.	Ecology appreciates the time and attention that the commenter committed to reviewing the draft EIS and for expressing their thoughts in support or opposition to the proposed program. Ecology will review leachate management practices at the hazardous waste landfills under consideration and add discussion to the final EIS, if appropriate. Because we are considering only zero-discharge hazardous waste landfills, we will not include data or discussion of the risks associated with municipal waste landfills or non-zero-discharge hazardous waste landfills.	ORG-8-1

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Sierra Club and Earthjustice (Sonya Lunder)	ORG-8-1-14	The DEIS also failed to adequately account for landfills' potential releases of PFAS to the air. The DEIS describes the possibility of PFAS volatilizing from solidified AFFF as "very low." (Footnote 65) However, data on the failure rate for PFAS solidification should be also considered in context of new information about PFAS volatilization from landfills. The recent Tolaymat landfill review paper estimated that about 470 kg of PFAS per year up volatilizes into air annually from U.S. landfills. (Footnote 66) The amount of landfill gas generation depends on the amount of moisture and microbial activity in the landfill. Injecting landfill leachate back into the landfill for circulation would increase both the PFAS and the moisture content of the landfill. About three quarters of the landfill gas is captured or collected each year, with approximately 25% released to the air as fugitive emissions. (Footnote 67) For the gas that is captured, even when landfills are equipped with flares to burn landfill gas the flare temperatures of 650-850° C are lower than the temperatures that would be expected to destroy gaseous PFAS. Instead of assuming "low" releases from the volatilization of PFAS from landfills, Ecology must consider the latest research and estimate the potential for air releases over the centuries that landfilled AFFF would remain on site. Moreover, since EPA is still years away from regulating any PFAS as hazardous waste, Ecology cannot assume that existing landfill permits and federal regulations will be sufficient to prevent significant adverse impacts from PFAS in leachate or landfill gas.	Ecology appreciates the time and attention that the commenter committed to reviewing the draft EIS and for expressing their thoughts in support or opposition to the proposed program. Ecology notes that the Tolaymat study focuses on municipal solid waste landfills (Subtitle D), whereas the draft EIS is only considering hazardous waste landfills (Subtitle C). Ecology will review recent studies on PFAS in landfill gas and incorporate information into the final EIS, if appropriate, although we note that both the Idaho and Nevada hazardous waste landfills are zero-discharge facilities. Ecology recognizes that EPA has not designated any PFAS as hazardous waste, and that regulations may change in the future, as discussed in the Executive Summary. This is covered under Alternative 1, Approved Hold in Place, in which Ecology would wait on a final disposal decision until new technologies are developed or EPA provides guidance on disposal that would minimize long-term environmental risk.	ORG-8-1
Sierra Club and Earthjustice (Sonya Lunder)	ORG-8-1-15	The DEIS also understates the environmental justice impacts associated with PFAS incineration and landfilling, asserting that the risks associated with those disposal options are "low to insignificant." (Footnote 68) But Ecology underestimates both the likelihood of PFAS	Thank you for your comment. We have revised the environmental justice analysis for the final EIS. An additional sensitivity analysis was conducted to determine the best evaluation criteria to identify low-income populations and communities of color,	ORG-8-1

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		releases from those disposal options and the impacts of such releases on environmental justice communities who already bear a disproportionate burden of existing PFAS contamination. As Ecology acknowledges, “[t]he first step in an EJ assessment is to identify the study area.” (Footnote 69) The DEIS defines the study area too narrowly, focusing solely on effects within a 10-mile radius of AFFF storage locations or potential disposal sites. (Footnote 70) While that approach may be appropriate for pollutants with primarily localized impacts, it fails to capture the sweep of highly mobile and persistent chemicals like PFAS. [...] The communities that face the greatest risks from PFAS releases are not merely those nearest to the release site, but also those who are already exposed to PFAS contamination and are more susceptible to harm from further exposures. As with many toxic pollutants, PFAS disproportionately harm lower income communities and communities of color. Low income households are 15 percent more likely to live around PFAS-contaminated sites than would be expected based on their share of the population, and African American households are 48 percent more likely to live around PFAS-contaminated sites than would be expected. (Footnote 72) Another study found that “watersheds serving higher proportions of Hispanic/Latino and non-Hispanic Black populations had significantly greater odds of containing PFAS sources.” (Footnote 73) These inequities must be considered in Ecology’s environmental justice analysis, since people who already have elevated levels of PFAS in their bodies are more likely be harmed by any additional releases from Ecology’s AFFF disposal. Ecology’s finding that there are no “communities of concern” within a 10-mile radius of its proposed landfills or incinerators does not mean that the proposed PFAS disposal will have no significant environmental justice	rooted in Promising Practices for EJ Methodologies in NEPA Reviews by the U.S. EPA. Additionally, because the different technologies presented as disposal options in this EIS (landfilling, deep well-injection, incineration, etc.) have different release mechanisms and routes of exposure, the study area for each alternative is determined according to best practices and available data. Due to the mobile nature of air pollution, the study area for incineration options is 10 miles, whereas the study area for the other options is 0.25 miles. While we acknowledge that PFAS exposure and air pollution is a global phenomenon and can potentially travel great distances and cumulatively impact communities, the scope of this analysis is limited to areas of potential impacts for the proposed alternatives. We considered the potential for cumulative impacts for communities within the study areas. See Chapter 5 of the final EIS for an updated cumulative impacts analysis. Establishing the study area at 10 miles maximizes identifying potential disproportionate impacts to low-income populations and communities of color in proximity to the source and therefore most at risk, without diluting the data with a much larger radius. Also see Appendix A.8 of the final EIS for more information.	

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		impacts. (Footnote 74) It just means that Ecology has drawn its study radius too narrowly.		
Sierra Club and Earthjustice (Sonya Lunder)	ORG-8-1-16	Washington Ecology's EIS rigidly focused on three traditional methods of hazardous waste disposal, ignoring promising innovations that could be much safer and more effective than incineration, landfilling and deep well injection. [...] Advocates have long called for more equitable practices for hazardous waste disposal, to ensure the PFAS pollution crisis isn't simply shifted from one community to another. (Footnote 77) Several key principles are: (1) The need for tools that can be used onsite, obviating the need to transport waste long distances and keeping the hazardous waste impacts from being concentrated in historically burdened communities; (2) The need to treat waste in contained systems, which can ensure destruction is complete before wastes are released to the environment. (3) The need for a very high level of waste destruction efficiency with minimal formation of harmful byproducts.	In the absence of tools currently available that allow safe disposal of AFFF on site, the only on-site option explored was hold in place at firefighting stations. Ecology also analyzed the potential impacts to low-income populations and communities of color for all of the disposal options. We acknowledge the need for more equitable disposal practices that ensure PFAS does not continue to contribute to disproportionately and harmful environmental exposures and health disparities. More research is needed to explore and understand disposal innovations that are equitable and reliable. Environmental justice concerns, specifically the proximity of disposal locations to low-income populations and communities of color, and potential impacts arising from that proximity, are considered in the environmental justice portions of the final EIS, Section 3.11, and Appendix A.8: Environmental Justice Report. Ecology continues to review and research potential new innovations. However, until they are proven viable, we can only consider the current alternatives. If new technologies become available, Ecology would expand the environmental justice analysis to determine if there would be potential impacts to nearby communities.	ORG-8-1

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Sierra Club and Earthjustice (Sonya Lunder)	ORG-8-1-17	Two particular destruction technologies hold promise for achieving the key principles for equitable waste destruction. EPA scientists published a test of three commercial services using Super Critical Water Oxidation for AFFF destruction in 2022. It concluded, “as a destructive technology, SCWO may be an alternative to incineration.” (Footnote 78) SCWO is currently being used to treat PFAS in Michigan, (Footnote 79) and it has been used to destroy other persistent wastes, including chemical weapons, for decades. A second treatment option, Hydrothermal Alkaline Treatment or HALT, has also been used to destroy PFAS in AFFF, with notable reduction of measurable PFAS compounds. (Footnote 80)	For this draft EIS, Ecology reviewed the current literature on SCWO and other emerging destruction technologies. We believe these emerging technologies have promise. However, under Washington State Dangerous Waste Regulations (Chapter 173-303 WAC), PFAS-containing foam likely designates as a persistent state-only dangerous waste and must be disposed of at a RCRA-permitted treatment, storage, and disposal facility. Currently, there are no RCRA permitted facilities that implement SCWO or HALT technologies. State regulations permit the disposal of state-only dangerous waste at non-TSDs, if the Department of Ecology receives written permission from the receiving state. Ecology reached out in 2022 to Michigan where SCWO was being employed and was denied that permission. Because of this, Ecology dropped SCWO as a separately listed alternative. Please also see Master Response 6 for a discussion of other alternatives considered and eliminated. Ecology appreciates the time and attention that the commenter committed to reviewing the draft EIS and for expressing their thoughts in support or opposition to the proposed program.	ORG-8-1

Commenter	Comment Code	Comment	Ecology Response	Attachment 1 Commenter Reference ID
Sierra Club and Earthjustice (Sonya Lunder)	ORG-8-1-18	That alleged “uncertainty” is not a valid reason for rejecting those alternatives, particularly if they are capable of destroying PFAS with lower environmental and health impacts than traditional disposal options. First, as explained above, technologies like SCWO are readily “available” and have shown promise in treating AFFF. In one place, the DEIS references the potential use of a SCWO treatment facility in Grand Rapids, MI, but Ecology fails to explain why that option was not further pursued. (Footnote 82)	Ecology acknowledges that SCWO is an existing technology that has promise to destroy PFAS molecules. As with other emerging destruction technologies, there are data gaps in Ecology’s understanding of these technologies’ effectiveness at destroying the PFAS molecule. In addition, during draft EIS development, a separate alternative considering SCWO technology was eliminated for several reasons. Under Washington State Dangerous Waste Regulations, PFAS-containing foam must be disposed of at a RCRA-permitted treatment, storage, and disposal facility (TSD). Currently, there are no SCWO facilities at a TSD. However, state regulations permit the disposal of state-only dangerous waste at non-TSDs, if Ecology receives written permission from the receiving state. When the draft EIS was under development, there was a single SCWO facility treating AFFF. That was the Revive facility at Wyoming, Michigan. Michigan’s Department of Environment, Great Lakes, and Energy (EGLE) declined to grant Washington State permission to treat collected AFFF at the Wyoming facility. Without a facility to analyze, Ecology eliminated SCWO from further consideration. Please also see Master Response 6 for a discussion of other alternatives considered and eliminated.	ORG-8-1

Commenter	Comment Code	Comment	Ecology Response	Attachment 1 Commenter Reference ID
Sierra Club and Earthjustice (Sonya Lunder)	ORG-8-1-19	Nor does the alleged "uncertainty of acquiring the receiving state's approval" justify Ecology's failure to consider advanced treatment technologies. (Footnote 83) First, under state law, receiving state approval is not required if dangerous waste is sent to treatment facility that "is operating either: [u]nder a permit issued pursuant to the requirements of this chapter; or, if the TSD facility is located outside of this state, under interim status or a permit issued by United States EPA under 40 C.F.R. Part 270, or under interim status or a permit issued by another state which has been authorized by United States EPA pursuant to 40 C.F.R. Part 271." (Footnote 84) The DEIS fails to examine whether any advanced treatment technologies could be employed at any facilities that would not require out-of-state authorization. The DEIS also does not state whether Ecology has affirmatively sought authorization from all states with advanced treatment capacity, and what those states' responses have been. If Ecology has done so, it must describe those efforts in greater detail in the final EIS. If Ecology has not, it cannot reject treatment technologies based on its speculation over how other states may respond. (Footnote 85)	Under Washington State Dangerous Waste Regulations, PFAS-containing foam must be disposed of at a RCRA-permitted treatment, storage, and disposal facility (TSD). Currently, there are no SCWO or other emerging technology facilities at a TSD. However, state regulations permit the disposal of state-only dangerous waste at non-TSDs, if the Department of Ecology receives written permission from the receiving state. When the draft EIS was under development, there was only one SCWO facility that could take Ecology's collected AFFF. That was a Revive facility at Wyoming, Michigan. Ecology received notice from Michigan's Environment, Great Lakes, and Energy Department that the state would not grant Washington State permission to treat collected AFFF in Michigan.	ORG-8-1
Sierra Club and Earthjustice (Sonya Lunder)	ORG-8-1-20	Finally, during a public webinar on the DEIS, Ecology referenced questions over whether other Washington state regulations governing the storage and disposal of "dangerous wastes," including PFAS, may preclude the use of SCWO and other emerging treatment technologies. The DEIS does not specify the nature of those concerns, leaving the public unable to evaluate and respond to them. However, we note that Ecology's dangerous waste regulations permit "treatability studies" to determine "whether the waste is amenable to the treatment process; what pretreatment (if any) is required; the optimal process conditions needed to achieve the desired treatment; the efficiency of a treatment process for a specific waste or	The Washington State Dangerous Waste Rules impose strict limits on the quantity of waste that can be accumulated and the duration it can be stored on site. Under the Approved Hold in Place alternative, PFAS-containing foam would be required to be stored indefinitely at participating fire departments until emerging destruction technologies such as SCWO are deemed suitable. During the period in which Ecology assesses the feasibility of this technology, fire departments must handle the foam as a product. Failure to treat the stored foam as a product would classify it as waste, triggering accumulation restrictions and disposal deadlines.	ORG-8-1

Commenter	Comment Code	Comment	Ecology Response	Attachment 1 Commenter Reference ID
		wastes; or the characteristics and volumes of residuals from a particular treatment process." (Footnote 86) At a minimum, we urge Ecology to consider the use of some or all of the collected AFFF in a treatability study to evaluate advanced PFAS treatment technologies and inform future disposal decisions.	These limitations could disqualify a location from further consideration under the Approved Hold in Place alternative by terminating its ability to store the foam indefinitely. Furthermore, Ecology is collaborating with Aquagga on an R&D permit that would permit the company to treat PFAS waste at its Tacoma facility. This permit is currently in progress and is anticipated to take approximately a year to finalize.	
Sierra Club and Earthjustice (Sonya Lunder)	ORG-8-1-21	Finally, we urge Ecology to consider temporary, off-site storage at a permitted hazardous waste storage facility as a disposal option. The U.S. Environmental Protection Agency and other agencies are currently pursuing a series of short-term and medium term research and development initiatives related to PFAS disposal, which are intended to enable decision-makers "to make informed decisions about the tradeoffs between different risk management solutions, leading to better environmental outcomes." (Footnote 87) Interim off-site storage would enable Ecology to consider the results of this pending research and to make a more informed choice among disposal options. Moreover, the hazardous waste incinerator that Ecology identified as a potential recipient of the state's AFFF (Clean Harbors' Aragonite facility) is also permitted to store PFAS and hazardous waste. By Clean Harbors' own account, that facility has "ample on-site storage capacity," including "a bulk liquid tank farm (sixteen ~30,000 gallon tanks); container storage areas (~12,000 55-gallon drum capacity); direct burn tanker storage areas (~30,000 gallons total capacity); sludge storage tanks (~38,000 gallon total capacity); and bulk solids storage tanks (~1100 yd3 total capacity)." (Footnote 88) Moreover, while state regulations require hazardous waste generators to ship dangerous waste off-site within 90 days, they do not foreclose the use of safe off-state (and out-of-state)	The Washington State Dangerous Waste Rules impose strict limits on the quantity of waste that can be accumulated and the duration it can be stored on site. Under the Approved Hold in Place alternative, PFAS-containing foam would be required to be stored indefinitely at participating fire departments until emerging destruction technologies such as SCWO are deemed suitable. During the period in which Ecology assesses the feasibility of this technology, fire departments must handle the foam as a product. Failure to treat the stored foam as a product could classify it as waste, triggering accumulation restrictions and disposal deadlines. These limitations could disqualify a location from further consideration under the Approved Hold in Place alternative by terminating its ability to store the foam indefinitely. Furthermore, Ecology is collaborating with Aquagga on a one-year authorization permitting the company to test its treatment of PFAS waste at its Tacoma facility. This permit is currently in progress and is anticipated to take approximately a year to finalize.	ORG-8-1

Commenter	Comment Code	Comment	Ecology Response	Attachment 1 Commenter Reference ID
		disposal pending the results of testing that may identify a safer permanent disposal option.		
Geosyntec Consultants, Inc. (Vanessa Maldonado)	ORG-9-1-2	Also, Alternative 1 is not legally supported for large quantity generators (LQGs). If Alternative 1 is selected, a policy change to allow LQGs to hold AFFF in place would be required. How will the Department of Ecology address this issue? What is the strategy to overcome this challenge?	Thank you for your comment. Please see Master Response 2 regarding the regulatory framework for dangerous waste in Washington State.	ORG-9-1
Geosyntec Consultants, Inc. (Vanessa Maldonado)	ORG-9-1-3	Subsection 2.2.2: Alternative 2 Incineration, page 2-21 Although incineration has shown to destroy 99.9999% of legacy PFAS, the incineration of PFAS requires reaching a temperature of approximately 1100 °C. If the required temperature is not met, multiple PFAS can be converted to other PFAS at lower temperatures, resulting in high destruction efficiencies (e.g., 99.9999%) without full mineralization and the potential release of the remaining fluorocarbon portions to the environment. Further, although working temperatures below 1000 °C produce high destruction efficiencies for quantifiable PFAS, several nonpolar PFAS are emitted as products of incomplete combustion (Shields et al., 2023). Thus, the destruction efficiency alone is not the best indicator of total PFAS destruction. With this preamble, the following should be clarified in the DEIS: 1. How is the complete destruction of PFAS warranted with incineration without relying on the destruction efficiency? 2. How will the required operating conditions (e.g., temperature of at least 1100 °C) in approved incineration facilities be warranted and proven to comply? 3. How are the potential emissions of PFAS byproducts (e.g., products of incomplete combustion) going to be captured and monitored? What is the strategy to control air emissions in approved facilities? EPA's OTM-50 sampling technique for quantification of volatile fluorinated compounds is now available. The combination of OTM-50	Ecology appreciates the time and attention that Geosyntec committed to reviewing the draft EIS. Ecology acknowledges your comments regarding the reliance on the destruction efficiency of PFAS by incineration, formation and sampling of products of incomplete combustion, and the disposal facilities' ability to meet the necessary operating conditions for PFAS destruction. Ecology will take a close look and incorporate updates within the final EIS, if appropriate. We will also look to clarify the questions you listed above, specifically within the data gap discussion. Please also refer to Master Response 3, Development of Alternatives. The selected alternative would require compliance with permits and approvals under local, state, and federal rules for hazardous waste collection, transport, and disposal, including, in the case of Alternative 2, EPA operating permits for incinerators.	ORG-9-1

Commenter	Comment Code	Comment	Ecology Response	Attachment 1 Commenter Reference ID
		and OTM-45 would provide a more complete analysis of the potential PFAS in emission byproducts. The DEIS should clarify the intent to monitor/control these air byproducts if this Alternative 2 is selected. 4. If Alternative 2 is selected, does Ecology intend to cover 100% of the costs for incinerating thousands of gallons of AFFF? How is the cost feasibility considered?		
Geosyntec Consultants, Inc. (Vanessa Maldonado)	ORG-9-1-4	Subsection 2.2.3: Alternative 3 Solidification and Landfilling, page 2-22 Solidification and landfilling should not be considered as an alternative for AFFF foam disposal/treatment for the following reasons: 1. There is currently little to no research investigating the rates at which PFAS may leach from concrete into surrounding environmental matrices (Douglas et al., 2023) and potentially impact the receiving landfill(s). 2. Leachability studies have shown the presence of multiple PFAS (e.g., 6:2 FTS, PFBA, PFPeA) in the leachate that results from solidification/stabilization (Sörengård et al., 2019).We understand that generated leachate could be collected, treated, and disposed of in alandfill, however, as of today there are no treatment technologies that have been demonstrated to fully destroy PFAS in such complex matrix as landfill leachates (Berg etal, 2022). 3. It has been shown that the stabilization efficiency depends on the PFAS chain length, and it is less effective for perfluorocarboxylates (e.g., PFOA) and short-chain PFAS (Sörengårdet al., 2019). 4. Stabilization/solidification studies have been conducted and even field-tested to treat soiland sediments with carbon-based amendments. While this stabilization/solidification hasbeen employed to treat soils, sediments, and liquid waste (e.g., groundwater with low PFASconcentrations) containing a variety of chemical pollutants, the process applied to AFFF mixtures (liquid	Ecology appreciates the time and attention that the commenter committed to reviewing the draft EIS and for expressing their thoughts in support or opposition to the proposed program. Ecology will continue to review the comments and use them to inform future decisions as appropriate.	ORG-9-1

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		matrices with high concentrations of PFAS, [e.g., 3% PFOS]) has not been evaluated. The applicability of a technology does not necessarily translate between matrices and concentration ranges. Further research is necessary to prove the solidification/stabilization of PFAS would be feasible to stabilize pure AFFF foams. 5. The description of this alternative does not consider the real and negative implications of landfilling PFAS even if solidified in a neutral matrix such as concrete. Leachates containing landfill leachates emit volatile PFAS (e.g., 6:2 FTOH) which have negative environmental impacts. Thus, landfilling solidified PFAS is not just a leachate issue. The potential for emitting volatile PFAS should be included in the draft EIS and should be considered as a high-risk factor for the selection of such an alternative. 6. Although this alternative captures a high percentage of PFAS, it transfers part of the problem (PFAS) from one place to another. It does not seem to be solving it since notdestructive and could create additional problems (e.g., volatilization, leaching).		
Geosyntec Consultants, Inc. (Vanessa Maldonado)	ORG-9-1-5	Subsection 2.2.4: Alternative 4 Deep Well Injection, page 2-23 Although this is a relatively simple alternative, the potential for future groundwater contamination should be considered in this alternative evaluation, including future migration of PFAS from the depth injected to other aquifers. Although the selected locations for deep well injection are remote and planned beneath current drinking water aquifers, there is always a potential for migration and eventual contamination of other aquifers. Deeper aquifers are becoming more important for future water supplies in the face of climate change and the depletion of aquifers. Potential risks such as the risk of seismic effects from injection also should be accounted for and considered in the alternative description and selection.	Thank you for your comment. Release mechanisms and risk of release under Alternative 4 are discussed in Section 3.3.4.6.	ORG-9-1

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Geosyntec Consultants, Inc. (Vanessa Maldonado)	ORG-9-1-6	Although airports, military sites, and industrial sites are not within the scope of the EIS, will the collection and disposal program be limited to municipal fire departments or expanded to more participants with AFFF inventory (e.g., airports) once approved?	Thank you for your comment. Currently, the AFFF disposal program is limited to the state's municipal fire departments, fire districts, fire authorities, port authority fire departments, and fire training facilities. Ecology's outreach to these entities identified at least 59,000 gallons for disposal. Federal law requires certain airports to have AFFF on site. From conversation with Washington's 11 commercial airports subject to federal law, Ecology estimates there is an equal if not greater amount of AFFF stored at these airports. The draft EIS investigates the environmental and public health impacts associated with the collection, transport, and disposal of the fire departments' foam stockpiles. If the disposal of this foam is successful, Ecology may consider expanding the program to facilities such as airports.	ORG-9-1
Geosyntec Consultants, Inc. (Vanessa Maldonado)	ORG-9-1-7	Will Ecology accept rinse water from municipal fire departments who are cleaning their systems when transitioning for fluorine free products? If not, how should this be disposed of?	Thank you for your comment. When Ecology selects an alternative, details of the implementation will be developed and communicated to participating fire departments. Ecology also developed best management practices[24] for fire departments and others to use when cleaning fire engines and other apparatus contaminated with PFAS containing foam. This guidance provides recommendations on the cleaning and/or replacing of contaminated equipment. The guidance contains expectations for handling and disposing of the cleaning rinsate. Currently, Ecology is not accepting this rinsate under the AFFF disposal program.	ORG-9-1

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[24] https://apps.ecology.wa.gov/publications/SummaryPages/2404042.html

Commenter	Comment Code	Comment	Ecology Response	Attachment 1 Commenter Reference ID
Geosyntec Consultants, Inc. (Vanessa Maldonado)	ORG-9-1-8	The potential issues associated with transportation of AFFF (e.g., potential for spills and emissions during the transportation process) should be considered in the selection of the alternatives, as it is for non-vehicle transport (Section 2.2.6.2)	Emissions during truck transportation are evaluated in Section 3.1.2.1, Table 3.1-2. The risk of spills and impacts during transportation is discussed in Section 3.3.4.2, 3.10.2, and 3.10.3. The risk of a significant impact to air quality, earth and water resources, aquatic resources, or terrestrial species and habitats was determined to be low.	ORG-9-1
Geosyntec Consultants, Inc. (Vanessa Maldonado)	ORG-9-1-9	The Alternatives Assessment in Section 2.2 does not appear to address technology costs. It is important to consider the economic feasibility of alternatives due to significant differences. For instance, the cost for incineration of PFAS is significantly higher when compared to any of the other alternatives selected.	Thank you for your comment. As discussed in Master Response 1, Ecology will assist participating fire departments and first responders with collection and disposal of excess AFFF at no cost to them. The SEPA EIS process is a tool for identifying and analyzing probable adverse environmental impacts, reasonable alternatives, and possible mitigation. The lead agency is not required to include all information conceivable relevant to a proposal (WAC 197-11-402). The EIS does not need to include an evaluation of all possible impacts, including economic and other considerations not outlined in the elements of the environment (WAC 197-11-444). A cost-benefit analysis is not required as part of SEPA. Therefore, economic considerations such as disposal costs are not included in this EIS. The EIS, however, is not a decision document and is intended to be used, with other reports and relevant information, to plan actions and make decisions. Other potential project considerations, including cost, will be considered along with the information in the EIS by Ecology before a disposal method is selected. Ecology management will use the EIS to select a disposal option at a later date. At that time, Ecology may be required to take additional action, such as contracting with a hazardous waste hauler, to implement the program. The contract process would be the appropriate place to incorporate economic considerations.	ORG-9-1

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American Chemistry Council (Stephen Risotto)	ORG-10-1-1	The American Chemistry Council (ACC) supports the Department's efforts to collect waste aqueous film forming foam (AFFF) and appreciates its analysis of alternative approaches to disposal of this material. ACC previously supported the Department's 2020 Determination of Non-Significance for its proposal to send the foam to the existing Clean Harbors Incineration Facility in Aragonite, Utah.	Ecology appreciates the time and attention that the commenter committed to reviewing the draft EIS and for expressing their thoughts in support or opposition to the proposed program. Ecology will continue to review the comments and use them to inform future decisions as appropriate.	ORG-10-1
American Chemistry Council (Stephen Risotto)	ORG-10-1-2	As part of the draft Environmental Impact Statement (EIS), the Department has expanded its review to include solidification and landfill and Class 1 deep well injection as disposal options. ACC agrees with the Department's assessment that these two additional disposal options also do not present significant adverse effects on human health and safety or the environment.	Ecology appreciates the time and attention that the commenter committed to reviewing the draft EIS and for expressing their thoughts in support or opposition to the proposed program. Ecology will continue to review the comments and use them to inform future decisions as appropriate.	ORG-10-1
American Chemistry Council (Stephen Risotto)	ORG-10-1-3	Based on its assessment, we encourage the Department to consider all three of these alternatives (incineration, solidification/landfill, deep well injection) as safe and effective approaches to the disposal of waste AFFF. This conclusion is the same reached by the US Department of Defense (DOD) as part of guidance issued in July 2023. (Footnote 1) In its guidance, DOD noted that hazardous waste incinerators, hazardous waste landfills, and solid waste landfills (Footnote 2) are available options "that maximize reduction of PFAS releases or emissions to the environment and human health exposures." (Footnote 3)	Ecology appreciates the time and attention that the commenter committed to reviewing the draft EIS and for expressing their thoughts in support or opposition to the proposed program. Ecology will continue to review the comments and use them to inform future decisions as appropriate.	ORG-10-1
American Chemistry Council (Stephen Risotto)	ORG-10-1-4	ACC is very concerned, however, about the inclusion of "Approved Hold in Place" of AFFF at participating fire stations as an alternative in the Department's assessment. The EIS identifies issues associated with regulations controlling long-term storage of waste and permitting, but does not consider the increased risk of environmental release at numerous locations that such storage presents. While treatment technologies may	Ecology appreciates the time and attention that the commenter committed to reviewing the draft EIS and for expressing their thoughts in support or opposition to the proposed program. Ecology will continue to review the comments and use them to inform future decisions as appropriate.	ORG-10-1

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		continue to advance, it is neither correct nor a clarification to suggest that long-term storage of AFFF waste is an appropriate method for handling PFAS waste when effective methods currently exist. (Footnote 4) We urge the Department to reassess the ranking of long-term storage as an appropriate alternative to handling AFFF waste that runs counter to the intent of solid and hazardous waste regulatory structures and that may encourage stockpiling of material. This could lead to more environmentally detrimental effects than the other alternatives. Additionally, this method increases the cost of materials management due to the required handling and storage cell construction and maintenance for all regulated entities.		
Port Angeles Fire Department	ORG-11-1-1	Disposal Preference: Incineration.	Ecology appreciates the time and attention that the commenter committed to reviewing the draft EIS and for expressing their thoughts in support or opposition to the proposed program. Ecology will continue to review the comments and use them to inform future decisions as appropriate.	ORG-11-1
Port Angeles Fire Department	ORG-11-1-2	We firmly believe that storage on site of individual fire agencies and taking no action are the worst options. This creates small pockets of Hazardous Waste storage at fire stations across the state until an indeterminate future solution is developed. The increased regulatory requirements and permitting may not be possible for all agencies to ensure safe storage.	Ecology appreciates the time and attention that the commenter committed to reviewing the draft EIS and for expressing their thoughts in support or opposition to the proposed program. Ecology will continue to review the comments and use them to inform future decisions as appropriate.	ORG-11-1
Port Angeles Fire Department	ORG-11-1-3	Guidance Needed: We echo the same concerns mentioned in the comment by the Tumwater Fire Department regarding the removal of AFFF stored in our apparatus. Departments will need guidance for the removal of all AFFF from onboard apparatus tank storage, cleaning run-off capture, and disposal of runoff.	Ecology values your participation in Ecology's Product Replacement Program. Please see Master Response 1 for more information about this program, including the anticipated timeframe for launching the program in fall of 2024. Ecology developed best management practices[25] for	ORG-11-1

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[25] https://apps.ecology.wa.gov/publications/SummaryPages/2404042.html

Commenter	Comment Code	Comment	Ecology Response	Attachment 1 Commenter Reference ID
			fire departments and others to use when cleaning fire engines and other apparatus contaminated with PFAS-containing foam. This guidance will provide recommendations on the cleaning and/or replacing of contaminated equipment. The guidance will contain expectations for handling and disposing of the cleaning rinsate.	
Friends of Rocky Top (Scott Cave)	ORG-12-1-1	While the state recognizes the potential threat posed at 'secondary sources' (landfills that received and disposed of AFFF) from AFFF/PFAS contamination of groundwater in this DEIS, it does not include them, and strictly considers AFFF fire service release sites only. Given the AFFF/PFAS threat to groundwater at known secondary sources, Ecology should separately evaluate the benefit of AFFF/PFAS monitoring at secondary sources that would establish baseline data and increase early detection at problem sites.	The draft EIS presents impacts and mitigation measures associated with landfill disposal (Alternative 3) throughout Section 3, Affected Environment and Environmental Consequences. The discussion includes the landfill permit requirements of groundwater monitoring and reporting at each of the landfills being considered by Ecology. Please also refer to Master Response 5, which discusses mitigation measures. Ecology appreciates the time and attention that the commenter committed to reviewing the draft EIS and for expressing their thoughts in support or opposition to the proposed program.	ORG-12-1
Friends of Rocky Top (Scott Cave)	ORG-12-1-2	Between 2004 and 2006, contaminated soils containing elevated concentration levels of AFFF/PFAS were removed from the U.S. Army, Department of Defense, Yakima Training Center (YTC) near Selah and remediated and disposed at the Anderson PCS site and landfill on Rocky Top, Yakima County, respectively. [...] But what about the people and communities near unlined 'secondary sources' that are known to have received and disposed of AFFF/PFAS materials and contamination soils? As noted by in the above Ecology quote, the contaminated AFFF/PFAS soils approved for remediation and disposal at Rocky Top contained "elevated concentrations". Today,	The comments present environmental concerns that are unrelated to this draft EIS. Please see Master Response 1: Overview of Ecology's Product Replacement Program and Fire Department Participation, which describes the scope of this draft EIS as helping fire departments and other first responders in Washington collect, remove, and dispose of stockpiles of AFFF. For more information, please visit Ecology's PFAS webpage.[26] Ecology appreciates the time and attention that the commenter committed to reviewing the draft EIS and for expressing their thoughts in support or opposition to the proposed program.	ORG-12-1

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[26] ecology.wa.gov/pfas

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		EPA considers even minimal exposure of AFFF/PFAS harmful to human health, and the elevated concentration levels in the soils remediated and disposed on Rocky Top would be considered hazardous today, requiring site controls for containment, handling and transfer, and disposal at a Subtitle C facility (out of state). The two unlined facilities have not historically monitored for PFAS. The landfill (3 wells) was required to add PFAS to future quarterly monitoring. For years, Ecology and the YHD have requested DTG to drill additional monitoring wells to update site characterization, and establish a compliant groundwater monitoring system, which is the drinking water source for neighbors. DTG has informed regulators of its intention to drill wells in 2024. Neighbor concerns about the lack of groundwater monitoring and determination of contamination flowpaths is exasperated by the threat posed by 'forever chemicals' in the liner of the landfill and PCS site.		
Friends of Rocky Top (Scott Cave)	ORG-12-1-3	In September, 2022, Ecology determined a portion of the landfill a MTCA site and has signed an Agreed Order with DTG to investigate the area, identify workplans and implement remedies. However, Ecology paused the investigation pending completion of the emergency effort to remediate landfill fires. The MTCA investigation should include the AFFF/PFAS soil layer in Cell 1.	The comments present environmental concerns that are unrelated to this draft EIS. Please see Master Response 1: Overview of Ecology's Product Replacement Program and Fire Department Participation, which describes the scope of this draft EIS as helping fire departments and other first responders in Washington collect, remove, and dispose of stockpiles of AFFF. For more information, please visit Ecology's PFAS webpage.[27] Ecology appreciates the time and attention that the commenter committed to reviewing the draft EIS and for expressing their thoughts in support or opposition to the proposed program.	ORG-12-1

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[27] ecology.wa.gov/pfas

Commenter	Comment Code	Comment	Ecology Response	Attachment 1 Commenter Reference ID
Friends of Rocky Top (Scott Cave)	ORG-12-1-4	The toxic fumes and fire reflect poor management, potentially suspect disposal and a constrained, limited regulatory structure of oversight. More concerning is the potential for the landfill to generate leachate, increasing the risk of migration to downgradient, nearby drinking supply wells. The failure of adequate property setbacks and reduced environmental controls (no liner or leachate collection system), limited regulatory oversight and coordination, and ability and willingness to enforce permit and code violations, all contributed to the facility proximity to neighbors, loose compaction, steep slopes and subsurface fires that required purchase of adjacent property. The state should recognize and evaluate the gaps in the current regulatory structure and landfill air emission monitoring system that failed to detect obvious toxic emissions and landfill fires. Specifically, the state should consider increasing the monitoring requirements for groundwater and methane emissions, similar to those recently proposed for MSW landfills.	The comments present environmental concerns that are unrelated to this draft EIS. Please see Master Response 1: Overview of Ecology's Product Replacement Program and Fire Department Participation, which describes the scope of this draft EIS as helping fire departments and other first responders in Washington collect, remove, and dispose of stockpiles of AFFF. For more information, please visit Ecology's PFAS webpage.[28] Ecology appreciates the time and attention that the commenter committed to reviewing the draft EIS and for expressing their thoughts in support or opposition to the proposed program.	ORG-12-1

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[28] ecology.wa.gov/pfas

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Friends of Rocky Top (Scott Cave)	ORG-12-1-5	Exposure to these highly fluorinated chemicals are of grave concern to Rocky Top neighbors, recreationalists, and nearby residents whose air quality has been compromised by DTG facilities and operations. Like Selah, DTG Rocky Top neighbors fear future groundwater contamination. As reported, the DoD is responsible for the U.S. Army Yakima Training Center (YTC) near Selah, and the resulting AAAF and PFAS contamination of local groundwater. Arguably, it would bear responsibility for future PFAS contamination of groundwater at Rocky Top, the 'secondary source' that received, remediated, and disposal of 743 cubic yards of YTC AAAF contaminated soils with elevated concentration levels of PFAS.	The comments present environmental concerns that are unrelated to this draft EIS. Please see Master Response 1: Overview of Ecology's Product Replacement Program and Fire Department Participation, which describes the scope of this draft EIS as helping fire departments and other first responders in Washington collect, remove, and dispose of stockpiles of AFFF. For more information, please visit Ecology's PFAS webpage.[29] Ecology appreciates the time and attention that the commenter committed to reviewing the draft EIS and for expressing their thoughts in support or opposition to the proposed program.	ORG-12-1
Friends of Rocky Top (Scott Cave)	ORG-12-1-6	While PFAS has been added to the quarterly landfill monitoring, regulators did not support local neighbor's request for PFAS sampling of nearby drinking supply wells. We respectfully request the state to consider sampling at 'secondary sources', and for the MTCA investigation to include the PFAS soil layer in Cell 1.	The comments present environmental concerns that are unrelated to this draft EIS. Please see Master Response 1: Overview of Ecology's Product Replacement Program and Fire Department Participation, which describes the scope of this draft EIS as helping fire departments and other first responders in Washington collect, remove, and dispose of stockpiles of AFFF. For more information, please visit Ecology's PFAS webpage.[30] Ecology appreciates the time and attention that the commenter committed to reviewing the draft EIS and for expressing their thoughts in support or opposition to the proposed program.	ORG-12-1
Friends of Rocky Top (Scott Cave)	ORG-12-1-7	Important to this DEIS, was the remediation and disposal of 743 cy of YTC PFAS soils at elevated concentrations at the Anderson PCS site and landfill, when PFAS was not fully understood or regulated as hazardous. Federal and state agencies need to reconsider the potential threat from known secondary sources of PFAS contamination,	The comments present environmental concerns that are unrelated to this draft EIS. Please see Master Response 1: Overview of Ecology's Product Replacement Program and Fire Department Participation, which describes the scope of this draft EIS as helping fire departments and other first	ORG-12-1

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[29] ecology.wa.gov/pfas
[30] ecology.wa.gov/pfas

Commenter	Comment Code	Comment	Ecology Response	Attachment 1 Commenter Reference ID
		including the Macquarie/East Mountain Investments, Inc., DTG/Anderson contaminated site on Rocky Top. […] The state should acknowledge 'secondary sources' of AFFF/PFAS disposal that have or the state suspects could detect contamination, due to their risk to human health and the environment, including at Rocky Top from DTG's facilities, and consider agency legislation to address known suspected or known secondary sources, including at DTG's facilities on Rocky Top that accepted, remediated and disposed of 743 cy of PFAS contaminated soils. Forthcoming MCLs, ground and air monitoring requirements, potential waste acceptance limitations, material handling modifications for worker safety, and contamination remedies, present a mix of uncertainty and future potential challenges for landfills, including at 'secondary sources.	responders in Washington collect, remove, and dispose of stockpiles of AFFF. For more information, please visit Ecology's PFAS webpage.[31] Ecology appreciates the time and attention that the commenter committed to reviewing the draft EIS and for expressing their thoughts in support or opposition to the proposed program.	
Friends of Rocky Top (Scott Cave)	ORG-12-1-8	… It may be worthwhile for the state to consider PFAS 'destruction technologies' for onsite remediation at municipal fire stations, in addition to the proposed five alternatives. If applicable, given the long-term costs and liability for PFAS removal and disposal, this could be a viable option for some fire service agencies.	Ecology appreciates the time and attention committed to reviewing the draft EIS. Please see Master Response 3 describing the development of alternatives and Master Response 6 that describes alternatives that were considered but eliminated.	ORG-12-1

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[31] ecology.wa.gov/pfas

Commenter	Comment Code	Comment	Ecology Response	Attachment 1 Commenter Reference ID
Port of Seattle - Seattle-Tacoma International Airport (Megan King)	GOV-2-1-1	Timeframe. During the selection process, we encourage Ecology to consider the timeframe in which each of the evaluated alternatives can be implemented. Since the EIS determined all evaluated alternatives pose 'less than significant effect' for all Environmental Resource categories, we encourage you to consider the speed that a program can be implemented as part of your decision-making process. More than five years have past since state funding was appropriated for the AFFF Collection and Disposal program. The more time that passes with AFFF stored throughout our communities, the more opportunity for accidental and inadvertent release of this material. Please take expedient action to lead the removal and disposal of AFFF that is no longer needed or in use in our state.	Ecology appreciates the time and attention that the Port of Seattle committed to reviewing the draft EIS and for expressing their thoughts in support or opposition to the proposed program. Ecology will consider the suggestion that implementation timeframe be considered in the evaluations, and we will modify the final EIS, if appropriate. Please also see Master Response 1, which describes the overall product replacement program. Ecology anticipates program implementation in fall of 2024.	GOV-2-1
Port of Seattle - Seattle-Tacoma International Airport (Megan King)	GOV-2-1-1	Alternative Selection. We understand the rationale for inclusion of Alternative 5: No Action, and Alternative 1: Hold In Place, however we encourage Ecology to select an alternative that includes active collection and disposal processes now. Selecting No Action, or Hold In Place does not, in our opinion, meet the intent of a collection and disposal program, and only moves the burden for disposal of this material further into the future, and onto the individual Fire Departments to coordinate on their own.	As discussed in Master Response 4, No Action Alternative, Ecology is required to evaluate a no action alternative under SEPA. However, the intent of this EIS is to inform decision-makers of the best options for disposal that align with the protection of human health and the environment. The no action alternative is not considered a viable option.	GOV-2-1

ATTACHMENT 1: PUBLIC COMMENTS AND PUBLIC HEARING TESTIMONY

Gov-1-1

Tom O'Connor

My fire department, like many others, no longer uses AFFF and has switched over to fluorine free foam for firefighting use. We've put all our AFFF in temporary storage and have been waiting for Ecology to implement a disposal program as previously communicated. While I understand the DEIS requirement and process, it is concerning to see two of the five "disposal options" aren't disposal options at all and would require firefighting agencies to maintain storage of PFAS containing foam. I do not have the required expertise to take a position on disposal methods, but respectfully request that an actual disposal method is selected and implemented.

Gov-2-1

SEA
Seattle-Tacoma
International
Airport

PO Box 68727
Seattle, WA 98168-0727

FlySEA.org

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Operated by the
Port of Seattle

February 5, 2024

To:
Sean Smith, Product Replacement Program Manager
Washington State Department of Ecology - NWRO
P.O. Box 330316
Shoreline, WA 98133-9716

Subject: Comments on Ecology's Draft Programmatic Environmental Impact Statement for the Aqueous Film-Forming Foam Collection and Disposal Program

Dear Mr. Smith,

Thank you for the opportunity to review and provide comments on the Department of Ecology's Draft Programmatic Environmental Impact Statement (EIS) for the Aqueous Film-Forming Foam (AFFF) Collection and Disposal Program.

During finalization of this EIS, and subsequent selection and implementation of a collection and disposal method, please consider the following comments:

1. **Timeframe.** During the selection process, we encourage Ecology to consider the timeframe in which each of the evaluated alternatives can be implemented. Since the EIS determined all evaluated alternatives pose 'less than significant effect' for all Environmental Resource categories, we encourage you to consider the speed that a program can be implemented as part of your decision-making process. More than five years have past since state funding was appropriated for the AFFF Collection and Disposal program. The more time that passes with AFFF stored throughout our communities, the more opportunity for accidental and inadvertent release of this material. Please take expedient action to lead the removal and disposal of AFFF that is no longer needed or in use in our state.
2. **Alternative Selection.** We understand the rationale for inclusion of Alternative 5: No Action, and Alternative 1: Hold In Place, however we encourage Ecology to select an alternative that includes active collection and disposal processes now. Selecting No Action, or Hold In Place does not, in our opinion, meet the intent of a collection and disposal program, and only moves the burden for disposal of this material further into the future, and onto the individual Fire Departments to coordinate on their own.

We thank you again for your progress on development of this program. Please feel free to reach out to my technical staff (Megan King, king.m@portseattle.org) with any clarifying questions, or opportunities for collaboration.

Regards,

Sarah Cox

Sarah Cox
Director, Aviation Environment & Sustainability

Gov-2-1

Ecy EIS Comment Letter_SEA

Final Audit Report 2024-02-05

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I-1-1

Christy Pruitt

It is imperative this firefighting foam is removed ASAP from ALL WA stocks. It isn't a matter of "can" cause cancer; it WILL cause cancer to people who are exposed to it. It is absolutely unacceptable that WA government has not budgeted to have this completed before now- this has been a known issue for many years. The fact that the state hasn't remedied this situation shows a complete lack of concern for our firefighters, their families, the individuals who have had tragic fires & their families, pets, as well as the communities the foam is released in. Washington State prides itself on being forward thinking in it's environmental protection and justice. Yet, these chemicals kill fish in whatever community waterways this leaks into (drains in every neighborhood and every highway system around the state). Not to mention the harm that comes to the forests, prairies, and wildlife that this is dumped on during all wildfires across the entire state. This all runs off into the Puget Sound, where our fish species and even beloved orca whale populations are sickening, washing up dead, wasted away due to various factors- all due to pollutants, of which I'm sure fire fighting foam is part of; Washington admits to holding & using large stores - I cannot imagine port fires are exempt.

Washington State is liable for all this and needs to replace these stores by the end of 2024. To set a date beyond this (and add the inevitable missed deadlines) would be disrespectful to the people who live and visit Washington State (who have a reasonable expectation of safety) and the environment- of which we are stewards, and need to pass on to next generations without shame of lasting damage. As a race, we have come far, and are far too intelligent to allow this to continue. You are exposed. You are now 100% liable, and tax payers are tired of paying off millions for avoidable lawsuits, of which you can PREVENT at any time. You need to be accountable and settle this issue now.

I-2-1

Ryan Dailey

I have no major comments on the draft itself, but would like to share a promising technology myself and peers have been following regarding PFA's cleanup. I am in no manner affilliated with this company, I simply have an environmental engineering background and am very impressed with BioLargo's PFA's cleanup technology:

https://www.biolargoengineering.com/biolargo-aec/

BioLargo Aqueous Electrostatic Concentrator (AEC) is designed to provide rapid, effective, and affordable concentration of per- and polyfluoroalkyl substances (PFAS) in water. It works by separating PFAS compounds in an electrostatic field and forcing them through a proprietary membrane system.

The result � the AEC removes >99% PFAS from water in continuous flow, at energy costs as low as 30 cents per 1,000 gallons.

Advantages over other technologies:
- More energy-efficient
- More affordable on per-gallon basis
- Much less PFAS-laden waste produced
- Less activated carbon required in PFAS life cycle
- Higher purity of final water
- Compact; small footprint
- Development and commercialization of the AEC is supported in part by a grant provided by the US EPA SBIR.

I highly encourage relevant stakeholders to consider utilizing the AEC technology as the state continues to pick up PFAS cleanup contracts over the coming years.

I-3-1

Erick McWayne

Thank you for the opportunity to provide comments on the AFFF disposal guidelines. I recommend presenting the disposal options as "destructive" and "non-destructive" options. In addition to incineration, other destructive PFAS treatment technologies applicable to AFFF include electrochemical oxidation, plasma treatment, supercritical water oxidation, alkaline hydrothermal liquefaction, and sonochemical methods. A generic placeholder for new destructive technologies could also be included as "other destructive treatment technologies applicable to AFFF". Ecology may wish to specify that all residuals from destructive treatment be disposed of at a permitted and lined landfill with leachate collection system. A requirement for testing residuals prior to disposal may also be included to confirm PFAS destruction. Testing treatment residuals for ultra-shortchain PFAS including carbon tetrafluoride and trifluoroacetate to confirm complete PFAS destruction, or other similar confirmation is recommended. Thank you!

I-4-1

Peter Storch

I am an environmental/chemical engineer working for Arcadis and I have been involved in the development and execution of foam transition projects in Australia, including disposal of AFFF, since 2017. I have lead foam transition programs in the aviation, emergency response, chemical manufacturing, and petroleum industries. My experience and engineering assessments have taught me that effective disposal of the AFFF concentrate is one of the greatest risk reducing steps in the program. My experience working with regulators in Australia has also showed that strong regulatory leadership in the disposal of this highly-concentrated PFAS waste is critical to reduce the risk of releasing PFAS to the environment.

The disposal option that is most sustainable, risk reducing, and protective of human health and the environment is destruction of AFFF concentrate by engineered incineration. Incineration in a controlled, monitored process at a licenced facility is the accepted, preferred and required method of disposal for AFFF in Australia, and is recommended in the Australian and New Zealand PFAS National Environmental Management Plan, Heads of EPA, V2 2020.

Given the established and unique risks posed by PFAS, and as a concerned professional engineer and citizen of the world, I believe the alternative disposal options for AFFF concentrate short of destruction, represents unreasonable risk to human health and the environment.

Sincerely, Peter Storch

Peter Storch, P.E. | Principal Chemical Engineer | peter.storch@arcadis.com Senior Technical Director Lvl 35 |111 EagleStreet | Queensland 4000 | Australia T. +61 (07) 3337 0000 | M. +61 427 782 68 1 www.arcadis.com

Lance Safley

One option is to burn. That puts this in a risk vs reward situation when using it to actually put out a fire. Local fire departments don't put out an actual house fire but every 25 years and unless the home has neighbors go ahead and let it burn.

I suppose the 1 in a million that putting out the fire is to save lives in the home then that falls into the risk vs reward and use the spray.

How many gallons are they using on practice fires and such? That's a criminal act unless they had no MSDS chart and that also is criminal act.

On MSDS sheet, how do they load this into their pump trucks or is this delivered to them in concealed fire extinguishers? How has firefighters handled this product to stay safe? And everything loses pressure over time, these things are poisoning and contaminating its surroundings every day.

Then this stuff in our schools and not added to their MSDS sheet? No wonder child cancer is at epidemic raise.

Why use it on car fires when once again by the time fire department get there there is no lives to save.

Or is this just a money grab as someone clearly didn't care about environment for many years.

Lance Safley

I-6-1

John Worthington

Please Pay for disposal by creating a nautical mile tax on China/Asia firefighting products.

An additional nautical mile tax should be applied to American ingredients sent to China/Asia to make said firefighting products.

In other words double down on world economy taxes and make those sneaky corporate greeds pay to pollute for once.

John Worthington

I-7-1

Patrice Murphy

I believe these types of chemicals should be banned and better, safer alternatives to the enviroment found and used. My son was highly alergic and had multiple issues due to these chemicals. i am not sure what the lasting effects on his health will be. Also the effects on the marine life must be addressed.
thank you
Patrice Murphy

I-8-1

Petr Pospisil

For treatment of AFFF (unused or from drainage), all of the proposed options cannot avoid release of PFAS into the environment with time.
See e.g., https://www.sciencedirect.com/science/article/abs/pii/S0045653520318543
Therefore, any method should be first diligently tested on a small scale with evaluation of long term effects, and different methods must be adapted to local conditions.
AFFF gets most likely into the environment in case if fire fighting operations.
Drainage from surfaces where AFFF is applied for fire fighting must be retained as far as possible, with a retainment capacity large enough for fire fighting water from a large fire.
(e.g. roads, ports and airports, industrial facilities etc.)
It is not acceptable that overflow is spilled into the environment, as it is e.g. in current road projects.
Drainage must be adequately treated. Alternatively to adsorption on charcoal or incineration, modern treatment methods should be evaluated. See e.g.,
https://www.umsicht.fraunhofer.de/de/projekte/pfas-perfluorAd.html

I-9-1

Todd Bauernfeind

I have limited knowledge and yield to those that do, such as the many great comments I read. I support complete ban on these chemicals until the future development of other measures. I do work in health care and understand the impact on everyone human and animal in natural eco-system.

I live within eye sight of both airports in the West Plains of Spokane, no action has been taken to test my wells, nor have been able to find how to have my wells tested.

Regards,
Todd Bauernfeind

I-10-1

Nathan Anonymous

Are we so stupid as to allow UNSTABLE CHEMICALS - who we've been lulled into thinking are stable (they are ACIDS!!!!!)

UNSTABLE, HARMFUL, COROSIVE ACIDS HAVE NO ROOM IN AGRICULTURE OR SOCIETY.

perfluorooctanoic acid (PFOA)
and perfluorooctane sulfonic acid (PFOS)
Perfluorohexane sulfonic acid (PFHxS)
and Perfluorononanoic acid (PFNA)
Hexavalent chromium - Cr(VI) is known to cause cancer. In addition, it targets the respiratory system, kidneys, liver, skin and eyes.

Hexavalent chromium — known more commonly as chromium-6 or "the Erin Brockovich chemical" — gained international notoriety in the 1990s, after Brockovich discovered that it was contaminating drinking water and making people sick in the San Bernardino County town of Hinkley, Calif.Mar 24, 2022. FORD. FORD. FORD. FORD. FORD . .. $$$$$$$

GET THE $ OUT OF OUR LIVES FORD. TRIBAR.

Twelve chemical companies are responsible for the majority of the global PFAS production: AGC, Arkema, Chemours, Daikin, 3M, Solvay, Dongyue, Archroma, Merck, Bayer, BASF and Honeywell.May 22, 2023

WAKEUP

Caroline Armon

After reading the information and 5 alternatives, I support alternative 2- incineration. It seems to have the least potential impacts. I do not support alternative 1- approved leave in place, nor no action alternative, as that has been the status quo and impacts are happening: https://www.sanjuanjournal.com/news/hannah-heights-water-system-highly-contaminated/ I do not support alternative 4- class 1 deep well injection, with flooding and sea levels rising there is still potential contamination. Thank you for your time and consideration, Caroline Armon

I-12-1

Kat Krohn

My preferred disposal option is approved hold in place. This allows Ecology to continue to monitor evolving technologies for disposal as stated in 2.2.1.1. The inability to monitor class 1 deep well injection as stated in 2.2.4.2 makes this my least preferred disposal method. The mention of potential leachate from solidification and landfilling also makes this a least preferred disposal method. My greatest concern with AFFF disposal is groundwater contamination.

The research on the effectiveness of incineration in incomplete according to the EPA (https://www.epa.gov/sites/default/files/2019-09/documents/technical_brief_pfas_incineration_ioaa_approved_final_july_2019.pdf). Using the approved hold in place alternative would provide a stop gap measure while further research is being done on incineration.

I-13-1

Julie Shumway

My current job is with Environmental Protection with a Coast Salish tribe but before this I was a Project Manager for many years in a DoD lab where I specialized in AFFF projects. I feel I have a bit of knowledge in the subject.

While several of the compounds currently used in AFFF (over 5,000) are unknown in what they actually do it’s known what PFAS / PFOA do. To simplify things they mix very well with water to create a blanket over oil based fires to smother them. While I strongly believe the compounds needs to be phased out of every day life use as lubricants I’m not necessarily anti-AFFF. Currently there is a strong argument showing Best Management Practices in case of oil based emergencies. A clean up utilizing a double gac system and disposal has worked.

As far as how to dispose of AFFF it is not listed in RCRA but should still be solidified and shipped to a non- hazardous waste landfill which accepts this types of waste. Injection is the worst idea! Thermal destruction would be the second choice.

I-14-1

Liora Llewellyn

For the store-in-place option: in the spirit of pollution prevention, could the storage area be a (only one) central location where all AFFF foam can be stored in one place, overseen by Ecology, with proper BMPs in place for longer term storage of hazardous materials? This would centralize the possible pollution, and avoid the possibility of accidental use or release, improper storage, and ease the burden of longer-term storage on volunteer firefighting communities. It would be particularly beneficial to provide transportation/shipping for this effort. This would be a great first step for any of the proposed actions (except do nothing).

I-15-1

Chuck Danner

Hello,

I’d like to submit this comment with regard to the AFFF Disposal plan.

Of the five options listed, I believe incineration to make the most sense. My understanding is that if incinerated above certain temperatures the chemicals are broken down and rendered to be completely harmless. Completely harmless should be the desired goal/outcome. If incineration attains that goal the rest is basically a No-Brainer!

I don’t believe any of the other four options have any merit!

Chuck Danner

I-16-1

Marli Heininger

From the perspective of an electric utility that operates in generation, transmission, and distribution within WA, management options that are highly compatible with Polychlorinated Biphenyls that are incidental in electric equipment is very desirable. A plan for general industry to be able to hold small quantities safely until disposal would be very useful. Aside from bagging product and staging it near other regulated chemicals/waste, there's not much else to do. I have encountered a situation where there is brand new, unadulterated, unused product in it's original container, yet waste profiling is a pain. All efforts to get more details from the manufacturer have gone nowhere, and I do not have much confidence in lab analysis in addition to the unnecessary costs to identify something that has known hazards. Guidance for that would be helpful.

Considering how PCBs are either buried or incinerated, I am inclined to follow those practices. However, landfilling a forever chemical still poses ongoing risk. Since hormone interference is among the health effects, solidification in concrete sounds extremely insufficient and is certainly not secure against any sort of natural disaster. The same goes for deep well injection - that sounds like the most dangerous and expensive of all the options. That is an entire industry that doesn't exist, creates more exposure, and will leave more natural spaces poisoned for years and years. Human error is the biggest factor here.

Incineration is an ideal treatment method since that infrastructure and process stream already exists. Plus, we can scientifically determine what needs to be done to burn the material hot enough for cleaner emissions. If ever a landfill of any kind needs to be remediated - such as the Pasco Landfill, a nasty intensive project - the long term costs will be so much greater and continue to spread around potential exposure or spills. A one and done solution should be prioritized for workers, the general public, carbon emissions, and permanent destruction of a chemical that won't be destroyed by any other natural elements. The fact that these TSCA chemicals like PCBs and PFAs are remarkably resistant to any sort of chemical degradation and cannot be effectively removed from drinking water is a very important element to consider to actually protect public health for multiple generations to come. More novel treatment methods could develop in time, but that also includes spreading the material around and spending more carbon from our finite resources. A good road map with benchmarks for the timeline on how the state might collectively work to dispose of this chemical would be very helpful for industries that have contact with this chemical but aren't necessarily experts with regards to its performance.

A specific set of waste profiles with prescribed treatment methods would also be helpful. While we can all declare our own waste and perform our own testing, this entire TSCA update revolves around manufacturer responsibility, and I strongly support that. They profited for decades, and this is the cost of business. If companies will refuse to share "proprietary" information, I think the regulatory agencies should hold them accountable, and in the interest of efficient disposal that isn't hindered with excessive red tape, having categorical or concentration based profiles would be very helpful. It makes no sense to sample unused product when *someone* in the industry knows what it is. It isn't fair to all the waste workers, lab techs, and field crews to have to expose themselves to collect samples over an arbitrary threshold. If the PFAs are there, they're there. For AFFF specifically, it's obviously not flammable or corrosive, but it doesn't neatly fall under a toxic character either.

I really appreciate all the work the state of WA is doing proactively for this regulatory update - I wish others on the West Coast were employing the same! Thank you for your work and reminders for the public comment period.

I-17-1

Nancy Lust

I want to commend the Dept of Ecology for recognizing the dangers associated with PFAS getting into the groundwater, but I think they need to broaden their scope. This DEIS focuses on what to do with existing supplies of firefighting foam contaminated with PFAS, but my concern is how soils contaminated with petroleum and PFAS have already been disposed of in Yakima County. Right now, all levels of government are working to figure out a way to get clean water to residents in East Selah, who have the misfortune of living near the US Army Training Center, where the Army trained soldiers to put out gas fires with PFAS foam. Their wells are contaminated now. The Army has stopped this practice, but much of the contaminated soils generated for years at the US Army Training Center were disposed at the Anderson limited purpose landfill, now owned by DTG Recycle. These soils were put into an UNLINED LANDFILL. I live near this landfill and very little exploratory work has been done to determine if the groundwater has been contaminated. At a minimum, I would like Ecology to determine where other PFAS-contaminated soils may have been disposed of in Washington State, and develop a protocol for testing the groundwaters around these sites. As of now, it is my understanding that DTG will be adding PFAS to the list of chemicals it tests when it does routine groundwater sampling, but there are no plans to my knowledge for testing neighboring wells. I would support such testing of neighboring wells to make sure PFAS has not seeped into our water supply.

I know this is beyond the scope of this particular DEIS, but I want it in the record that this problem with PFAS is bigger than this program will address.

I-18-1

AFFF Collection & Disposal DEIS Public Hearing

Public Comments Transcript | January 31, 2024

Public Comment #1: Meisam Vajdi, Missouri University of Science and Technology

- Good afternoon. I’m Meisam Vajdi, at Missouri University of Science Technology. I’m very happy and glad to be with you here, and thanks for this event, it’s very informative to me. So, is there a detector for PFAS materials? Are you seeking, or is that important to have detectors, for example, in the incinerator facilities? I think that it’s necessary to have detectors to detect and monitor the air and environment in that facility, to understand if the process is accurately done or not. So, I’m curious to know what the importance is of having detectors, especially in the air, for PFAS materials. Thank you.

AFFF Collection & Disposal DEIS Public Hearing

Public Comments Transcript | January 31, 2024

Public Comment #2: Alice Green, Green Party of Washington

- Hello, I'm Alice Green, I'm representing Green Party of Washington. We've been in discussion of PFAS and other endocrine-disrupting chemicals, which are becoming a health hazard. My concern is for first responders and firefighters and their exposure to PFAS, which has increased their cancer rates and some health hazard to them. I would like to know: is incineration the only means for which it can actually chemically change the molecule from PFAS? Also, our concern is for any water seepage and water contamination. I want to let you know that we really appreciate you exploring this comment, I think there are a lot of states that are lagging behind in PFAS remediation. So, first of all, if you could just let me know – is incineration really the only way that the actual molecule can be altered? Thank you.

I-20-1

AFFF Collection & Disposal DEIS Public Hearing

Public Comments Transcript | January 31, 2024

Public Comment #3: John Lovie

- Thanks for taking the comment, and this isn't meant as a reply to the previous comment, but it might accidentally work that way. I've read that there are some other technologies in the works, such as lower temperature hydrolysis in non-aqueous solvents, that might work adequately for removing PFAS in fairly concentrated solutions, like returned firefighting foam concentrate. So, I'm hoping that, in consideration of these alternatives, that you take a look out on the horizon and see what might be coming down the pike in terms of alternative destruction technologies. The picture in 2 or 3 years might look quite different than the way it does right now, and it would be a shame to go down an irreversible path that doesn't give us the option to take advantage of those newer technologies.

Ind-1-1

James L Denson
PNW/BC Area Env Protection Mgr
Waste Management
720 4th Avenue, Suite 400
Kirkland, WA 98033

Mr. Sean Smith
Product Replacement Program Manager
Washington State Department of Ecology
Northwest Region Office
P.O. Box 330316
Shoreline, WA 98133-9716

RE: Aqueous Film Forming Foam Collection and Disposal Program – Draft PEIS

Dear Mr. Smith:

WM is submitting these comments on the Washington State Department of Ecology's (the Department's) Aqueous Film-Forming Foam (AFFF) Collection and Disposal Program Draft Programmatic Environmental Impact Statement (Publication Number 23-04-064, December 2023).

WM is the leading provider of environmental services in North America, with nearly 50,000 employees operating 263 solid waste landfills, 348 transfer stations, 103 materials recovery facilities, 44 organics processing facilities, 6 hazardous waste facilities, and a fleet of nearly 20,000 collection vehicles throughout the United States and Canada. WM's deep expertise in the collection, transportation, storage, treatment, and disposal of wastes (both hazardous and non-hazardous) means we are uniquely qualified to handle the proper collection and disposal of Washington state's existing AFFF inventories currently located at fire departments throughout the state.

BACKGROUND

Per- and polyfluoroalkyl substances (PFAS) are a class of manufactured chemicals comprising carbon chains that have multiple fluorine atoms attached. PFAS have been used for decades in a variety of consumer and industrial applications, including AFFF used in firefighting. PFAS have fire resistance characteristics that make them uniquely well-suited for use in AFFF formulations. However, the use of AFFF in firefighting, both in real emergency and training scenarios, has contaminated environmental media (soil / surface water / groundwater). Therefore, agency regulators at both the federal and state levels have sought to remove PFAS from AFFF and to prohibit the use of PFAS-containing AFFF. So, as the Department's draft Programmatic Environmental Impact Statement (PEIS) states, fire stations and other similar locations throughout Washington state have inventories of PFAS-containing AFFF that can't be used and must be either destroyed or disposed of in a safe and compliant way.

ALTERNATIVES FOR MANAGEMENT - DISCUSSION

The Department's PEIS discusses five alternatives for management of existing AFFF inventories in need of destruction or disposal:

1. Approved Hold-In-Place
2. Incineration
3. Solidification and Landfilling
4. Class I Deep Well Injection
5. No Action

APPROVED HOLD-IN-PLACE / NO ACTION

WM believes the Hold-In-Place and No Action alternatives are unsuitable because these alternatives do not solve the problem of proper management and place an undue burden on Washington facilities, some of which may have limited resources, to safely store unused AFFF and prevent releases of these materials to the environment. The Hold-In-Place alternative is slightly favorable, because the Department commits to providing suitable containment for use by facilities storing the material. However, WM believes neither alternative directly addresses the problem and unreasonably delays pursuit of existing alternative solutions.

CLASS I DEEP WELL INJECTION

WM largely agrees with the Department's assessment of the Class I Deep Well Injection alternative. However, we respectfully disagree with some of the discussed disadvantages. For example, the PEIS states that deep well injection means the "*disposed AFFF concentrate mass remains in place with no method for verifying PFAS destruction*". Deep well injection, by definition, is not a destruction technology, but rather a disposal technology that ensures a waste is injected into a geologically isolated injection zone bounded by confining layers of rock that prevent migration of wastes into underground sources of drinking water (USDWs). Class I deep wells are carefully located and constructed in geological zones specifically designed to make waste mobility/migration impossible due to the imperviousness of the confining layers. So even though deep well injected wastes are not destroyed, they are confined and isolated so that they are forever trapped inside the injection zone, effectively rendering them harmless to USDWs.

The PEIS also states that *"deep well injection facilities are generally operated under limited compliance monitoring; therefore, the long-term stability of injected wastes is undocumented."* WM strongly disagrees with this assertion as Class I deep well injection wells are regulatorily required to meet rigorous environmental standards to ensure environmentally safe disposal of wastes they are permitted to accept. Deep well facilities are required to conduct numerous monitoring activities, including groundwater, air, mechanical integrity as well as monitoring of the confining structure to ensure wastes are properly injected into the confining geologic zone. Deep well operations must periodically perform extensive testing and evaluation to prove there is no-migration occurring and that the injection zone is geologically stable and sufficiently free of faults or fractures to prevent fluid movement.

INCINERATION

WM believes the Department must consider the incineration capacity shortfall that is currently impacting waste disposal via incineration, as this capacity shortfall is expected to continue for several years in the future. Currently scheduling non-bulk, containerized wastes into these facilities is highly limited and many months out. This issue would certainly present a challenge to the disposal of AFFF inventories, which are largely containerized wastes. This could exacerbate the already challenging issue of transporting AFFF over large distances to the incineration facilities highlighted by the Department, as these less than bulk loads may have to be placed in temporary storage at transfer stations until an incineration facility is willing to accept them. In addition, the Department needs to re-analyze this alternative based on the Significance Criteria in Section 3.12.2.2. Specifically, the Significance Criteria in this section states that the Approved Hold in

Place alternative would not be consistent with the program objectives and legislative code, and then concludes that there would be less than significant impacts on police, fire departments, and emergency services. This analysis does not consider that, when viewed in light of the incineration capacity shortfall, the Incineration alternative necessarily includes an indeterminate period of the impacts associated with the Approved Hold in Place alternative. Fire departments that currently have AFFF will be required to implement many of the administrative and engineering controls listed in Section 3.1.3. for an unspecified period, in addition to other administrative and engineering controls associated with storing and managing hazardous substances. The PEIR does not acknowledge the demands implementing these controls for an indeterminate period will have on fire department resources, as well as whether the concomitant delay in permanently disposing of AFFF waste is consistent with the program objectives and legislative code, as noted in Section 3.12.2.2.

The PEIR also does not analyze the criteria and hazardous air pollutants, and Greenhouse Gas Emissions associated with combustion of fuel to heat the incinerator. The PEIR seems to assume that hazardous waste incinerators are continuously operated at a temperature capable of destroying PFAS. U.S. EPA's 2020 Interim Guidance on the Destruction and Disposal of PFAS and PFAS-Containing Materials states that breaking the carbon-flourine bond requires 1.5 times more energy compared to the thermal energy required to break carbon-chlorine bonds. An incineration facility that is operated to minimize costs and emissions is unlikely to consume additional energy and generate additional combustion emissions by always operating at the higher temperatures and times required to destroy PFAS. The PEIR should be revised to evaluate whether hazardous waste incinerators use additional energy to reach the higher operating temperatures necessary to destroy PFAS, any resulting impacts to the various resource areas, including air quality and Greenhouse Gas Emissions, and energy demands, as well as any mitigation measures that might reduce these impacts. The Department should also compare these additional impacts to other legal alternatives for the permanent management and disposal of AFFF wastes.

Ind-1-1

James L Denson
PNW/BC Area Env Protection Mgr
Waste Management
720 4th Avenue, Suite 400
Kirkland, WA 98033

SOLIDIFICATION AND LANDFILLING

Subtitle C Landfills

WM agrees with the Department's assessment that permitted hazardous waste landfills are required by RCRA Subtitle C to be designed with "…rigorous liner and cap systems that limit the risk of releases." In addition, WM also agrees with the Department's assessment that landfill leachate is collected and properly treated or disposed, and that federal and state regulatory requirements also require landfills to monitor groundwater in the landfill area. It is important to note that the PEIR correctly references U.S. EPA's 2020 Interim Guidance on the Destruction and Disposal of PFAS and PFAS-Containing Materials, including that EPA found permitted hazardous waste landfills carry a lower level of uncertainty in their ability to control the migration of PFAS to the environment. Nevertheless, the Department's AFFF collection and disposal program lists incineration as the planned disposal method for AFFF wastes.

WM notes that the Department constrains its analysis of potential disposal facilities to sites that are currently under contract with the Department for waste disposal services. WM believes the Department should expand the PEIR's analysis to include any properly permitted waste disposal facility, regardless of whether that facility is currently under contract with the Department to provide waste disposal services. By restricting the population of facilities to only those with existing contracts, the PEIR prioritizes administrative convenience over environmental protection, and does not consider the potential to reduce numerous environmental impacts, including air quality, Greenhouse Gas Emissions, Human Health and Safety, Transportation and Truck Safety, and Public Services and Utilities that would result from disposing of AFFF wastes at the closest, properly permitted disposal facility that also carries the least uncertainty in preventing PFAS migration into the environment.

For example, by expanding the population of facilities that could be used for disposal, WM's Chemical Waste Management of the Northwest (CWMNW) Subtitle C facility in Arlington OR would be a potential disposal location, as it is a suitable alternative for AFFF disposal. The CWMNW facility has been safely solidifying and disposing of these PFAS containing waste (Including AFFF) from across the country for several years. The facility is located in a very protective environmental setting with regard to safety for air, climate, groundwater, and exceeds Subtitle C landfill design standards. Notability the CWMNW facility is rail served with regular service from Seattle. As noted in sections 3.1.2.1, 3.2.1.2, and 3.10.1, travel distance is a key variable affecting criteria pollutant emissions, Greenhouse Gas Emissions, as well as Transportation and Truck Safety impacts. By transporting AFFF wastes a shorter distance to the CWMNW facility, there would be a reduction in each of these impacts compared to transporting the wastes to more remote locations. At the same time, the PEIR does not analyze the increased risks to Transportation and Truck Safety, as well as other resource areas such as Public Services and Utilities, associated with having AFFF wastes in transit over longer distances and longer periods. Because the PEIR assumes that the transportation risks are the same regardless of whether AFFF waste travels one mile or 1,000 miles, the PEIR does not consider that each additional mile traveled extends the risks of collisions, equipment failure, or various human errors that might occur, resulting in an increased risk of releasing PFAS into the environment. It is again worth noting here that the Arlington facility is rail served and significantly reduces GHG emissions and the risks associated with over the road transportation. A PEIR that properly considers these risks would discuss the advantages of permanently managing AFFF wastes near its current location and take into account the benefits of rail transportation.

Subtitle D landfills

Subtitle D landfills are also subject to extensive federal, state, and local environmental, health and safety requirements including detailed design criteria, location restrictions, financial assurance capability, corrective action standards and requirements for closure and post-closure periods. Therefore, Subtitle D landfills in the proper environmental setting are well suited for safe disposal of AFFF and should be considered by the Department as a viable alternative for disposal. Expanding the list of alternatives to include Subtitle D landfills may result in closer locations for disposal, thus minimizing the risk of transporting AFFF over long distances to a final destruction or disposal destination.

Most Subtitle C facilities, and many Subtitle D facilities like the Arlington facilities, have closed-loop systems that manage leachate within the facility rather than discharging their leachate for offsite treatment. PFAS waste streams that are disposed in landfills that produce minimal leachate volumes, especially those facilities that employ stabilization or solidification technologies and are located in dry climates, afford heightened levels of environmental protection.

Ind-1-1

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CONCLUSION

As owners of RCRA regulated Subtitle C hazardous landfills, Subtitle D non-hazardous landfills, and Class I deep injection wells across the Country, WM understands the importance of being good environmental stewards and ensuring that our operations do not result in harm to human health and the environment. Our facilities must maintain compliance with all our RCRA and solid waste permits along with strict CAA and CWA regulations. Further, the Arlington facilities routinely engage in community outreach and engagement. This engagement is used to disseminate relevant information about our facilities and the operations performed. Regular community outreach also allows our employees the opportunity to participate in meaningful dialogue with the community and receive feedback on the impacts of facility operations with an understanding of local health trends, existing health conditions, and environmental justice concerns. Finally, as stated throughout our comments, WM encourages the Department to keep all proven technologies on the table as it works to finalize this Draft.

As noted above, the PEIR needs revision and additional analysis to properly inform AFFF disposal managers of the environmental impacts and mitigation measures associated with all legal methods of disposal of AFFF wastes, enabling the managers to make the choice with the least environmental impacts, and the least uncertainty with preventing PFAS migration into the environment, unconstrained by the administrative conveniences associated with government contracting. WM appreciates the opportunity to submit comments on this draft PEIS. If you have further questions or concerns, feel free to contact Jim Denson via email at jdenson@wm.com or by telephone at 602-757-3352.

Sincerely,

James Denson
Waste Management
PNW/BC Area Environmental Protection Manager

Org-1-1

Washington Association
of Sewer & Water Districts
EDUCATE ▪ ADVOCATE ▪ COLLABORATE

January 23, 2024

Department of Ecology

Via comment website

[Aqueous Film-Forming Foam Draft Environmental Impact Statement (commentinput.com)]

RE: Comments on AFFF Disposal Options EIS

Thank you for the opportunity to comment on the AFFF Disposal Options. The Washington Association of Sewer and Water Districts represents more than 180 public sewer and water districts in the state, serving nearly 20% of our state's population. These districts provide cost-effective sewer and water services—ranging from the state's largest population centers, to the smallest rural communities. Clean water is a major concern to both our membership and the clients they serve. The potential for contamination is always a concern, especially since, beyond our wellheads and collection points, we have no control over what is sprayed, injected, discharged or built near our facilities. The situation with PFAS over the entire country is especially alarming given the longevity and ease of travel of these compounds.

We appreciate Ecology's efforts to develop the best solutions for disposal of AFFF. Our focus will always be to keep contaminants out of water supplies, as it is more difficult and expensive to remove them than to keep them out in the first place. Our reasoning and preferences for the options in the EIS are as follows:

1. Solidification and Landfilling

   We would not support this option. There will be the hazards of collection and transport, and the resulting solids when buried, still carry the possibility of leaching into the environment. There is also no way to recover this material and treat the PFAS compounds when technology becomes available.

2. Deep Well Injection

   We would not support this option. Again, hazards of collection and transport exist, plus the possibility of polluting the environment and groundwater supplies, and lack of recoverability for future treatment.

3. Incineration
   This may be an option. While collection and transport hazards are present, at the endpoint the compounds are destroyed and residuals are dealt with in a safe manner. This is, of course, predicated on proper safeguards at the incineration facility that do not allow pollutants to go airborne.

4. Approved Hold in Place
   This may be the best option of the 5 outlined. Collection and transport hazards are eliminated for the short term. As indicated, approved containment would be required. There may be an issue of how safe the containment is from vandalism, accident or natural disaster. There may also be an issue of space availability for smaller facilities. The AFFF remains available in the future for destruction as technologies develop.

5. No Action
   Not an option. Regulators must know where it is kept, and that it is safe from contaminating the environment, as well as plan for future remediation of these compounds.

We would like to reopen a 6th option that was closed by Ecology, and that is the collection of AFFF into one site. Collection and transport hazards would exist, but robust containment could be designed, and it would not be scattered across the state in smaller containment units that would be in population centers. When the time came, destruction technologies could be set up at just one site, reducing costs and dangers of release near people.

We appreciate the thought, work and research that has gone into developing these options.

Sincerely,

Judi Gladstone

Judi Gladstone
Executive Director
WASWD

Tumwater Fire Department

We at Tumwater Fire have AFFF stored in 5-gallon pails and in the onboard foam tanks on our engines. We can surmise from the draft plan how we will go about disposing of the AFFF that resides in stored pails. We are concerned with how we will properly dispose of AFFF that resides right now in onboard 30-gallon tanks on each fire engine.

We can drain these tanks into empty 5-gallon pails and re-label them accordingly. Would this be acceptable? Then we could flush the foam systems including the tanks. This will require a large volume of water flow and result in diluted contaminant from our discharge to be released. Is the flushing acceptable and if so, where should this take place?

There is an interest here to transition to new foam so we can get the Legacy AFFF off the engines. We have not yet purchased any replacement for our legacy AFFF but we will as soon as we have a plan to transition.

Thank you, explicit guidance on this issue will be necessary.

Missouri University of Science & Technology

Hi, Good Afternoon!

Would you please find attached file,

Sincerely,
Meisam

Missouri University of
Science and Technology
Rolla, Missouri

**Electrical & Computer
Engineering Department**
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301 W. 16th Street
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ece.mst.edu

Washington

Org-3-1

CLASSIFIED

Project: Deployment of 1000 PFAS Detectors Through Washington Ports and Residential Areas by PFAS Action Response Team.

Employer: Air Quality Program | Washington Department of Ecology.

Project Manager: Missouri University of Science and Technology.

Date: Wednesday, January 31, 2024

Project Description:

What are PFAS?

Per – and polyfluoroalkyl substances (PFAS) are a group of manufactured chemicals not found naturally in the environment. The unique physical and chemical properties make them resistant to water, oil and heat. For decades PFAS have been used in various industrial applications such as fire-fighting foams and metal plating, as well as consumer products including on carpeting, waterproof clothing and upholstery. Much of what is known about PFAS is based on studies on perfluorooctanoic acid (PFOA) and perfluorooctane sulfonate (PFOS).

Why should be concerned about PFAS?

PFAS do not break down easily in the environment which means these chemicals last for a long time once released. With repeated exposure some PFAS compounds may build up in the blood and organs, and they have been shown to be associated with some adverse health effects.

Can PFAS be found in outdoor air?

Yes, PFAS have reportedly been detected in outdoor air. These detections have been geographically associated with PFAS chemical production sites or large industrial manufacturing process utilizing PFAS-containing materials.

Can PFAS be found in indoor air?

Yes, some PFAS chemicals have been measured in indoor air and household dust. Certain PFAS chemicals like fluorotelomer alcohols (FTOHs) are often found in indoor air while PFOS and PFOA have been detected in household dust. Levels in the home will depend on the types of consumer products in the home. However, there is limited information about health risks associated with inhalation of the various PFAS that have been found in indoor air.

Are levels higher in outdoor or indoor air?

Because of the concentrated presence of consumer products containing PFAS and lower air circulation rates, typical levels of PFAS are expected to be higher indoors, compared to outdoor air.

Do PFAS have an odor?

No.

Is there a difference to health between inhaling of PFAS or ingesting PFAS-containing dust?

If present in air, PFAS is likely absorbed into the body by the inhalation route of exposure; however, this route of exposure likely contributes far less PFAS to the body than eating and drinking contaminated food and water.

Does inhaling PFAS while showering pose a health risk?

Showering with water containing the common PFAS chemicals, PFOS and PFOA, is not likely a health risk because exposure during a shower is not long enough to inhale significant amounts of PFAS. Also, PFOS and PFOA would not be present in the steam at shower water temperatures due to their higher than water boiling points. However, it is advisable to follow any public health recommendation in place for water.

Is the outdoor air safe to breath if a known source of PFAS is identified?

Air concentrations below standards are anticipated to pose no or minimal risk to the public health, including sensitive individuals such as the elderly and children. The concentrations that exceeded the health-based standards were found around large manufacturing facilities for PFAS.

Which PFAS are most volatile (e.g., most likely to evaporate)?

Most PFAS evaporate into the air at very low rates. However, it is known that certain types of PFAS are more volatile than others. Based on differences in volatility and the variety of industrial uses of PFAS chemicals, additional information is needed to more fully understand the transport and transformation of PFAS and the associated human exposure routes.

Can PFAS be released into the air from an industrial smokestack?

Yes. Stack test data have confirmed PFAS emissions from smokestacks using a modified version of an existing test method. These sources include PFAS manufacturing facilities and large industrial users of PFAS-containing products. No USEPA approved stack test method for measuring PFAS in air is currently available.

What is the temperature at which PFAS can be destroyed in an incinerator?

Most references in the published literature report PFAS destruction at temperatures greater than 1,200°F. However, some sources call for temperatures greater than 2,000°F, along with the consideration of other important combustion parameters needed for complete destruction.

What air pollution control devices are best for PFAS?

No facilities currently have air pollution control devices that were installed specifically to address PFAS emissions. Some have installed controls for PFAS emissions including thermal oxidizers, carbon absorption and wet scrubbers with packed bed fiber filters. The appropriate control strategy will likely vary based on the specific PFAS chemicals involved. More research is necessary to determine if the PFAS is permanently captured and not simply transferred to other media, such as wastewater or sludge.

What are known sources of PFAS to the air?

Known (and suspected) air sources have been identified at Teflon manufacturing facilities, PFAS containing coating facilities, chrome platers, landfills, and wastewater treatment plants.

How do air sources of PFAS contaminate water?

PFAS can attach to particles or dissolve in rain and snow, which are then deposited to land and water from the air. This is a process known as atmospheric deposition.

What are the recommended methods for monitoring PFAS in air and rain?

There is currently no U.S. Environmental Protection Agency (USEPA) approved method for ambient air monitoring of PFAS, although method development is underway.

What stack ("smokestack") test method is recommended for PFAS?

There is currently no USEPA approved stack test methodology.

Can PFAS be transported long distances in air?

Yes. Atmospheric deposition of PFAS many miles downwind from a manufacturing facility has been demonstrated. Contaminated groundwater was caused by atmospheric deposition of PFAS from industrial emissions of PFAS. Additionally, PFAS have been sampled and found in remote regions such as the arctic.

Can PFAS be transformed in air?

Yes, some PFAS compounds transform in the air. For example, volatile precursors like 8:2 FTOH can transform to PFOA in the air.

What regulations cover PFAS in air?

At the federal level, chrome platers are not allowed to add additional PFOS-containing mist/fume suppressants (above 1%) after 9/21/2015. The AQD's inspections of affected chrome plating sources in 2017 and 2018 showed compliance with this requirement. However, most replacement

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mist/fume suppressants still contain PFAS chemicals, just not the specific compound called PFOS. If PFAS are emitted above certain thresholds, they would be required to meet a health-based screening level in the air before a company could be issued an air permit. However, several permitting exemptions exist for PFAS use under the current air toxics regulations.

What health-based screening levels exist for air?

The AQD derived health-based screening levels for PFOA and PFOS. Both screening levels are 0.07 micrograms per cubic meter (μg/m³) with a 24-hour averaging time. If both PFOA and PFOS are present in the air emissions, the combined concentration of these substances must be below 0.07 μg/m³, with a 24- hour averaging time. Screening levels are health protective values, such that if air concentrations do not exceed these levels, adverse health effects are not expected. Screening levels are designed to be protective for sensitive individuals, including children and the elderly. Additional screening levels could be developed as other PFAS are identified in future permit applications.

Are different states finding PFAS in air?

Yes. Minnesota found PFAS in outdoor air several years ago, and NC found PFAS in rainwater.

What are the USEPA and Agency for Toxic Substances and Disease Registry (ATSDR) doing regarding PFAS in air?

On February 14, 2018, the USEPA announced their PFAS Action Plan and associated Fact Sheet:

https://www.epa.gov/sites/default/files/2019-02/documents/pfas_action_plan_021319_508compliant_1.pdf

ATSDR also maintains a web site dedicated to PFAS:

https://www.atsdr.cdc.gov/pfas/index.html

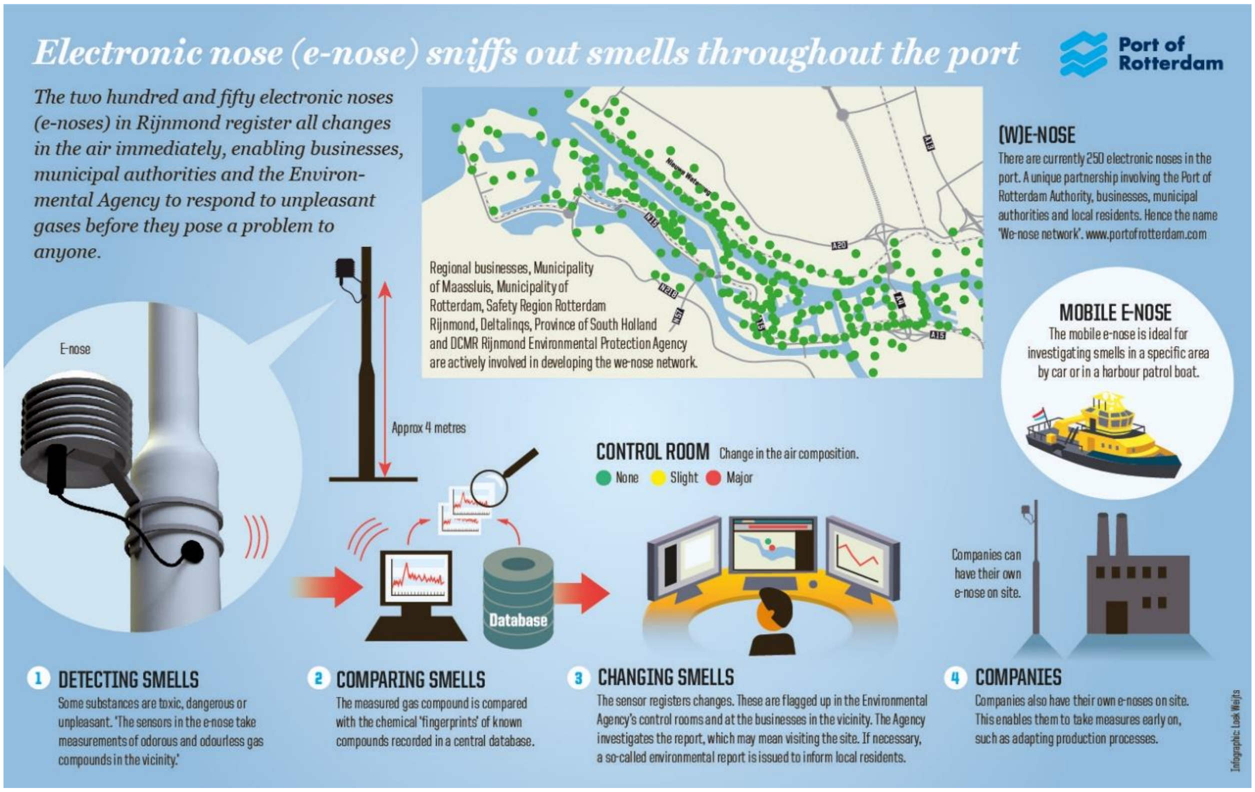
FACT SHEET: Biden-Harris Administration Takes New ...:

https://www.whitehouse.gov/briefing-room/statements-releases/2023/03/14/fact-sheet-biden-harris-administration-takes-new-action-to-protect-communities-from-pfas-pollution/

Cutting-Edge Advanced Technologies

“Electronic nose or E-nose” and “open ended hollow coaxial cable resonator sensors” are two technologies that sniff out gases throughout the ports. 1000 electronic noses and resonator sensors distributed through Washington ports and residential areas, register all changes in the air immediately enabling businesses, municipal authorities, and environmental agency to respond to unpleasing gases before they pose a problem to anyone.

Some substances are toxic, dangerous, or unpleasant. The sensors in the E-nose and resonator sensors take measurements of odorous and odorless gas compounds in the vicinity. The measured gas compound is compared with the chemical fingerprints of known compounds recorded in a central cloud database.



Electronic nose (e-nose) sniffs out smells throughout the port

The two hundred and fifty electronic noses (e-noses) in Rijnmond register all changes in the air immediately, enabling businesses, municipal authorities and the Environmental Agency to respond to unpleasant gases before they pose a problem to anyone.

Regional businesses, Municipality of Maassluis, Municipality of Rotterdam, Safety Region Rotterdam Rijnmond, Deltalinqs, Province of South Holland and DCMR Rijnmond Environmental Protection Agency are actively involved in developing the we-nose network.

(W)E-NOSE

There are currently 250 electronic noses in the port. A unique partnership involving the Port of Rotterdam Authority, businesses, municipal authorities and local residents. Hence the name 'We-nose network'. www.portofrotterdam.com

MOBILE E-NOSE

The mobile e-nose is ideal for investigating smells in a specific area by car or in a harbour patrol boat.

CONTROL ROOM Change in the air composition.

🟢 None 🟡 Slight 🔴 Major

Companies can have their own e-nose on site.

1 DETECTING SMELLS

Some substances are toxic, dangerous or unpleasant. 'The sensors in the e-nose take measurements of odorous and odourless gas compounds in the vicinity.'

2 COMPARING SMELLS

The measured gas compound is compared with the chemical 'fingerprints' of known compounds recorded in a central database.

3 CHANGING SMELLS

The sensor registers changes. These are flagged up in the Environmental Agency's control rooms and at the businesses in the vicinity. The Agency investigates the report, which may mean visiting the site. If necessary, a so-called environmental report is issued to inform local residents.

4 COMPANIES

Companies also have their own e-noses on site. This enables them to take measures early on, such as adapting production processes.

These are flagged up in the environmental agency's control rooms and at the businesses in the vicinity. the agency investigates the report, which may mean visiting the site. if necessary, an environmental report is issued to inform residents. Companies also have their own e-noses on sites. This enables them to take measures early on, such as adapting production processes.

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The **mobile** E-nose is ideal for investigating gases in a specific area by car or in a harbor patrol boat. Deployment of 1000 electronic noses and resonator sensors in the ports creates a unique partnership involving Washington environmental authorities, businesses, and residents. Hence the name “**we-nose network**”.

Mission:

Developing health-based screening levels for PFAS compounds, as needed. Learning about how PFAS is used and estimating potential air releases. As the uses of PFAS chemicals by industry are identified through air permit applications the AQD will screen allowed emissions for any potential adverse health effects as required in the air toxics rules. Appropriate air permitting measures for PFAS (such as material limits, material substitution, control requirements, emission limits and/or stack dispersion requirements) will be included in future air permits, as necessary.

Sincerely,

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Org-4-1

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January 22, 2024

Mr. Sean Smith, M.S.
Product Replacement Program Manager
Washington Department of Ecology
Northwest Regional Office
PO Box 330316
Shoreline, WA 98133-9716

Submitted online via ecology.wa.gov/AFFF-comment.

Re: Draft AFFF Environmental Impact Statement

Dear Mr. Smith,

Washington Department of Ecology has presented a comprehensive preparation of the Draft EIS document. After a review of the draft document several comments are appropriate that may contribute to the continuing evaluation of the five listed alternatives and selection of the most appropriate one.

On behalf of Clean Harbors Environmental Services, Inc. these comments are submitted to clarify several sections of the draft EIS.

Products of Incomplete Combustion

The draft EIS did not include reference to a recent test EPA performed at the Raleigh NC facility “rainbow furnace”. AFFF was injected into the furnace at multiple temperatures and stack gas samples were analyzed using an OTM-50 methodology. EPA was able to confirm > 99.999% destruction but also confirmed that products of incomplete combustion was virtually zero when temperatures above 1090°C were used.

Section 1.5.1.3 – National Defense Authorization Act

The Clean Harbors PFAS Destruction test at the Aragonite UT facility was shared with both EPA and DoD. EPA did not have that data when the initial PFAS disposal guidance was developed but both agencies got it shortly after that publication.

Section 2.1.5.10 – Dangerous Waste Transport, Treatment and Disposal Facilities Contracted with Washington Department of Ecology

“People and Technology Creating a Better Environment”

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The Clean Harbors section includes information from a PFAS Destruction Test performed in 2021. That report was shared with several state and federal agencies including EPA, DoD, and the Department of Ecology. In addition to determining destruction removal efficiency, stack emissions were sampled and analyzed using EPA OTM-45. That data was run through EPA risk modeling and the results were 5-8 orders of magnitude below any state or federal air ambient limit/guideline in effect at the time. This risk assessment is the same required under RCRA for hazardous waste combustors.

The report and data were peer reviewed by Dr. Phil Taylor, a recognized incineration expert who has worked on PFAS destruction for decades. Dr. Taylor confirmed the destruction study was professionally designed and executed.

Section 3.1.4 – Data Gaps

As noted above, the PFAS destruction test was peer reviewed by Dr. Phil Taylor.

Page 3.3.10

Both the Aragonite UT and Kimball NE facilities have zero water discharge operations. All waste is managed in RCRA permitted containment to prevent any release to the environment.

Table 3.11-4 – Relative Risk Associated with Alternative 2 by Resource

The human health & safety impacts column does not mention the risk assessment modeling performed. This confirmed stack emissions are protective of human health.

Clean Harbors Environmental Services (CHES) elected to conduct its first full-scale testing of PFAS destruction at its HWC in Aragonite, Utah. The Team of EA Engineering, Science, and Technology, Inc. and Montrose Environmental Group, Inc. was retained by CHES to develop a comprehensive program for PFAS destruction testing at Aragonite, to conduct the testing and to report the results, under technical oversight by Focus Environmental, Inc. The testing was conducted June 2021 and included sampling and analysis for forty-nine target PFAS analytes in HWC process waste feed streams, treatment chemical feed streams, solid and liquid process residue streams, and HWC stack gases.

Three sets of waste feed conditions were evaluated by running triplicate tests under each condition.

1. Test Condition 1 was intended to establish a baseline, by feeding a typical waste profile, without adding additional PFAS spiking compounds to the waste feed (Test Runs 1 - 3).
2. During Test Condition 2 (Test Runs 4 - 6), the feed rates of perfluorooctanoic acid (PFOA) (CAS# 335-67-1), perfluorooctanesulfonic acid (PFOS) (CAS# 1763-23-1), perfluorohexane sulfonic acid (PFHxS) (CAS# 355-46-4), and hexafluoropropylene oxide – dimer acid (HFPO-DA or GenX) (CAS# 13252-13-6) were augmented by spiking to facilitate calculation of destruction and removal efficiency (DRE) values for these compounds.
3. During Test Condition 3 (Test Runs 7 - 9), aqueous film forming foam (AFFF) concentrate was also fed to the HWC.

U.S. Environmental Protection Agency Other Test Method 45 (OTM-45) was employed for sampling stack gas during the testing. The PFAS analytical method employed for this test program was Liquid Chromatography/Tandem Mass Spectrometry (LC/MS/MS) with Department of Defense Isotope Dilution for the forty-nine targeted PFAS analytes. U.S. Environmental Protection Agency Method 26A was employed for determination of hydrogen fluoride (HF) concentration in stack gas.

The results of the June 2021 testing demonstrate that common legacy PFAS (perfluorooctanoic acid (PFOA), perfluorooctanesulfonic acid (PFOS), perfluorohexane sulfonic acid (PFHxS), and hexafluoropropylene oxide – dimer acid (HFPO-DA or GenX are **effectively destroyed in the Aragonite incineration system at levels exceeding 99.9999 percent (%) DRE**. This was demonstrated during all three test runs (Test Runs 4–6) when spiking was conducted. It should be noted that RCRA and TSCA regulations require a 99.9999% DRE be demonstrated to destroy dioxins and polychlorinated biphenyls (PCB's).

In all cases DRE values were calculated using the most conservative approach. Analytes that were not detected in the feed materials were included as zero values in the waste feed material mass balance. PFAS contributions from treatment chemicals were not included in the DRE calculations (per Resource Conservation and Recovery Act (RCRA) regulations).
Analytes that were not detected in the stack gas samples were assumed to be present at the method detection limit (MDL) in the mass balance. Because of these various conservative assumptions, it is likely that all the actual DREs are greater than the values presented in this report.

Stack gas concentrations for all forty-nine target PFAS analytes were either not detectable, or if detectable results were near the limit of quantitation. The individual PFAS stack gas mass emission rates were extremely low, ranging from 10^{-9} to 10^{-7} pounds per hour (lb./hr.), with an aggregate stack emission rate for all target PFAS on the order of 10^{-6} lb./hr. **Stack gas**

emissions were modeled using EPA’s AERMOD program and were 5 to 8 orders of magnitude lower than any state or federal ambient air quality guideline if effect.

The Aragonite HWC is a zero-water discharge facility and all solids generated are sent to a RCRA hazardous waste landfill for secure disposal.

In summary, the test data supports RCRA permitted high temperature thermal destruction units can effectively destroy PFAS chemicals. Stack gas emissions were modeled using EPA methodology and are 5-8 orders of magnitude below any state or federal ambient air quality guideline if effect.

We appreciate the opportunity to provide comments.

Sincerely,

Michael Crisenbery

Michael Crisenbery, CHMM
SVP, Facilities Compliance and Government Affairs
Clean Harbors Environmental Services, Inc.

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Coalition for Responsible Waste Incineration

Sean

Thanks for the opportunity to comment on this document. We have already submitted a copy to the docket via email but wanted to send you a courtesy copy.

Please contact me if you have any questions.

Melvin Keener
Executive Director
CRWI
703-431-7343

Org-5-1

CRWI
Coalition for Responsible Waste Incineration

MEMBER COMPANIES

Bayer CropScience
Clean Harbors Environmental Services
Eastman Chemical Company
Heritage Thermal Services
INV Nylon Chemicals Americas, LLC
Ross Incineration Services, Inc.
The Dow Chemical Company
Veolia ES Technical Solutions, LLC
Westlake US 2, LLC

GENERATOR MEMBERS

Eli Lilly and Company
Formosa Plastics Corporation, USA
3M

ASSOCIATE MEMBERS

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Civil & Environmental Consultants, Inc.
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Spectrum Environmental Solutions LLC
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TEConsulting, LLC
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Wood, PLC

INDIVIDUAL MEMBERS

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New Jersey Institute of Technology
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February 5, 2024

Washington State Department of Ecology
Attn: Sean Smith
P.O. Box 330316
Shoreline, WA 98133-9716

The Coalition for Responsible Waste Incineration (CRWI) appreciates the opportunity to submit a response to the *Draft Environmental Impact Statement (EIS); Aqueous Film-Forming Foam (AFFF)* as posted on December 20, 2023. CRWI is a trade association comprised of 29 members representing companies that own and operate hazardous waste combustors and companies that provide equipment and services to the combustion industry.

Attached are our specific comments.

Thank you for the opportunity to comment. If you have any questions, please contact me at (703-431-7343 or mel@crwi.org).

Sincerely yours,

Melvin E. Keener, Ph.D.
Executive Director

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Specific comments

1. Products of incomplete combustion

The draft repeats the following statement several times (in various forms)

> "PFAS destruction with these treatment devices remains uncertain due to concerns about products of incomplete combustion (PICs) and release of non-PFAS pollution."

The draft acknowledges that EPA is continuing research in this area. CRWI would like to point the State to a recent publication[1] that directly addresses this issue. Here the Agency reports experimental work using their Rainbow Furnace to destroy legacy aqueous film-forming foam (AFFF). The paper shows greater than 99.99% destruction for all of the PFAS components of this AFFF sample except for PFBA when fed directly into the flame. We suspect that this one example is an artifact since their results show 99.99% destruction at a slightly lower temperature (1090 °C). In fact, these results show greater than 99.999% destruction for a large number of the component PFAS compounds some as low as 970 °C. These results are consistent with those shown at Clean Harbors Aragonite and Chemours Fayetteville (discussion below). But more important, this paper shows the levels of PICs produced at various temperatures (see Table 3 in the publication, duplicated below with totals for each column added).

Table 3. Volatile PFAS and Other Gases Quantified in the Emissions from AFFF Incineration

	Temperature (°C)					
	Flame	1180	1090	970	870	810
Canister Analyses (µg/m^3)						
tetrafluoromethane	ND	ND	ND	ND	ND	ND
hexafluoroethane	ND	ND	ND	11.4	9.36	6.51
chlorotrifluoromethane	ND	ND	ND	ND	ND	ND
fluoroform	ND	ND	ND	5.47	601	7530
octafluoropropane	ND	ND	ND	267	903	795
difluoromethane	ND	ND	ND	2.87	8.51	94.4
pentafluoroethane	0.70	1.35	0.65	3.99	276	8950
octafluorocyclobutane	ND	ND	ND	ND	ND	14.1
fluoromethane	ND	ND	ND	ND	ND	1.30
tetrafluoroethylene	ND	ND	ND	ND	1.16	149

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[1] Pilot-Scale Thermal Destruction of Per- and Polyfluoroalkyl Substances in a Legacy Aqueous Film Forming Foam. 2023. Erin P. Shields, Jonathan D. Krug, William R. Roberson, Stephen R. Jackson, Marci G. Smeltz, Matthew R. Allen, R. Preston Burnette, John T. Nash, Larry Virtaranta, William Preston, Hannah K. Liberatore, M. Ariel Geer Wallace, Jeffrey V. Ryan, Peter H. Kariher, Paul M. Lemieux, and William P. Linak. https://pubs.acs.org/doi/10.1021/acsestengg.3c00098?ref=PDF.

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hexafluoropropylene	ND	0.19	ND	0.31	4.96	567
1,1,1-trifluoroethane	ND	ND	ND	ND	ND	ND
hexafluoropropene oxide	ND	ND	ND	ND	ND	ND
chlorodifluoromethane	ND	ND	ND	ND	ND	ND
1,1,1,2-tetrafluoroethane	ND	ND	ND	3.39	1.84	64.2
perfluorobutane	ND	0.30	ND	ND	434	620
1H-heptafluoropropane	ND	0.99	ND	ND	86.8	2480
octafluorocyclopentene	ND	ND	ND	ND	5.15	235
trichlorofluoromethane	0.40	0.17	0.57	0.57	0.40	0.57
dodecafluoro-n-pentane	ND	ND	ND	ND	51.2	503
1H-nonafluorobutane	ND	0.64	ND	ND	59.8	1230
tetradecafluorohexane	ND	ND	ND	ND	1.41	307
1H-perfluoropentane	ND	ND	ND	ND	12.1	1000
E1[a]	ND	ND	ND	ND	ND	ND
hexadecafluoroheptane	ND	ND	ND	ND	ND	85.81
1H-perfluorohexane	ND	ND	ND	ND	6.65	1090
perfluorooctane	ND	ND	ND	ND	ND	291
1H-perfluoroheptane	ND	ND	ND	ND	ND	316
1H-perfluorooctane	ND	ND	ND	ND	ND	203
E2[b]	ND	ND	ND	ND	ND	ND
Total	1.1	3.64	1.22	295	2463.34	26532.89
FTIR Analytes						
CO (ppm)	7.2	3.6	4.5	5.7	109	1730
CO_2 (%)	6.2	6.3	5.2	5.0	4.4	4
HF (ppm)[c]	427	340	278	266	260	227
NO (ppm)[c]	86.7	91	63.5	38.1	4.9	0.4
SO_2 (ppm)[c]	60.9	41.7	34	31.4	35.2	35.4
Other Gas						
Oxygen, O_2 (dry, %)	7.9	7.2	9.0	9.2	11.8	12.000

Table footnotes:

[a] Heptafluoropropyl 1,2,2,2-tetrafluoroethyl ether
[b] 2H-Pefluoro-5-methyl-3,6-dioxanonane
[c] Values not verified with CEM data or certified transfer standard

When closely examined, this data shows that AFFF when subjected to injection into the flame, 1180 °C, and 1090 °C have virtually no PICs measured when using current methods. When subjected to temperatures of 970 °C, the number goes up. This is primarily due to one compound, octafluoropropane, which accounts for approximately 90% of the PIC emissions at that temperature.

It is also interesting to note that carbon monoxide (CO) seems to be a good indicator of PIC emissions. This is exactly what EPA discovered in the 1980's when trying to measure PIC emissions during the destruction of organic compounds[2]. At that time, the Agency was focused on organic chemicals and chlorinated organic chemicals. Based on the evidence in the Table above, it appears that fluorinated organic compounds behave in a similar manner as all other organic chemicals. While the conditions needed for destruction may vary based on the chemistry of the materials being destroyed, the concepts developed to show destruction and continued compliance under RCRA[3] and carried over into the Clean Air Act requirements[4] apply for fluorinated organics as well.

CRWI believes there are data showing that under certain conditions, few fluorinated PICs are emitted. At destruction temperatures above 1000 °C, the highest concentration is 4 ppb. The vast majority were non-detects. We believe that the final EIS should include the same conclusions.

2. The draft environmental impact statement also lists advantages and disadvantages of using hazardous waste incinerators to destroy AFFF. The draft states that incineration is “one of only a few technologies that can potentially destroy PFAS, thus reducing future risks to public health and adverse effects on the environment.” CRWI agrees with that assessment but would take it one step further. It is the only commercially available technology that can handle the volumes of materials that need destruction. Tests at Clean Harbors Aragonite and Chemours Fayetteville for 2020[5] and 2022[6] have shown at least 99.99% reductions for the PFAS compounds fed.

   Under disadvantages, the draft states that “EPA research on incineration continues to evaluate effective destruction temperatures and treatment time, the potential to generate products of incomplete combustion, stack gas analyses, deposition onto land, and other risk factors.” Given the release of the 2023 paper (footnote 1), CRWI contends that the destruction temperature and residence time window is sufficiently defined. The research data from EPA used a variant of OTM-50 to sample and analyze PICs from the Rainbow Furnace. This method[7] was released by EPA on January 18, 2024. Now that it is available, facilities can start developing emissions data for the 30 PFAS compounds currently included in the method. These 30 compounds closely mirror the analysis done in the 2023 EPA paper (footnote1).

3. The draft includes the following data gaps. After each is a discussion on how CRWI believes these data gaps have been at least partially filled.

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[2] 55 FR 17,882, April 27, 1990
[3] 40 CFR 264.343(a)
[4] 40 CFR 63.1219(c)
[5] https://www.chemours.com/en/-/media/files/corporate/fayetteville-works/2020-03-thermal-oxidizer-test-report.pdf
[6] https://www.deq.nc.gov/coastal-management/gis/data/air-sampling/chemours-feb-2022-de-test-report-final/download?attachment
[7] https://www.epa.gov/system/files/documents/2024-01/otm-50-release-1_0.pdf

- "Clean Harbors reports that testing demonstrates that the Aragonite Incinerator destruction and removal efficiencies (DREs) exceed 99.9999 percent for common PFAS compounds (EA, 2021). It is not reported if these results have been subjected to peer review or scrutiny by regulatory agencies."

  While the Aragonite report was not peer-reviewed in the traditional sense, it was reviewed by Dr. Philip Taylor, one of the pre-eminent researchers in the field of combustion chemistry. EPA scientists at the Office of Research and development have a copy of this data and are presumably using it in the next draft of their disposal and destruction guidance document. The report has also been reviewed by the Department of Defense and the Utah Department of Environmental Quality.

- "PFAS are difficult to destroy due to the strength of the carbon-fluorine bond. Incomplete destruction or recombination of reactive intermediates can potentially result in the formation of new PFAS or other PICs of concern (EPA 2020c). Information regarding the emissions of PICs from PFAS incineration and their control is lacking."

  The carbon-fluoride bond is one of the strongest chemical bonds. However, it can be broken using the proper combustion fundamentals. This has been demonstrated numerous times in the laboratory and the field (see discussions above). EPA and the combustion industry have recognized this since the 1980's and developed a method to show destruction and continuous compliance with the conditions that guarantee destruction. This is accomplished by requiring hazardous waste combustion facilities to select one or more compounds that is more difficult to destroy than the compounds that they would normally combust and show at least 99.99% destruction removal efficiency (DRE) for those compounds. This concept was developed early in the regulation of hazardous waste incinerators under Subpart O of the RCRA regulations. In the guidance document for hazardous waste incinerators[8], EPA discusses the concepts for demonstrating DRE for organic hazardous waste. In the opening paragraphs of this guidance document, EPA explains this concept.

  > "The Subpart O regulations require that POHC's (Principal Organic Hazardous Constituents) be designated for each waste feed. The required DRE must then be demonstrated for the POHC's during the trial burn. Since the POHC's must be representative of the waste feed, they are chosen on factors such as difficulty to incinerate and concentration in the waste feed. The operator is then limited in the permit to burning only waste containing hazardous constituents no more difficult to incinerate than the POHC's for

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[8] Guidance on Setting Permit Conditions and reporting Trial Burn Results. Volume II of the Hazardous Waste Incineration Guidance Series, January 1989, EPA/625/6-89/019

> which compliance was demonstrated during the trial burn. The heat of combustion of the hazardous constituents has been used to rank the incinerability of compounds on the premise that compounds with a lower heat of combustion are more difficult to burn."

The guidance gives detailed instructions on selecting POHCs and the entire process of demonstrating DRE. Hazardous waste facilities have used this guidance since 1989 to demonstrate the ability to meet these criteria. Appendix VIII of the guidance contains a list of organic compounds ranked on how difficult they are to destroy (incinerability index). This idea was initially suggested by the researchers at the University of Dayton[9]. Class 1 chemicals on this list are the most difficult to destroy. For example, chlorobenzene is a Class 1 chemical. When a facility demonstrates a minimum DRE of 99.99% for chlorobenzene, it can be inferred that the facility can destroy a similar or greater percentage of any organic chemical ranked lower in Class 1 or any chemical in Classes 2, 3, or 4.

In a recent paper, Blotevogel, et, al.,[10] concluded that perfluorooctanoic acid would fit into Class 3 of the incinerability index and hexafluoropropylene oxide dimer acid would fit into Class 5. This shows that the initial destruction of the original compounds is relatively easy. The PIC question has been addressed by EPA research (discussed above).

- "PFAS chemicals are not specifically addressed in incinerator RCRA permits. The optimal conditions for PFAS destruction, allowable feed rates, and emissions have not been characterized."

  The draft environmental impact statement is correct that PFAS chemicals are not currently addressed in RCRA permits. This is because no PFAS compound has been designated as a hazardous waste. However, the optimal conditions for destruction has been demonstrated from by the data developed by Clean Harbors, Chemours, and EPA's Office of Research and Development.

- "Standardized methods for testing levels of PFAS emissions from stationary sources remain under development."

  While this may have been partially correct when the draft was released (OTM-45 has been available since 2021), OTM-50 was released early in 2024. These two test methods do not cover all the potential PFAS emissions but will give facilities and regulators the tools they need to determine if the original

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[9] Dellinger, B. and D. L. Hall. 1986. The Viability of Using Surrogate Compounds for Monitoring the Effectiveness of Incineration Systems. Journal of the Air Pollution Control Association, 36:179-183

[10] Blotevogel, J, R. J. Giraud, A. K. Rapp´e. 2023. PFAS compounds Incinerability of PFOA and HFPO-DA: Mechanisms, kinetics, and thermal stability ranking. Chemical Engineering Journal, Vol. 457, February 1, 2023. https://www.sciencedirect.com/science/article/pii/S138589472206716X.

compounds are destroyed and whether there are significant PICs produced in the process.

4. The relative risk associated with incineration is low.

The conclusions of the draft environmental impact statement states:

> "Human Health & Safety Impacts – Incomplete incineration of AFFF may deposit residual PFAS in the surrounding soils and nearby surface waterbodies if thermal treatment does not adequately control fluorinated products of incomplete combustion. Discharge from the incineration of AFFF from the project would not affect water resources. Deposition onto soils could occur in trace or very low measurable quantities. Therefore, the risk to these resources from incineration is low."

EPA's data shown in the table above supports this conclusion. For combustion temperatures above 1000 °C, the total PIC concentrations are less than 4 ppb. Ony when the combustion temperature falls below 1000 °C does the total PIC concentration show an increase and majority of this is from one compound, octafluoropropane. Toxicity information does not exist for this compound but according to the safety data sheets, octafluoropropane is relatively inert, nonflammable, and nontoxic.[11] CRWI believes that based on EPA data, this conclusion is correct.

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[11] https://cameochemicals.noaa.gov/chemical/4105#:~:text=Octafluoropropane%20is%20a%20colorless%2C%20odorless,because%20of%20displacement%20of%20oxygen

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REVIVE ENVIRONMENTAL TECHNOLOGY, LLC'S PUBLIC COMMENT IN RESPONSE TO THE STATE OF WASHINGTON DEPARTMENT OF ECOLOGY'S DRAFT ENVIRONMENTAL IMPACT STATEMENT REGARDING AQUEOUS FILM-FORMING FOAM COLLECTION AND DISPOSAL PROGRAM

INTRODUCTION

On December 22, 2023, the Washington Department of Ecology ("DoE") issued a draft Environmental Impact Statement ("EIS") regarding the State's proposed collection and disposal program for aqueous film-forming foam ("AFFF"). AFFF is a fire suppressant containing high concentrations of per- and polyfluoroalkyl Substances ("PFAS"), chemical compounds often known as "forever chemicals" due to the extremely strong carbon and fluorine bond.

Most notably, the EIS proposed four separate potential actions that could be used to implement the proposed AFFF collection and disposal program[1]: (1) Approved Hold in Place; (2) Incineration; (3) Solidification and Landfilling; and (4) Deep Well Injection. DoE also recognized that it could take no action at this time.

In addition to those listed actions, the EIS refers to "emerging technologies"[2] that were considered in the process. DoE stated, however, "[g]iven the uncertainty of when these technologies could be available for commercial use, and the uncertainty of acquiring the receiving state's approval to ship the AFFF, they were eliminated from further consideration as well. However, if one or more of these emerging treatments is further developed and becomes technically and commercially viable, the technology could be implemented under Alternative 1 in the future."

As detailed further below, Revive respectfully submits that supercritical water oxidation ("SCWO"), one of the listed emerging technologies, has been technically ready and commercially available since May 2023 and should be given additional and further consideration as one of the listed Alternatives. Pending that addition, we believe Alternative #1 ("Approved Hold in Place") in the EIS to be the only responsible action for DoE[3].

SUPERCRITICAL WATER OXIDATION AND PER- AND POLYFLUOROALKYL SUBSTANCES

SCWO is an advanced technology which destroys PFAS by leveraging the distinctive attributes of supercritical water to mineralize PFAS compounds. This "special phase" is achieved at temperatures above 374°C and pressures surpassing 22.1 MPa. These elevated pressures and temperatures allow for the broad and complete mineralization of PFAS within seconds. That has two implications:

- SCWO completely destroys all types of PFAS (long and short chain compounds), often to non-detect levels.
- SCWO only produces non-toxic byproducts - carbon dioxide, water, and brine.

SCWO treats all types of PFAS waste, including AFFF, landfill leachate, industrial wastewater, and contaminated groundwater.

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[1] See Washington State Department of Ecology, AFFF Collection and Disposal Program Draft EIS, Chapter 2: Project Description and Alternatives, Section 2.2

[2] See Washington State Department of Ecology, AFFF Collection and Disposal Program Draft EIS, Chapter 2: Project Description and Alternatives, Table 2-3: PFAS Destruction Technologies Considered and Eliminated as Alternatives, pages 2-25 and 2-26

[3] Revive would further support a consolidated collection program whereby all AFFF is collected and stored in a single facility

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There are multiple companies[4], in various stages of development, currently using SCWO-based technology systems to destroy PFAS compounds.

REVIVE ENVIRONMENTAL TECHNOLOGY IS COMMERCIALLY AVAILABLE; RESULTS

Revive is a clean technology spinout of Battelle, a nonprofit and the largest independent applied science and technology organization in the world, which has decades of environmental remediation technology experience. Revive was conceived six years ago to target the permanent destruction of PFAS in multiple applications, was formally established in December 2022, in financial partnership with Viking Global Investors, and operates as its own commercial entity today.

As a fully capitalized and independent firm, Revive became the first commercially available, fully permitted, complete PFAS destruction solution available in the U.S. Revive has successfully partnered with multiple state and local regulators to secure the necessary air and water discharge permits[5]. Revive rapidly scaled its capability and has seven operational PFAS Annihilators®, which have a combined ability to treat 700,000,000 gallons of PFAS-laden waste annually, when combined with other pre-treatment technologies.

In the first-ever deployments of a PFAS destruction technology in North America, Revive's PFAS Annihilators® are currently operating and destroying PFAS around the country, including over 55,000,000 gallons combined of landfill leachate, AFFF, industrial wastewater, and groundwater.

Importantly, because SCWO (and the PFAS Annihilator®) is a chemical process, its efficacy can be measured and verified to a far greater extent than landfilling, incineration, or deep well injection ("Incumbent Disposal Options"). Revive can produce batch-by-batch analytical evidence of the complete PFAS destruction and zero harmful byproducts, thus providing a higher level of transparency and certainty. To date, all deployments of the PFAS Annihilator® have destroyed PFAS molecules below the U.S. EPA's proposed 4 parts per trillion drinking water standards.

Finally, and perhaps most significantly, Revive is already assisting multiple states organize and conduct AFFF Takeback programs. Revive has been working with New Hampshire[6] and Ohio[7] on their respective takeback programs, which are scheduled for 2024. In addition to destroying their respective AFFF stockpiles, we are providing program infrastructure support, including arranging for collection, tracking, storage, destruction, and disposal. Thus, we have real world experience at every stage of the collection and disposal process.

SCWO AND PFAS ANNIHILATOR®'S REDUCED POTENTIAL OF ADVERSE ENVIRONMENTAL IMPACTS[8]

"The intent of [DoE's] DEIS, as detailed in Chapter 1, is to provide sufficient information on the best options for AFFF disposal that align with the protection of human health and the environment. With this information, [DoE] will make an informed decision on which alternative or alternatives should be selected for implementation."[9] Pursuant to this mission, DoE sought to analyze the "potential adverse

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[4] Revive Environmental Technology, General Atomics, and 374Water are companies actively deploying SCWO technology to destroy PFAS

[5] Revive has operated within all necessary permits or exemptions in Michigan and is currently in the process of receiving permits and exemptions in Ohio

[6] https://newhampshirebulletin.com/2023/07/25/nh-is-first-state-to-partner-with-pfas-annihilator-to-destroy-firefighting-foams/

[7] https://governor.ohio.gov/media/news-and-media/governor-dewine-announces-project-to-destroy-toxic-firefighting-foam

[8] Please note these responses are from Revive's perspective. While SCWO technologies are similar, Revive does not have any experience with other SCWO providers to be able to speak to their capabilities in regard to individual risks

[9] Washington State Department of Ecology, AFFF Collection and Disposal Program Draft EIS, Chapter 2: Project Description and Alternatives, Section 2.1, page 2-1

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environmental impacts" of the available PFAS disposal options on "earth, water, and air quality, and sensitive biological species and communities."

When compared to the Incumbent Disposal Options, the PFAS Annihilator® presents the same or less potential adverse environmental impacts[10].

- Its air emissions are demonstrably cleaner than those from an incinerator, consisting of only carbon dioxide and no PFAS molecules.
- Likewise, the impact on aquatic resources and terrestrial habitats is near zero due to the destruction of the PFAS molecules. Landfilling and deep well injection only move PFAS around without addressing the core problem.
- Concerns about spills from vehicle accidents or other handling mishaps can be greatly reduced due to PFAS Annihilator's® ability to be deployed on site, significantly decreasing the cumulative transport miles needed to destroy the AFFF.
- Unlike the Incumbent Disposal Options, the PFAS Annihilator® does not have environmental justice concerns. Landfills and incinerators are frequently located in or near environmental justice communities, with harmful effects disproportionately impacting disadvantaged low-income, overburdened communities.

CONCLUSION

Revive strongly recommends the Washington Department of Ecology reconsider the exclusion of SCWO as an approved disposal method in its upcoming AFFF disposal program. SCWO technology not only aligns with the DoE's commitment to protect human health and the environment but also offers a more sustainable and transparent solution compared to Incumbent Disposal Options. By including SCWO, the DoE will benefit from a proven, commercially viable technology that guarantees complete destruction of PFAS with minimal environmental impact. We urge the Department to prioritize innovative, effective solutions like ours in its final decision, ensuring a safer and cleaner future for Washington's communities and natural resources.

Until such time as DoE has completed the additional review needed to include SCWO as a listed Alternative, DoE should proceed with Alternative #1 ("Approved Hold in Place").

Respectfully submitted,

David Trueba
Chief Executive Officer

REVIVE ENVIRONMENTAL TECHNOLOGY, LLC
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[10] See Exhibit 1 for a detailed summary of the reduced environmental impacts of the PFAS Annihilator®

EXHIBIT 1
CATEGORY-BY-CATEGORY ANALYSIS OF PFAS ANNIHILATOR® WITH REGARD TO POTENTIAL ADVERSE ENVIRONMENTAL IMPACTS

Below is greater detail of the limited potential environmental impacts of the PFAS Annihilator® based on the categories used in the EIS.

Greenhouse Gas Emissions – Revive's PFAS Annihilator® produces a de minimus amount of carbon dioxide during the treatment process. In fact, state regulators in Ohio and Michigan have determined that the amount was so low as to not require any type of permit. Despite the lack of harmful emissions, all exhaust from the PFAS Annihilator® is run through a vapor polishing process to ensure there are no detrimental emissions.

Transportation and Truck Safety – Revive's PFAS Annihilator® is built inside a conex box and designed to be mobile, so it can be delivered to a DoE-selected location to destroy the AFFF. A central collection and storage location would greatly reduce the risk of potential spills from vehicle accidents or other handling mishaps due to PFAS Annihilator's® ability to be deployed on site, significantly decreasing the cumulative transport miles needed to destroy the AFFF.

Earth and Water Resources – Revive's PFAS Annihilator® would have even fewer potential adverse effects on soils, surface water, and groundwater. While the risks for vehicle accidents or spills in transport exist, Revive's complete destruction of PFAS means there are no harmful byproducts, and no further contamination risk, after processing. Conversely, this is not true for the Incumbent Disposal Options. Solidification and landfilling can always seep back into landfill leachate and sanitary sewers. Deep well injection necessarily puts untreated AFFF directly into the ground with the hope that it will not contaminate groundwater. And the emissions from incineration may contain PFAS particulate that can land in lakes and waterways.

Aquatic Resources; Terrestrial Habitats; Vegetation – The PFAS Annihilator® poses virtually no risk of an adverse environmental impact to earth – from aquatic resources to vegetation - for multiple reasons. First, the PFAS Annihilator® can be deployed to locations close to previously collected AFFF significantly reducing risks associated with transporting AFFF. Second, the complete mineralization of the PFAS in the AFFF means there is no risk of PFAS eventually making its way into Washington's waterways.

Human Health and Safety; Tribal Resources; Cultural and Historical Resources – For the reasons state above, there are no risks to inhabitants of Washington State during the processing and destruction of PFAS via the PFAS Annihilator®.

Environmental Justice - There are societal benefits to SCWO and Revive's PFAS Annihilator® beyond the complete and broad destruction of PFAS. Many incumbent PFAS disposal methods are problematic beyond the uncertainties regarding their effectiveness. Landfills and incinerators are frequently located in marginalized areas, with their harmful effects disproportionately impacting low-income, minority communities. This siting practice contributes to health disparities and environmental burdens in these areas. The communities affected by these siting decisions lack the political and economic power to oppose such facilities, leading to a concentration of pollution and associated health risks in regions already facing socio-economic challenges. Because SCWO and Revive's PFAS Annihilator® completely mineralizes PFAS without creating harmful byproducts, it is safe for every community.

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Environmental Technology Council

1112 16th Street NW • Suite 420 • Washington DC 20036 • (202) 783-0870

Electronically Filed February 5, 2024

Mr. Sean Smith
Product Replacement Program Manager
Washington State Department of Ecology
Northwest Region Office
P.O. Box 330316
Shoreline, WA 98133-9716

RE: **Aqueous Film-Forming Foam Collection and Disposal Program: Draft Programmatic Environmental Impact Statement**

Dear Mr. Smith:

The Environmental Technology Council (ETC) submits these comments on Washington State Department of Ecology's Aqueous Film-Forming Foam Collection and Disposal Program: Draft Environmental Impact Statement, Publication Number 23-04-064 (December 2023).

Statement of Interest

These comments are filed by the ETC, a national trade association of commercial firms that provide technologies and services to customers for recycling, treatment, and secure disposal of industrial and hazardous wastes. ETC member companies own and operate a wide variety of commercial units, including spent solvent distillation, oil recovery, metals reclamation, mercury recovery from fluorescent lamps, wastewater treatment plants, collection, and transfer stations, Resource Conservation and Recovery Act (RCRA) regulated secure landfills, high-temperature incinerators, cement kilns, and a variety of other technologies. ETC member companies have worked with states and federal agencies on matters concerning the safe and proper destruction and disposal of PFAS compounds, materials containing PFAS and aqueous film-forming foam (AFFF). Additionally, these companies have advanced environmental management systems to comply with the strict standards of RCRA, the Clean Air Act (CAA), the Clean Water Act (CWA), the Toxic Substances Control Act (TSCA) and many other environmental, health, and safety laws.

Background

PFAS references a large class of man-made chemicals characterized by having a carbon skeleton with multiple fluorine atoms attached. PFAS represents thousands of different chemical compounds rather than a single chemical. PFAS compounds have been used since the 1940s and are found in many consumer products like cookware, food packaging, and stain repellents, as well as in the plating and metal finishing industry. These chemical compounds are also used extensively in AFFF. While perfluorooctanoic acid (PFOA) and perfluorooctane sulfonic acid (PFOS) are the most studied PFAS compounds,

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they have been phased out by industry in the United States, Europe, and Japan. Other PFAS compounds found in GenX and ADONA chemicals are still used in commerce. Given the relatively recent increase in interest in these compounds, a key question is what technologies can be used to safely dispose of or destroy PFAS containing AFFF. Over the years Congress and the states have been working to find answers to these questions and to get a better understanding of the technologies currently available to address both destruction and disposal.

The Aqueous Film-Forming Foam Collection and Disposal Program: Draft Programmatic Environmental Impact Statement on which the Department seeks comment focuses on the most effective collection, treatment, and disposal of AFFF stored at fire departments throughout the state of Washington. The Draft identifies a range of options for the treatment, disposal, and long-term lower risk storage of AFFF. The options presented include:

- Incineration – AFFF would be collected and transported to a selected existing treatment facility for incineration.
- Solidification and Landfilling – AFFF would be collected and transported to a selected landfill facility or facilities for solidification and disposal.
- Class I Deep Well Injection – AFFF would be collected and transported to a selected Class I Deep Well injection facility or facilities for disposal.
- Approved Hold in Place – AFFF would be held in place at participating fire stations with suitable containment approved and reimbursed by the Department until acceptable advanced treatment technology becomes available.
- No Action – AFFF would remain as is at participating fire stations.

It is worth noting that collection and storage of AFFF at a centralized location, non-vehicle (air and maritime) transport of AFFF materials and the use of emerging technologies for commercial PFAS treatment were also considered by the Department, but the Department decided to eliminate them from consideration for purposes of the Draft.

High Temperature Incineration

Understanding the chemical structure of PFAS compounds is important to ensuring destruction through incineration. PFAS compounds are mid-length carbon-chain compounds with the most common having eight carbons. However, the number of carbon atoms can range from as few as four to as many as 12. Each carbon atom on the chain has 2 or 3 fluorine atoms attached, except for the terminal carbon. The terminal carbon atom can be attached to a carboxylic acid group (PFOA), a sulfonic acid group (PFOS), or other heteroatom-containing groups such as sulfonamides (PFOSA).

In discussing hazardous waste combustion technologies, the Draft correctly points out that incineration is one of only a few technologies that can potentially destroy PFAS compounds. This is because commercial incinerators have the ability to achieve temperatures and residence times sufficient to break apart PFAS compounds contained in the waste stream being thermally treated. In fact, RCRA permitted hazardous waste facilities must follow stringent regulatory requirements and are required by EPA to conduct testing to determine Destruction and Removal Efficiency (DRE) performance. 40 CFR 63.1219(c). Time, temperature, and turbulence ensure good combustion and high DRE. The purpose of DRE testing is to show a percentage that represents the number of molecules of a compound destroyed in an incinerator relative to the number of molecules that entered the system. For hazardous waste combustion units EPA requires a minimum DRE of 99.99%. ETC member company Clean Harbors recently conducted tests which demonstrated a DRE of 99.9999% (test results can be requested at https://www.cleanharbors.com/PFAS-Study). Additionally, the U.S. Department of Defense lists 140 research projects on the destruction of materials containing PFAS compounds that can be found at https://serdp-estcp.org/focusareas/deb5c156-f647-4934-8313-fa00364ff55e/treatment-of-pfas-impacted-matrices.

Additionally, we stress the position that RCRA and CAA permitting requirements that provide additional regulatory oversight and include operating requirements and emission limitations to safely and effectively treat hazardous and non-hazardous contaminants cannot be overlooked. RCRA hazardous waste facilities are subject to CAA Title V permitting requirements and to maximum achievable control technology standards pursuant to § 112 of the CAA that include, emission limitations for metals, dioxin/furans, particulate matter, hydrogen chloride and chlorine gas, and carbon monoxide or hydrocarbons, as well as limits on minimum organic DRE. Also, under the authority of RCRA's "omnibus" clause (§ 3005(c)(3); and 40 CFR 270.32 (b)(2)), RCRA permit writers may impose additional terms and conditions on a site-specific basis as may be necessary to protect human health and the environment. Due to these additional safeguards, we believe RCRA regulated commercial incinerators are well suited to safely and properly destroy materials containing PFAS compounds such as AFFF.

While the Draft considers incineration as a viable destruction option, it also considers landfills and deep well injections as viable disposal options. Keeping all options in the toolbox is important given the environmental and human health harms that can be caused by PFAS compounds found in AFFF.

Solidification and Landfilling

In addition to regulated hazardous waste incinerators, ETC members also own and operate RCRA Subtitle C and D landfills. As noted in the Draft, permitted hazardous waste landfills are designed, per RCRA requirements, with rigorous liner and cap systems to limit the risk of releases to the environment. Specifically, Subtitle C of RCRA establishes stringent requirements for the proper management of hazardous wastes to minimize potential risks to human health and the environment. Subtitle C landfills employ extensive environmental controls such as double liner systems, waste immobilization techniques, leachate collection technologies, and leak detection systems. Additionally, they are subject to frequent agency inspections and are required by regulations and permits to maintain extensive record keeping to track and prevent any migration of waste to the environment. Finally, RCRA regulations and specific permits require Subtitle C landfill operators to frequently conduct inspections to ensure operating conditions and environmental controls are always operating at their optimal capabilities. Subtitle D landfills are also subject to extensive federal, state, and local environmental, health and safety requirements including detailed design criteria, location restrictions, financial assurance capability, corrective action standards and requirements for closure and post-closure periods. Therefore, Subtitle D landfills should also be considered a viable option for disposal.

ETC encourages the Department to include Subtitle C and Subtitle D facilities in the mix of viable technologies to address AFFF treatment and disposal as they are very well suited to manage highly concentrated PFAS compounds in waste streams. For example, treatment methods used to stabilize wastes are applied to minimize the mobilization and migration of PFAS out of these disposed wastes. Most Subtitle C facilities, and many Subtitle D facilities, have closed-loop systems that manage leachate within the facility rather than discharging leachate for offsite treatment. PFAS compounds in waste streams that are disposed in landfills that produce minimal leachate volumes, especially those facilities that employ stabilization or solidification technologies and are in dry climates, afford heightened levels of environmental protection. Accordingly, ETC recommends that the Department recognize that these facilities offer a reduced risk of PFAS compound migration into the environment and should be considered a viable disposal option for AFFF. Again, it is important to keep all proven technologies in the mix of destruction and disposal options.

Class I Deep Well Injection

In addition to high temperature incineration and landfilling, ETC also views underground injection as a viable option for the disposal of AFFF. Along these lines, some ETC member companies own and operate Class I waste disposal wells. These wells are designed to dispose of and isolate liquid waste below the land surface and beneath underground sources of drinking water (USDW). The standards associated with the construction, operation and monitoring of Class I waste disposal wells are designed to ensure protection of USDW. For example, these standards include at least one confining layer between the zone in which the fluid will be emplaced and the lowest USDW.

The Draft indicates that a disadvantage of Class I deep well injection is that deep well injection facilities are generally operated under limited compliance monitoring; therefore, the long-term stability of injected wastes is undocumented. To the contrary, waste disposal via Class I injection wells is only permitted if the operator can demonstrate the waste will remain in place where it has been injected. To demonstrate this an operator must receive approval of a “no-migration petition” from EPA. A no-migration petition is used to give EPA information and modeling results using data on local and regional geology, waste characteristics, geochemical conditions of the well site, injection history, and many other factors EPA uses to determine whether the operator has adequately demonstrated that the waste will not migrate from the disposal site. These strict requirements and oversight coupled with the fact that Class I waste disposal wells are designed to dispose of and isolate liquid wastes below the land surface and beneath USDW, make these wells a viable option for the disposal of certain PFAS compounds.

Understanding that this technology may not be available everywhere, ETC supports its use where appropriate. Underground injection to Class I waste wells can reduce the potential risks of human exposure to injected materials, assist in avoiding discharge to surface and shallow groundwater and virtually eliminate air emissions. Since Class I wells are only sited in geological areas conducive to injection operations, we agree with the Department's assessment that this may be a limited technology. However, due to the benefits of this technology it must be kept in the mix of options for destruction and disposal.

Approved Hold in Place

The alternative option "approved hold in place" is essentially storage. While storage of AFFF is not a destruction or disposal technology, the Draft does note that extended interim storage may be an appropriate strategy until identified uncertainties are addressed and appropriate destruction and disposal technologies can be recommended. ETC **does not** support storage in lieu of disposal. Allowing for storage of certain AFFF would create the risks of spills and accidental releases which we believe are unacceptable. Also, the presence of certain PFAS compounds when deemed a hazardous substance under the Comprehensive Environmental Response Compensation and Liability Act and supported as such under the current Administration, creates long- term liability risk to property owners, operators, parties handling waste and others that encounter material managed from a site where PFAS was identified.

Alternatives and Actions Eliminated from Further Consideration

Regarding the collection and storage of AFFF at a centralized location and the non-vehicle transport (i.e., air and maritime) of AFFF materials, ETC agrees with the Department that these options should not be considered. As noted previously, allowing storage of certain PFAS and AFFF would create the risks of spills and accidental releases. In the case of non-vehicle transport, the Department points out that the releases could be to air and water, thus the elimination of this option.

ETC understands that there is much uncertainty as to when many emerging PFAS compound treatment technologies will become available for commercial use. However, we encourage the Department to closely monitor the research and development conducted in this area. ETC member companies are constantly engaging in such efforts to bring about innovative technologies to address PFAS treatment and disposal.

Conclusion

As owners of RCRA regulated hazardous waste incinerators, landfills, and Class I deep injection wells, ETC member companies understand the importance of being good environmental stewards and ensuring that our operations do not result in harm to human health and the environment. Not only must we maintain compliance with our RCRA permits, but also with strict CAA and CWA regulations. Further, ETC member companies routinely engage in community outreach. This engagement is used to disseminate relevant information about our facilities and the operations performed. Regular community outreach also allows our member company employees the opportunity to participate in meaningful dialogue with the community and receive feedback on the impacts of facility operations with an understanding of local health trends, existing health conditions, and environmental justice concerns. Finally, as stated throughout our comments, ETC encourages the Department to keep all proven technologies in the mix of destruction and disposal options as it works to finalize this Draft.

In closing, ETC would like to thank the Department for the opportunity to submit comments on this important topic. If you have any questions, please feel free to contact James A. Williams via email at jwilliams@etc.org or at 202-731-1815.

Sincerely,

James A. Williams

James A. Williams
Executive Director

SIERRA CLUB

EARTHJUSTICE

February 5, 2024

Via Online Submission
Washington State Department of Ecology
Attn: Sean Smith
P.O. Box 330316
Shoreline, WA 98133

Re: Aqueous Film-Forming Foam Collection and Disposal Program: Draft Programmatic Environmental Impact Statement

Dear Mr. Smith:

The Sierra Club and Earthjustice respectfully submit these comments on the Washington State Department of Ecology's ("Ecology") Draft Programmatic Environmental Impact Statement ("DEIS") for the planned collection and disposal of Aqueous Film-Forming Foam ("AFFF") from fire stations across the state.

To begin, we support the state's AFFF collection and disposal efforts. For much of the last century, fire stations, airports, military bases, and other facilities used AFFF made from toxic per- and polyfluoroalkyl substances ("PFAS"), a large class of dangerously persistent chemicals. The PFAS in AFFF are associated with an increased risk of cancer, developmental and reproductive harm, immune system toxicity, and other severe health effects. In 2018, the state legislature passed a law to restrict AFFF due to the dangers it poses to firefighter health and because it had contaminated drinking water across the state. Fire stations now have stockpiles of highly toxic PFAS foams. Moreover, because of PFAS' "extreme persistence … [and] mobility,"[1] many treatment and disposal technologies fail to destroy or permanently contain PFAS, but rather continue the cycle of contamination by releasing additional PFAS to the air and water. Washington's AFFF collection and disposal program allows the state to make coordinated and informed decisions about the best methods of PFAS disposal, while relieving individual fire departments of the logistical and financial burdens associated with such disposal.

We also strongly support Ecology's decision to prepare an EIS for its AFFF disposal program. As the Environmental Protection Agency has acknowledged, "significant uncertainties remain" with respect to the effectiveness and environmental impact of traditional waste disposal methods – landfilling, incineration, and deep-well injection – when applied to PFAS-containing wastes.[2] AFFF disposal presents substantial environmental and health risks, and the EIS process

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[1] Carol F. Kwiatkowski et al., *Scientific Basis for Managing PFAS as a Chemical Class*, 7 Env't Sci. & Tech. Letters 532-543 (2020), DOI: 10.1021/acs.estlett.0c00255.

[2] EPA, *Interim Guidance on the Destruction and Disposal of Perfluoroalkyl and Polyfluoroalkyl Substances and Materials Containing Perfluoroalkyl and Polyfluoroalkyl Substances* at 4 (Dec. 2020), https://www.epa.gov/system/files/documents/2021-11/epa-hq-olem-2020-0527-0002_content.pdf.

offers an opportunity to carefully evaluate those impacts and to identify the safest and most effective disposal option.

However, Ecology's DEIS fails to provide the "impartial discussion of significant environmental impacts and … reasonable alternatives" that the State Environmental Policy Act ("SEPA") requires.[3] Ecology selected a private contractor with close ties to the hazardous waste incineration industry to prepare the EIS, a conflict that raises serious questions about the objectivity of the underlying analysis. The DEIS understates the harms associated with PFAS landfilling and incineration, declaring those impacts to be minimal based on a misapplication of industry test data while ignoring substantial evidence of data gaps and health risks. Ecology also understates the impacts of PFAS disposal on environmental justice communities, focusing exclusively on communities in the immediate vicinity of disposal sites even though PFAS are highly mobile and are known to cause disproportionate harms to lower income communities, Indigenous communities, and communities of color nationwide. Finally, Ecology fails to seriously consider several advanced PFAS destruction alternatives that have the potential to eliminate or reduce the impacts associated with traditional disposal technologies, such as super critical water oxidation ("SCWO") – which has been used to treat AFFF in other locations – and closed-loop Hydrothermal Alkaline Treatment ("HALT") technology developed by Washington-based Aquagga, the winner of EPA's Innovative Ways to Destroy PFAS Challenge.[4]

The impacts of Ecology's PFAS disposal decisions extend far beyond the 59,000 gallons of AFFF covered by the current collection and disposal program. In addition to fire stations, AFFF is also stored at ferry terminals, airports, refineries, and other industrial facilities across the state, and Ecology has acknowledged the potential for expanded collection and disposal efforts in the future. More broadly, other states, municipalities, and private parties are struggling with similar issues concerning PFAS disposal and are searching for better solutions. Ecology has a statutory obligation to carefully evaluate the environmental and health impacts of its PFAS disposal program, and its analysis and selection of alternatives has the potential to inform future decisions and move the nation towards more protective PFAS disposal technologies. In its final EIS, we urge Ecology to fully account for the risks associated with PFAS incineration as well as the potential benefits of alternative destruction technologies.

I. SEPA Requires Ecology to Carefully Evaluate the Environmental Impacts of Its AFFF Collection and Disposal Program, Including Alternative Disposal Options

SEPA "sets forth a state policy of protection, restoration and enhancement of the environment."[5] "The most important aspect of SEPA is full consideration of environmental values … and this policy is carried out by the EIS procedure."[6] The preparation of an EIS

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[3] Wash. Admin. Code § 197-11-400.

[4] EPA, Innovative Ways to Destroy PFAS Challenge: Winners, https://www.epa.gov/innovation/innovative-ways-destroy-pfas-challenge#Winners.

[5] *Polygon Corp. v. City of Seattle*, 578 P.2d 1309, 1312 (1978); *see also* Wash. Rev. Code § 43.21C.010; *Leschi Imp. Council v. Wash. State Highway Comm'n*, 525 P.2d 774, 781 (1974) (SEPA "indicates in the strongest possible terms the basic importance of environmental concerns to the people of this state.")

[6] *Sisley v. San Juan County*, 569 P. 2d 712, 718 (1977) (citation omitted).

"assures a full disclosure and consideration of environmental information prior to the [commencement] of the project."[7]

SEPA requires an EIS to "provide impartial discussion of significant environmental impacts and … inform decision makers and the public of reasonable alternatives, including mitigation measures, that would avoid or minimize adverse impacts or enhance environmental quality."[8] The test for significance of an environmental impact is "a reasonable likelihood of more than a moderate adverse impact on environmental quality."[9] This fact- and context-specific inquiry "does not lend itself to a formula or quantifiable test,"[10] but rather is "best determined 'on a case-by-case basis guided by all of the policy and factual considerations reasonably related to SEPA's terse directives."[11] Those factors must be considered in light of SEPA's underlying policy of maintenance, enhancement and restoration of the environment.[12]

SEPA also requires an EIS to contain a detailed discussion of reasonable alternatives to the agency's proposed action.[13] SEPA's administrative rules provide that an EIS must consider as alternatives those "actions that could feasibly attain or approximate a proposal's objectives, but at a lower environmental cost or decreased level of environmental degradation."[14] "The required discussion of alternatives to a proposed project is of major importance, because it provides a basis for a reasoned decision among alternatives having differing environmental impacts."[15]

Finally, SEPA "confers substantive authority to the deciding agency to act on the basis of the impacts disclosed."[16] SEPA is not purely an informational or procedural statute; it is intended to inform and promote decisions that further the statute's aims of environmental and health protection.

II. **Ecology Must Investigate and Disclose the Potential Conflicts Involving the Contractor It Selected to Prepare the EIS**

To prepare the DEIS, Ecology retained TRC Companies ("TRC"), a private consultant with longstanding ties to the hazardous waste incineration industry.[17] By its own account, TRC represents and "produce[s] bottom-line results for our commercial, solid and hazardous waste

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[7] *Id.; see also Asarco Inc. v. Air Quality Coal.*, 601 P.2d 501, 512 (1979) (SEPA demands a "thoughtful decision-making process").

[8] Wash. Admin. Code § 197-11-400.

[9] *Id.* § 197-11-794.

[10] *Id.*

[11] *Klickitat County Citizens Against Imported Waste v. Klickitat County*, 860 P.2d 390, 398-99 (1993) (citations omitted); *Cheney v. City of Mountlake Terrace*, 552 P.3d 184, 188-89 (1976).

[12] *Polygon Corp.*, 576 P.2d at 1312.

[13] Wash. Rev. Code § 43.21C.030(c)(iii).

[14] Wash. Admin. Code § 197-11-440(5)(b).

[15] *Weyerhaeuser v. Pierce County*, 873 P.2d 498, 504-05 (1994).

[16] *Polygon Corp.*, 578 P.2d at 1312.

[17] DEIS at 1-3 ("During the summer of 2021, Ecology completed a Request for Quotes and Qualification bid process and selected TRC to prepare the EIS report.")

clients."[18] For years, TRC has also been an associate member of the Coalition for Responsible Waste Incineration ("CRWI"), a trade association created in the 1980s by Dow, 3M, Monsanto and other hazardous waste generators to promote hazardous waste incineration.[19] CRWI members currently include hazardous waste incineration companies such as Clean Harbors Environmental Services, Heritage Thermal Services, Ross Incineration Services, and Veolia ES Technical Solutions, as well as numerous chemical and pesticide manufacturers.[20] TRC is listed as an "associate member," a membership tier designed for "companies that provide goods and services to the hazardous waste combustion industry."[21]

TRC's close ties to the incineration industry raise serious concerns about the objectivity of the DEIS, and in particular Ecology's assessment of the impacts of incinerating AFFF. The mission statement of CRWI states that "high temperature combustion is an integral part of the solution to the waste management challenge facing hazardous waste generators today" and that "for many wastes … combustion remains the safest, most appropriate treatment method."[22] CRWI has openly lobbied the White House Office of Science and Technology Policy to endorse PFAS incineration, which CRWI erroneously claimed to be the "only … commercially available method for destroying PFAS compounds."[23] TRC's membership in a trade organization that exists to encourage hazardous waste incineration, and that declared has incineration to be the "only" viable option for PFAS destruction, raises serious questions about whether TRC can even-handedly assess the environmental and health impacts of PFAS incineration and other disposal methods, as SEPA requires.

Ecology must immediately disclose the extent of TRC's role in the preparation of the DEIS, as well as any screening that Ecology conducted to evaluate potential conflicts of interest before retaining TRC to work on the EIS. While SEPA authorizes Ecology to use outside consultants to prepare an EIS, Ecology remains responsible for "assur[ing] that the EIS is prepared in a professional manner."[24] Here, Ecology failed to perform that required oversight. As described in greater detail below, the DEIS's assessment of the risks from PFAS incineration rely heavily on a single test conducted by Clean Harbors, a hazardous waste incinerator and CRWI member. The DEIS also identifies two Clean Harbors incinerators as potential disposal locations, without any discussion of the substantial gaps in Clean Harbors' testing or Clean Harbors' relationship to TRC. The public has the right to know whether TRC has any current or past contractual relationship with Clean Harbors or any other hazardous waste management company, and Ecology must ensure the "impartial[ity]" of the EIS by more closely scrutinizing TRC's analysis of incineration and other disposal methods, as set forth in greater detail below.[25]

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[18] TRC, Solid Waste Management, https://www.trccompanies.com/services/remediation-and-materials-management/solid-waste-management/.

[19] CRWI: Meeting a Vital Need, https://www.crwi.org/textfiles/about.htm; *see also, e.g.,* CRWI Update: December 31, 2023, https://www.crwi.org/textfiles/updec23.pdf (listing TRC as an "associate member" of CRWA).

[20] CRWI Update: December 31, 2023, https://www.crwi.org/textfiles/updec23.pdf.

[21] CRWI, CRWI Membership, https://www.crwi.org/textfiles/why.pdf.

[22] CRWI, Meeting a Vital Need, https://www.crwi.org/textfiles/about.htm.

[23] CRWI, Comments on Request for Information; Identifying Critical Data Gaps and Needs to Inform Federal Strategic Plan for PFAS Research and Development (Aug. 29, 2022), https://www.crwi.org/textfiles/ostp22.pdf; *see also* pp. 4-9 *infra* (describing the risks associated with PFAS incineration).

[24] Wash. Admin. Code § 197-11-420(2).

[25] *Id.* § 197-11-794.

III. Ecology Overlooks Significant Environmental and Health Risks Associated With PFAS Incineration

The DEIS badly understates the concerns regarding the safety of incineration as a disposal option for PFAS. Ecology fails to critically assess industry data effectiveness of PFAS incineration, overlooks potentially harmful byproducts of incineration, and presents an unrealistic view of the ability of compliance-plagued hazardous waste incinerators to operate at ideal conditions when incinerating PFAS stockpiles.

Ecology erroneously asserts that "[i]ncineration is one of only a few technologies that can potentially destroy PFAS … reducing future risks to public health and adverse effects on the environment."[26] The only cited support for that claim is a study conducted by a hazardous waste incinerator, without any government oversight, that purportedly found "destruction of 99.9999 percent of common legacy PFAS compounds."[27] But that study did not, and could not, establish the safety of PFAS incineration, since it did not measure the PFAS and other byproducts that are most likely to be produced during the incineration process.

Destruction and removal efficiency ("DRE") compares the levels of certain target PFAS in the feedstock waste with the levels of those chemicals in stack emissions following incineration. But it doesn't account for the formation of harmful byproducts that may be generated as result. The incineration of PFAS releases highly reactive fluorine molecules that can form a variety of harmful fluorinated compounds, including but not limited to new PFAS. As the Department of Energy and U.S. Environmental Protection have acknowledged, "incineration can result in the formation of other PFAS compounds in [stack] emissions," as well as other harmful products of incomplete combustion ("PICs") "which may become problematic in their own right."[28] A "destruction" method that merely converts one PFAS to another or generates toxic PICs does not "reduc[e] future risks to public health and adverse effects on the environment."[29]

A. The EIS Relies Exclusively on an Industry-Funded Study That Didn't Examine Harmful Byproducts of Incineration

The incineration destruction figure cited by Ecology comes from a single test conducted at Clean Harbors' Aragonite, Utah incinerator in July 2021.[30] This study measured PFAS emissions using EPA Other Test Method 45 ("OTM-45") for air, which is capable of detecting

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[26] DEIS at 2-21.

[27] *Id.*

[28] *See* Dep't of Energy, DOE Commercial Potential Evaluation (CPE) Report: PFAS in Wastewater at 30 (Aug. 2023), https://science.osti.gov/-/media/sbir/pdf/Application_Resources/2023/CPE-PFAS-Final-Report.pdf; EPA, Technical Brief: Per- and Polyfluoroalkyl Substances (PFAS) Incineration to Manage PFAS Waste Streams (Feb. 2020), https://www.epa.gov/sites/default/files/2019-09/documents/technical_brief_pfas_incineration_ioaa_approved_final_july_2019.pdf (findings that PFAS "can result in the formation of smaller PFAS products, or products of incomplete combustion (PICs), which may not have been researched and thus could be a potential chemical of concern.")

[29] DEIS at 2-21.

[30] *See* EA Eng'g, Sci. & Tech. and Montrose Envt'l Gr., *Report on PFAS Destruction Testing Results at Clean Harbors' Aragonite, Utah Hazardous Waste Incinerator* (Nov. 2021) ("Clean Harbors Test Report").

approximately 50 semi-volatile and polar PFAS, less than 1% of the PFAS class.[31] But PFAS incineration is also expected to produce a variety of volatile, nonpolar PFAS, which are not detected by OTM-45.[32] Clean Harbors thus cannot say whether its alleged destruction of PFOA and PFOS is actually creating new PFAS that it failed to measure its pilot study.[33]

Notably, while Washington presents the data on PFAS incineration as clear cut, a PFAS incineration scientist commissioned by Clean Harbors to review its study data raised concerns about the formation of breakdown products and the low recovery of fluorine in the form of hydrofluoric acid.[34] The challenges of documenting the ultimate fate of the fluorine molecules released during incineration led the scientist to conclude, "[i]n summary, development of better analysis methods organic and inorganic fluoride are needed to support PFAS-performance testing at the full scale."[35]

EPA recently released a new draft test method for air, OTM-50, which will capture up to 30 highly volatile, nonpolar PFAS, the very type of breakdown products expected to be produced by PFAS incineration. This method will allow future experimental and observational studies to more fully report products of incomplete combustion of PFAS materials.[36] But it was not used by Clean Harbors or in any of the studies referenced in the DEIS, precluding a full assessment of the effectiveness and impacts of PFAS incineration.

B. A Recent Study by EPA Scientists Confirms the Potential Generation of PFAS and Toxic Byproducts During PFAS Incineration

In July 2023, a publication by EPA scientists ("Shields et al.") reviewed the safety and efficacy of PFAS incineration in a trial study at EPA's Rainbow research combustor.[37] This study also used EPA method OTM-45 to measure the destruction of PFAS from AFFF

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[31] *See* Suzanne Yohannan, *EPA Eyeing Paired Issuance of PFAS Disposal Guidance, Air Test Method*, Inside PFAS Policy (Dec. 11, 2023) ("OTM-45 … measures approximately 50 semi-volatile per- and polyfluoroalkyl substances (PFAS) and polar PFAS in air emissions"); Nat'l Inst. of Env't Health Sci., *Per- and Polyfluoroalkyl Substances (PFAS)*, https://www.niehs.nih.gov/health/topics/agents/pfc ("PFAS are a group of nearly 15,000 synthetic chemicals").

[32] Suzanne Yohannan, *EPA Eyeing Paired Issuance of PFAS Disposal Guidance, Air Test Method*, Inside PFAS Policy (Dec. 11, 2023); *see also* Jeff Ryan, EPA Off. of Res. and Dev., Presentation to EPA Region 4 Spring Grants/Planning Meeting at Slide 13 (May 23, 2019), https://cfpub.epa.gov/si/si_public_file_download.cfm?p_download_id=538634&Lab=NRMRL

[33] *See, e.g.,* Clean Harbors Test Report at 7-3 ("Given that laboratory standards enabling targeted analysis exist for only about 50 of the thousands of extant PFAS, other analytical tools such as non-targeted PFAS analysis and Total Organic Fluorine … could be employed in the future to more completely characterize the PFAS profiles in the waste and other process streams, as well as in the stack gas.")

[34] Phil Taylor & Associates, LLC, *Final Report: Assessment of a Report on PFAS Destruction Testing Results at Clean Harbors' Aragonite, Utah Hazardous Waste Incinerator. Prepared for Clean Harbors Environmental Services, Inc.* (Jan 26, 2022) (a copy of this report is attached to these comments as **Exhibit A**).

[35] *Id.*

[36] EPA, Other Test Method 50 (OTM-50): Sampling and Analysis of Volatile Fluorinated Compounds from Stationary Sources Using Passivated Stainless-Steel Canisters (2024), https://www.epa.gov/system/files/documents/2024-01/otm-50-release-1_0.pdf

[37] Erin P Shields et al., *Pilot-Scale Thermal Destruction of Per-and Polyfluoroalkyl Substances in a Legacy Aqueous Film Forming Foam*, 3 Env't Sci. & Tech Eng'g. 1308-1317 (2023), DOI:10.1021/acsestengg.3.c00098 (a copy of this study is attached to these comments as **Exhibit B**).

compounds, while using but nontarget analysis of OTM-45 cannisters to identify about 10 fluorochemicals as breakdown products. These include fluoroform, pentafluoroethane, 1H-hepafluoropropane, and 1H perflouroheptane, which are greenhouse gases with long residency times in the atmosphere. Of particular importance was the observation that PFAS breakdown and byproduct formation is highly temperature dependent, with notable performance declines below experimental temperatures of 1000° C. At 970° C less than 99.99% of two shorter chain PFAS chemicals (PFBA and PFPeA) were destroyed. At 870° C cannisters included at least 15 measurable breakdown products at concentrations ranging from 0.4 to 903 mg/m^3. The authors conclude: "These results suggest that [destruction efficiency] alone may not be the best indication of total PFAS destruction, and additional PIC characterization may be warranted."[38]

The Shields study also focused on steady-state combustor operations, noting that the real-world operating conditions of a hazardous waste incinerator will inevitably include temporary disruptions to oxygen and temperature depressions.[39] The authors state the "time dependent behavior of PFAS in [hazardous waste incinerators] and other batch fed systems will depend on the system's ability to smooth these transients and maintain high temperatures," concluding, "[m]ore research into rotary kiln systems and full-scale incinerators is needed."[40] Multiple studies have detected elevated PFAS concentrations in the vicinity of operating incinerators or thermal oxidizers designed to destroy gaseous PFAS waste, raising further concerns about the impacts of PFAS incineration.[41] Ecology failed to consider those studies or address those potential impacts in its DEIS.

C. Commercial Incinerators, including Clean Harbors Aragonite, Do Not Routinely Operate the Under the Ideal Combustion Conditions Tested by Clean Harbors and Shield

The Shields study highlights the role that temperature and residency time of incinerators play in the effectiveness of thermal destruction of PFAS. Thermal breakdown is dependent on proper residency time, temperature and turbulence inside the incinerator chamber. But neither Shields nor Clean Harbors tested incinerators during their real world, commercial operations. Instead, those tests were conducted under carefully controlled conditions; EPA and Clean Harbors aimed for temperatures and retention times at the upper edge of commercial operating efficiency and manipulated the feedstock and operating conditions to attain desired temperature ranges and retention times. Notably, both of the Clean Harbors incinerators referenced in the EIS

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[38] *Id.* at 1308.

[39] *Id.* at 1314-15.

[40] *Id.* at 1315.

[41] *See* Kaitlin V. Martin et al., *PFAS Soil Concentrations Surrounding a Hazardous Waste Incinerator in East Liverpool, Ohio, An Environmental Justice Community*, 30 Env't Sci. Pollution Res. Int'l 80643-80654 (June 10, 2023), doi: 10.1007/s11356-023-27880-8 (detecting elevated PFAS levels in the soil surrounding the Heritage Thermal Services incinerator in East Liverpool, OH); Bennington College Press Release, *First in the Nation Testing Reveals Toxic Contamination in Soil and Water Near Norlite Incinerator* (Apr. 27, 2020), https://www.bennington.edu/sites/default/files/sources/docs/Norlite%20News%20Release%20%5Bdb%20final%20updated%5D.pdf (detecting elevated PFAS levels in the soil and groundwater surrounding Norlite incinerator in Cohoes, NY); Jiaqi Zhou et al. *Legacy and Emerging Airborne PFAS Collected on PM2.5 Filters in Close Proximity to a Fluoropolymer Manufacturing Facility.* 12 Env't Sci.: Processes & Impacts 2272-2283 (2022), https://pubs.rsc.org/en/content/articlelanding/2022/em/d2em00358a/unauth (measuring PFAS in the air near the Chemours Fayetteville NC facility, which uses a thermal oxidizer to treat gases containing PFAS)

– in Aragonite, Utah and Kimball, Nebraska – have already received and incinerated large volumes of AFFF and other PFAS-containing waste, but they did not measure their releases of PFAS during those operations.[42]

Ecology states that hazardous waste incinerators have administrative controls like permit conditions, operating and maintenance procedure and trained personnel to ensure incineration happens under carefully controlled conditions.[43] In reality, however, incinerators like Clean Harbors' Aragonite facility routinely violate permit requirements.

The Aragonite facility has a long history of environmental non-compliance, including "incinerating mercury-containing wastes that are prohibited from incineration," "incinerating lead-containing wastes that are prohibited from incineration," "failing to properly categorize wastes and/or document the categorization of wastes," "failing to calibrate monitoring instruments," and dozens of other violations.[44]

The other Clean Harbors incinerator considered by Ecology, in Kimball, Nebraska, has a similarly checkered compliance history, as documented in the accompanying analysis of several hazardous waste incinerators' environmental violations.[45] In 2020, EPA and Clean Harbors reached a settlement agreement resolving alleged violations related to emissions limits and reporting, including "failure to manage and contain hazardous wastes; failure to comply with air emission limits; failure to comply with chemical accident prevention safety requirements; and failure to timely report use of certain toxic chemicals.[46] Our analysis of publicly available records also indicated the facility had at least 105 total violations of emission limits, operating permit limit ("OPLs"), or other permit terms.[47] The facility reported at least 57 instances where it exceeded the emissions standard for total hydrocarbon content ("THC").[48] Of these, two were expressly linked in the facility's reports to problems maintaining adequate minimum temperature for the combustor.[49] There was one additional reported violation during this span where the facility violated its minimum temperature requirement.[50] The facility also documented ten exceedances of the particulate matter standard.[51]

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[42] According to EPA, Clean Harbors Aragonite burned more than 60,000 kg of PFAS between January 2023 and September 2023, at least 460,000 kg since 2018, while Clean Harbors in Kimball burned at least 237,000 kg of PFAS waste between 2018 and 2023. *See* EPA, PFAS Analytical Tools (2024), https://awsedap.epa.gov/public/extensions/PFAS_Tools/PFAS_Tools.html.

[43] DEIS at 3.1-8.

[44] Utah Dep't of Env't Quality, *Compliance History, for the Clean Harbors Aragonite, LLC Facility* (Aug. 25, 2021), https://documents.deq.utah.gov/waste-management-and-radiation-control/facilities/clean-harbors/aragonite/DSHW-2014-018229.pdf.

[45] *See* Sierra Club and Earthjustice, *Incineration is Not a Safe Disposal Method for PFAS* (2022) (a copy of this analysis is attached as **Exhibit C**).

[46] EPA Press Release, *United States and State of Nebraska Reach Settlement with Clean Harbors Environmental Services Inc. for Violations of Multiple Environmental Laws* (Aug. 31, 2020), https://www.epa.gov/newsreleases/united-states-and-state-nebraska-reach-settlement-clean-harbors-environmental-services

[47] Exhibit C at 9.

[48] *Id.*

[49] *Id.*

[50] *Id.*

[51] *Id.*

Those reports may actually underrepresent the facility's compliance problems. A separate report related to leak-detection also included reporting of startup/shutdown events, revealing incidents that are not reflected in the list of OPL and emission limit violations reported for 2019. Summary reports filed by the facility show that, during 2019, the facility was in "upset" mode and reporting excess THC emissions for a total of 45.7 hours. Of this total, 27.25 hours were attributable to "startup/shutdown" events with the remaining being attributable to "process problems." The facility reported an additional 0.4 hours of excess emissions related to O2-related upset conditions. EPA has characterized the Kimball, NE incinerator as a "significant noncomplier" with the Resource Conservation and Recovery Act ("RCRA") in every quarter since 2021.[52]

Those violations are not unique to Clean Harbors; other hazardous waste incinerators have similar number and types of permit violations, including explosions and major malfunctions.[53] It is common for air permits to exempt pollutant limits during periods of Start-up, Shut-down, and Malfunction ("SSM") events.[54] Given the gaps in the available test data, the potential releases of PFAS and other toxic byproducts from hazardous waste incinerators, and the long history of permit violations by Clean Harbors and others, Ecology cannot reasonably conclude that PFAS incineration presents "minimal" impacts on public health and the environment.

IV. Ecology Overlooks Significant Environmental and Health Risks Associated With Landfill Disposal of PFAS

Ecology also understates the impacts associated with the disposal of AFFF at hazardous waste landfills in Idaho and Nevada. Without considering the latest research on potential PFAS releases from landfills, Ecology asserts that "[t]he risk of PFAS release [from landfills] is very low" and "[t]he consequences [of such releases] would be insignificant."[55] These conclusions are not supported by the record.

Due to their volatility and mobility in water, substantial volumes of PFAS are projected to be lost from landfills each year. A recent review paper authored by EPA scientists ("Tolaymat et al") estimated that 1,233 kg of landfills are released annually via leachate and landfill gas, or approximately 15 percent of the quantity of PFAS shipped to U.S. landfills on a given year.[56] More than 130 kg of those PFAS releases are projected to be uncontained and released directly to environment.[57]

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[52] EPA, Enforcement and Compliance History Online, *Detailed Facility Report*: *Clean Harbors Environmental Services Inc. 2247 S. Highway 71, Kimball, NE*, https://echo.epa.gov/detailed-facility-report?fid=110041638458&ej_type=sup&ej_compare=US (last visited Feb. 4, 2024).

[53] *See* Earthjustice et al., *Vestiges of Environmental Racism* (2021) https://earthjustice.org/wp-content/uploads/earthjustice_ca-incinerator-report_20211108.pdf; EPA, *Complaint and Notice of Opportunity to Request a Hearing*, Docket No. CAA-02-2020-1004 (2020), https://dec.ny.gov/environmental-protection/waste-management/hazardous-waste/norlite-llc/enforcement-history

[54] *See* 40 C.F.R. §§ 60.2918, 60.3025.

[55] DEIS at 3.1-14 to 3.1-15.

[56] Thabet Tolaymat et al, *A Critical Review of Perfluoroalkyl and Polyfluoroalkyl Substances (PFAS) Landfill Disposal in the United States*, 905 Sci. of the Total Env't 167185 at *1 (2023) DOI: 10.1016/j.scitotenv.2023.167185 (a copy of this study is attached as **Exhibit D**).

[57] *Id.*

While Ecology has considered solidifying AFFF before sending it to a hazardous waste landfill, evidence suggests that PFAS solidification doesn't fully immobilize the chemicals. One study reports that the "[o]verall immobilization of PFAS analytes that were detectable in the leachate from two PFAS contaminated soils ranged from 87.1% to 99.9%"[58] Ecology must evaluate the possibility that some PFAS escape from the solidified AFFF and enter the air, soil, or groundwater.

A. PFAS Leach from Landfills, Creating the Need for Perpetual Management of Liquid Waste and the Likelihood of Uncontained PFAS Releases

Ecology glosses over concerns about PFAS washing out of landfills in the liquid waste or "leachate," stating that "leaching of PFAS compounds would be detected by leak detection system and PFAS compounds would be captured by the leachate collection and recovery system."[59] Ecology further states "the consequences [of landfilling] would be insignificant because, as described above, the partial pressure of PFAS in AFFF in the groundwater would be very low and the resulting ambient PFAS concentrations would be much less than the significance criteria."[60] But studies have estimated a significant amount of uncaptured PFAS leachate, and landfills often fail to destroy or permanently contain the PFAS in the leachate that they do capture.

PFAS are commonly detected in landfill leachate, across many different geographic locations and landfill types. One paper in particular measured PFAS in leachate from a landfill housing only municipal solid waste incinerator ash. The ash was residues of materials that were burned at 950º C, yet the landfill leachate contained more than 2000 ng/L of PFAS.[61] This indicates both that notable amounts of PFAS remained after incineration and were soluble in landfill liquids.

PFAS also leach from hazardous waste landfills. An analysis of 29 leachate samples from two California hazardous waste landfills measured average PFAS concentrations of 68,000 ng/L, with a maximum measured value of 377,000 ng/L.[62] Given this evidence that PFAS will leach from even solidified AFFF waste, Washington must more carefully consider the management and fate of leachate generated from any landfill accepting PFAS waste.

The options for perpetual leachate collection and safe disposal are far more complex than the disposal of a single containerized shipment of AFFF waste. Some landfills send leachate to wastewater treatment plants that are ill-equipped to remove PFAS compounds.[63] Others return

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[58] E. Barth et al., *Investigation of an Immobilization Process for PFAS Contaminated Soils*, 296 J. Env't Mgmt., 113069 (2021), DOI: 10.1016/j.jenvman.2021.113069.

[59] DEIS at 3.1-14.

[60] *Id.*

[61] Tolaymat, *supra* note 60, at *7 (citing S Liu et al, *Perfluoroalkyl Substances (PFASs) in Leachate, Fly Ash, and Bottom Ash from Waste Incineration Plants: Implications for the Environmental Release Oof PFAS*, 795 Sci. of the Total Env't 148468 (2021)).

[62] *Id.* at *8 (citing California Water Boards's GeoTracker PFAS Map).

[63] *Id.* at *11 ("In the US, most landfill leachate generated from RCRA-permitted landfills is managed off-site … represent[ing] a significant flux of PFAS leaving the landfill.")

leachate into the landfill for perpetual circulation, increasing the likelihood that the PFAS will eventually leach into the environment. We are only aware of one instance in which a landfill is exploring the use of on-site advanced destruction technology to destroy PFAS in leachate liquids.[64] Ecology did not consider that leachate treatment option in the DEIS.

B. PFAS Volatilize From Landfills and are not Destroyed by Methane Gas Flares

The DEIS also failed to adequately account for landfills' potential releases of PFAS to the air. The DEIS describes the possibility of PFAS volatilizing from solidified AFFF as "very low."[65] However, data on the failure rate for PFAS solidification should be also considered in context of new information about PFAS volatilization from landfills. The recent Tolaymat landfill review paper estimated that about 470 kg of PFAS per year up volatilizes into air annually from U.S. landfills.[66] The amount of landfill gas generation depends on the amount of moisture and microbial activity in the landfill. Injecting landfill leachate back into the landfill for circulation would increase both the PFAS and the moisture content of the landfill.

About three quarters of the landfill gas is captured or collected each year, with approximately 25% released to the air as fugitive emissions.[67] For the gas that is captured, even when landfills are equipped with flares to burn landfill gas the flare temperatures of 650-850º C are lower than the temperatures that would be expected to destroy gaseous PFAS. Instead of assuming "low" releases from the volatilization of PFAS from landfills, Ecology must consider the latest research and estimate the potential for air releases over the centuries that landfilled AFFF would remain on site. Moreover, since EPA is still years away from regulating any PFAS as hazardous waste, Ecology cannot assume that existing landfill permits and federal regulations will be sufficient to prevent significant adverse impacts from PFAS in leachate or landfill gas.

V. Ecology Understates the Environmental Justice Impacts Associated with PFAS Landfilling and Disposal

The DEIS also understates the environmental justice impacts associated with PFAS incineration and landfilling, asserting that the risks associated with those disposal options are "low to insignificant."[68] But Ecology underestimates both the likelihood of PFAS releases from those disposal options and the impacts of such releases on environmental justice communities who already bear a disproportionate burden of existing PFAS contamination.

As Ecology acknowledges, "[t]he first step in an EJ assessment is to identify the study area."[69] The DEIS defines the study area too narrowly, focusing solely on effects within a 10-mile radius of AFFF storage locations or potential disposal sites.[70] While that approach may be appropriate for pollutants with primarily localized impacts, it fails to capture the sweep of highly

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[64] EPA, Town of Conway Landfill Leachate Treatment Emerging Contaminants Project (2002), https://www.epa.gov/system/files/documents/2022-11/Conway-CWSRF-Emerging-Contaminants.pdf

[65] DEIS at 3.1-13

[66] Tolaymat, *supra* note 60, at 1.

[67] *Id.* at 13.

[68] DEIS at 3.11-20 to 3.11-22.

[69] *Id.* at 3.11-2.

[70] *Id.* at 3.11-20 to 3.11-22.

mobile and persistent chemicals like PFAS. PFAS that are emitted by an incinerator, that volatize from a landfill, or that leach into groundwater do not remain within a 10-mile radius of their release point. They spread long distances through the air, water, and soil, leaving a trail of contamination that extends from the peaks of Mount Everest to the depths of the ocean floor.[71] The communities that face the greatest risks from PFAS releases are not merely those nearest to the release site, but also those who are already exposed to PFAS contamination and are more susceptible to harm from further exposures.

As with many toxic pollutants, PFAS disproportionately harm lower income communities and communities of color. Low income households are 15 percent more likely to live around PFAS-contaminated sites than would be expected based on their share of the population, and African American households are 48 percent more likely to live around PFAS-contaminated sites than would be expected.[72] Another study found that "watersheds serving higher proportions of Hispanic/Latino and non-Hispanic Black populations had significantly greater odds of containing PFAS sources."[73] These inequities must be considered in Ecology's environmental justice analysis, since people who already have elevated levels of PFAS in their bodies are more likely be harmed by any additional releases from Ecology's AFFF disposal. Ecology's finding that there are no "communities of concern" within a 10-mile radius of its proposed landfills or incinerators does not mean that the proposed PFAS disposal will have no significant environmental justice impacts.[74] It just means that Ecology has drawn its study radius too narrowly.

VI. Ecology Prematurely Dismisses Available Alternatives With Lower Environmental Impacts

Washington Ecology's EIS rigidly focused on three traditional methods of hazardous waste disposal, ignoring promising innovations that could be much safer and more effective than incineration, landfilling and deep well injection. Notably both EPA and the Department of Defense have invested time, staff power and research money in honing options for advanced destruction techniques. DOD recently announced a PFAS treatment hub to pilot test PFAS destruction technologies.[75] EPA's PFAS Innovative Treatment Team research project was a limited-duration effort to review alternative destruction tools. It determined that four techniques held promise for achieving high levels of PFAS destruction.[76]

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[71] Murray Carpenter, *'Forever Chemicals,' Other Pollutants Found Around the Summit of Everest*, Wash. Post (Apr. 17, 2021), https://www.washingtonpost.com/science/mt-everest-pollution/2021/04/16/7b341ff0-909f-11eb-bb49-5cb2a95f4cec_story.html;

[72] Genna Reed, Union of Concerned Scientists, *PFAS Contamination Is an Equity Issue, and President Trump's EPA Is Failing to Fix It* (Oct. 30, 2019), https://blog.ucsusa.org/genna-reed/pfas-contamination-is-an-equity-issue-president-trumps-epa-is-failing-to-fix-it/.

[73] Jahred M. Liddie et al., *Sociodemographic Factors Are Associated with the Abundance of PFAS Sources and Detection in U.S. Community Water Systems*, 57 Env't Sci. & Tech. 7902-7912 (2023), https://pubs.acs.org/doi/pdf/10.1021/acs.est.2c07255.

[74] DEIS at 3.11-20 to 3.11-22.

[75] Megan Quinn, *DOD Taps PFAS Remediation Companies, Including Clean Earth, for Mitigation Research Project*, Waste Dive (Jan. 23, 2024), https://www.wastedive.com/news/pfas-remediation-department-of-defense-clean-earth-arcadis-aquagga/705285/.

[76] EPA, *PFAS Innovative Treatment Team* (2021), https://www.epa.gov/chemical-research/pfas-innovative-treatment-team-pitt

Advocates have long called for more equitable practices for hazardous waste disposal, to ensure the PFAS pollution crisis isn't simply shifted from one community to another.[77] Several key principles are:

(1) The need for tools that can be used onsite, obviating the need to transport waste long distances and keeping the hazardous waste impacts from being concentrated in historically burdened communities;
(2) The need to treat waste in contained systems, which can ensure destruction is complete before wastes are released to the environment.
(3) The need for a very high level of waste destruction efficiency with minimal formation of harmful byproducts.

As described below, significant progress is being made to pilot alternative technologies that live up to these principles. Washington State should be at the forefront of this process.

Two particular destruction technologies hold promise for achieving the key principles for equitable waste destruction. EPA scientists published a test of three commercial services using Super Critical Water Oxidation for AFFF destruction in 2022. It concluded, "as a destructive technology, SCWO may be an alternative to incineration."[78] SCWO is currently being used to treat PFAS in Michigan,[79] and it has been used to destroy other persistent wastes, including chemical weapons, for decades. A second treatment option, Hydrothermal Alkaline Treatment or HALT, has also been used to destroy PFAS in AFFF, with notable reduction of measurable PFAS compounds.[80]

The DEIS acknowledges several emerging PFAS destruction technologies, but states that "[g]iven the uncertainty of when these technologies could be available for commercial use, and the uncertainty of acquiring the receiving state's approval to ship the AFFF, they were eliminated from further consideration as well."[81] That alleged "uncertainty" is not a valid reason for rejecting those alternatives, particularly if they are capable of destroying PFAS with lower environmental and health impacts than traditional disposal options. First, as explained above, technologies like SCWO are readily "available" and have shown promise in treating AFFF. In one place, the DEIS references the potential use of a SCWO treatment facility in Grand Rapids, MI, but Ecology fails to explain why that option was not further pursued.[82]

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[77] *See* Letter from 65 Community Leaders to Brenda Mallory, White House Council on Environmental Quality (Dec. 6, 2022), https://www.sierraclub.org/sites/www.sierraclub.org/files/2022-12/Biden_CEQ%20Letter-%20PFAS%20clean%20up%20and%20disposal%202022.pdf.

[78] Max J Krause et al., *Supercritical Water Oxidation as an Innovative Technology for PFAS Destruction*, J Env't Eng'g 05021006 (2021), https://www.ncbi.nlm.nih.gov/pmc/articles/PMC10428202/pdf/nihms-1786112.pdf; *see also* EPA, Industrial SCWO for the Treatment of PFAS/AFFF Within a Water Matrix (Sept. 2022), https://cfpub.epa.gov/si/si_public_file_download.cfm?p_download_id=546712&Lab=CESER (reporting >99.99% PFAS destruction from SCWO treatment of AFFF).

[79] *See* Isiah Holmes, *System to 'Annihilate' PFAS Chemicals Deployed in Michigan*, Wisc. Examine (June 27, 2023), https://wisconsinexaminer.com/2023/06/27/system-to-annihilate-pfas-chemicals-deployed-in-michigan/.

[80] Aquagga, *Case Studies, AFFF Stockpiles*, https://www.aquagga.com/case-studies.

[81] DEIS at 2-24.

[82] *Id.* at 3.9-9.

Nor does the alleged "uncertainty of acquiring the receiving state's approval" justify Ecology's failure to consider advanced treatment technologies.[83] First, under state law, receiving state approval is not required if dangerous waste is sent to treatment facility that "is operating either: [u]nder a permit issued pursuant to the requirements of this chapter; or, if the TSD facility is located outside of this state, under interim status or a permit issued by United States EPA under 40 C.F.R. Part 270, or under interim status or a permit issued by another state which has been authorized by United States EPA pursuant to 40 C.F.R. Part 271."[84] The DEIS fails to examine whether any advanced treatment technologies could be employed at any facilities that would not require out-of-state authorization. The DEIS also does not state whether Ecology has affirmatively sought authorization from all states with advanced treatment capacity, and what those states' responses have been. If Ecology has done so, it must describe those efforts in greater detail in the final EIS. If Ecology has not, it cannot reject treatment technologies based on its speculation over how other states may respond.[85]

Finally, during a public webinar on the DEIS, Ecology referenced questions over whether other Washington state regulations governing the storage and disposal of "dangerous wastes," including PFAS, may preclude the use of SCWO and other emerging treatment technologies. The DEIS does not specify the nature of those concerns, leaving the public unable to evaluate and respond to them. However, we note that Ecology's dangerous waste regulations permit "treatability studies" to determine "whether the waste is amenable to the treatment process; what pretreatment (if any) is required; the optimal process conditions needed to achieve the desired treatment; the efficiency of a treatment process for a specific waste or wastes; or the characteristics and volumes of residuals from a particular treatment process."[86] At a minimum, we urge Ecology to consider the use of some or all of the collected AFFF in a treatability study to evaluate advanced PFAS treatment technologies and inform future disposal decisions.

Finally, we urge Ecology to consider temporary, off-site storage at a permitted hazardous waste storage facility as a disposal option. The U.S. Environmental Protection Agency and other agencies are currently pursuing a series of short-term and medium term research and development initiatives related to PFAS disposal, which are intended to enable decision-makers "to make informed decisions about the tradeoffs between different risk management solutions, leading to better environmental outcomes."[87] Interim off-site storage would enable Ecology to consider the results of this pending research and to make a more informed choice among disposal options. Moreover, the hazardous waste incinerator that Ecology identified as a potential recipient of the state's AFFF (Clean Harbors' Aragonite facility) is also permitted to store PFAS and hazardous waste. By Clean Harbors' own account, that facility has "ample on-site storage capacity," including "a bulk liquid tank farm (sixteen ~30,000 gallon tanks); container storage areas (~12,000 55-gallon drum capacity); direct burn tanker storage areas (~30,000 gallons total capacity); sludge storage tanks (~38,000 gallon total capacity); and bulk solids storage tanks

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[83] *Id.* at 2-24.

[84] Wash. Admin. Code § 173-303-141.

[85] *See King County v. Cent. Puget Sound Bd.*, 979 P.2d 374 (1999) ("An alternative considered for purposes of an EIS need not be certain or uncontested, it must only be reasonable.")

[86] Wash. Admin. Code §§ 173-303-040, 173-303-071(3)(r).

[87] EPA, *Interim Guidance on the Destruction and Disposal of Perfluoroalkyl and Polyfluoroalkyl Substances and Materials Containing Perfluoroalkyl and Polyfluoroalkyl Substances* at 93–97.

(~1100 yd3 total capacity).”[88] Moreover, while state regulations require hazardous waste generators to ship dangerous waste off-site within 90 days, they do not foreclose the use of safe off-state (and out-of-state) disposal pending the results of testing that may identify a safer permanent disposal option.

VII. Conclusion

We recognize the time and effort that went into the preparation of the DEIS, and we appreciate Ecology’s efforts to ensure the safe and efficient disposal of its AFFF. To inform that decision, however, Ecology must do more to evaluate the adverse impacts of PFAS incineration and landfill disposal, as well as modern disposal technologies that can eliminate or reduce those impacts.

Respectfully submitted,

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[88] Clean Harbors, *Aragonite Incineration Facility*, https://fr.cleanharbors.com/node/1156 (last visited Feb. 4, 2024); Utah Dep’t of Env’t Quality, *Aragonite Permit: Clean Harbors, LLC*, https://deq.utah.gov/waste-management-and-radiation-control/aragonite-permit-clean-harbors-llc (last updated December 21, 2023).

Exhibit A

Final Report: Assessment of a Report on PFAS Destruction Testing Results at Clean Harbors' Aragonite, Utah Hazardous Waste Incinerator

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January 26, 2022

Outline of Assessment

This assessment is divided into two sections. The first section gives an overall assessment of the PFAS Destruction Testing Results. The focus is the attainment of the primary and secondary objectives of the testing program. As stated in the PFAS Destruction Testing Results report, the primary objective was to demonstrate high DRE for the four spiked chemicals PFOA, PFOS, PFHxS, and HFPO-DA. The secondary objectives were to develop a mass balance for incidental PFAS in the waste infeed and to demonstrate high HF removal efficiency coincident with the high PFAS DRE. Some additional comments are provided at the end of this section. The second section is a detailed review of the PFAS Destruction Testing Results report and Appendices with specific questions, answers from Clean Harbors or its representatives, and in some instances, follow-up questions and answers. This approach laid the foundation for the overall assessment of the testing program.

Overall Assessment

The primary objective of demonstrating high DRE for spiked PFAS compounds was clearly achieved. Although there were serious issues with the transfer of the stack gas samples to the analytical laboratories, the analytical data are not in question given the extremely high thermal stability of PFAS at ambient or near-ambient conditions. Calculations are provided in Attachment A demonstrating the extreme thermal stability of PFOA and PFOS, corroborating the assertions of the report that the stack gas sample transfers to the analytical laboratory did not affect the accuracy of the measurements.

Greater than 99.9999% DRE was achieved for the spiked PFAS (PFOA, PFOS, PFHxS, and HFPO-DA) for average temperatures of greater than 1000 C in both the RK and the AB and residence times of greater than 3.0 sec (AB). While the testing stands on its own merit, there are recent bench-scale experimental (PFOS) and theoretical (*ab initio* modeling) published studies (PFOS, PFBA, and PFPA) that provide scientific support for these measurements. I have taken the kinetics reported in the published studies and calculated DREs and the data is shown in Attachment B. The calculations suggest temperatures of 800 C is sufficient to achieve > 99.9999 DRE of these compounds for afterburner residence times of 2.0 sec. (Note that the highlighted cells point to the lowest energy pathways for each substance.) It is interesting to note that the dominant breakdown pathway for PFOS, PFBA, and PFPA is not C-C scission along the C_8 carbon chain, but instead HF elimination from the polar end of the molecules. The C_8 chain is left intact and requires higher temperatures for the C-C bonds to be ruptured. This is the likely source of the C_1 and C_2 perfluorocarbon (PFC) PICs that are of concern.

The secondary objectives were considered the most difficult to achieve as they involve more complex sampling issues.

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The PFAS mass balance is credible and the resulting assertions regarding a conservative DRE are also credible. It is possible that some of the PFAS that was not sampled in the infeed may have been more difficult to gasify and burn, contrary to the assertions in the report. However, studies have shown that PFOA is very reactive on surfaces at low temperatures. And once in the gas-phase, PFOA and other PFAS appear to be of modest thermal stability. Based on current understanding, I believe that the PFAS DRE is conservative as stated in the report.

The HF removal efficiency assertion is not quite as clearcut. The data collected in Attachment C, the revised fluorine mass balance calculations provided by Focus Environmental, point to serious issues with respect to the fluoride measurements. While a HF removal efficiency of >99.6% is reported, the sinks for the HF were not accurately quantitated leading to some question about the validity of the reported HF removal efficiency. A confounding issue is the claim that all fluorine in the waste is converted to HF upon combustion. For this assumption to be scientifically valid, a large excess of hydrogen to fluorine is needed. This data is not provided in the report. Likely sources of hydrogen beyond what is in the waste feed would be an auxiliary fuel, e.g., natural gas, burned during the testing and/or the presence of moisture in the waste feed. Proof of complete conversion of the organic fluorine to HF can also be shown with the analytical data. However, this was not the case. There was a demonstrated lack of accuracy of the analytical methods for measuring inorganic fluorine in the residual streams. The data in the revised fluorine mass balance (Attachment C) indicate mass balances of only 2-10%. An assessment of the reasons for this low recovery of fluorine suggests there were likely analytical issues associated with the slag and spray dryer solids samples. Development of better analysis methods (for complex matrices) for inorganic fluorine are needed before high HF removal efficiencies can be reported with confidence at the full-scale.

In a related matter, it is also likely from the analysis of the ratio of fluorine in the brine relative to the waste infeed that the accuracy of the organic fluorine measurements is also questionable. This ratio varied over a very wide range (52 to 457%) in this testing program.

In summary, development of better analysis methods for both organic and inorganic fluorine are needed to support PFAS performance testing at the full-scale.

Additional Comments

PIC Formation – Full-scale testing is not generally a good source of data to examine PIC formation. In this testing, the low DRE of PFBA in runs 1, 3 and 7 (< 99%) is suggestive of PIC formation as there were many longer chain perfluoroalkyl acids in the waste infeed that could yield PFBA by a simple mechanism, C-C bond rupture. However, the higher DREs for PFBA in runs 4-6 where PFOA was spiked at higher concentrations is inconsistent with this hypothesis. In addition, the low PFBA DREs may simply be due to very low waste infeed concentrations.

PFBA has also been seen in high relative concentrations in the stack gases for other PFAS testing programs, e.g., MacGregor et al., 38th IT3 Conference, January 27, 2021. From Attachment B, it is shown that PFBA is not predicted to be thermally stable relative to other PFAS such as PFOS and PFPA. It is therefore unclear what mechanism is responsible for its relatively high emission rate compared to other PFAS. Perhaps it is not related to PIC formation but some other phenomena or a sampling and analysis artifact.

Final Comments – It is my opinion that the high PFAS DREs observed in this testing program are consistent with the state of the science of PFAS combustion. This science suggests that many PFAS compounds including the ones spiked in the waste infeed in this program are of modest thermal stability. The larger question from an environmental viewpoint is the complete mineralization of these substances and the prevention of emission of highly stable C_1- C_2 PFCs. The extensive fluoride measurements performed in this study are commendable although they did not provide accurate data in support of the mineralization of these substances. It should also be noted that demonstration of PFAS mineralization was not a goal of this testing program.

References to the Literature used for Calculations in Attachment 1 and 2

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S. W. Benson, "Thermochemistry and Kinetics of Sulfur-Containing Molecules and Radicals," Chemical Reviews, 78, 1978, pp. 23.

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Specific Observations from Review of Report on PFAS Destruction Testing Results at Clean Harbors' Aragonite, Utah Hazardous Waste Incinerator

Executive Summary:

1. From report: It should also be noted that high temperature treatment processes such as incineration probably have an effect on hidden PFAS mass in a waste stream similar to the laboratory chemical/thermal oxidation in the TOPA.

Question: Please provide further context and justification for this assertion.

Response: The TOPA process is a chemical oxidation process at mildly elevated temperatures. The chemical oxidation cleaves some bonds in the PFAS molecules, resulting in lower molecular weight compounds that are more likely to be target analytes. For example, AFFF may contain a variety of PFAS compounds, including 4:2 FTS, 6:2 FTS, 8:2 FTS, 10:2 FTS, 12:2 FTS. The first four compound are target analytes by EPA Method 537, whereas 12:2 FTS is not. The TOPA analysis revealed increases in the concentrations of the first four compounds, which were likely the result of the oxidation of higher molecular weight compounds, including 12:2 FTS or possibly other compounds. It is likely that a similar process could occur in high temperature thermal treatment processes, but at a much higher conversion efficiency.

Follow-up response: No additional questions.

2. From report: Due to the high efficiency of the dual dry scrubber/wet scrubber system, low HF emissions were measured throughout the testing. Measured values of fluorine ion in the stack gas samples were all J flagged values (values falling between the method detection limit and the limit of quantitation). The associated HF stack emission rate averaged 8.13E-03 lb/hr during the testing and the HF gas stack concentrations ranged from 0.07 to 0.14 parts per million dry volume basis, corrected to 7% oxygen. There are currently no HF emission limits under either the RCRA Hazardous Waste Incinerator Standards or the HWC Maximum Achievable Control Technology Standard. However, as points of comparison, the RCRA hydrogen chloride emission limit is 4.0 lb/hr and the Maximum Achievable Control Technology hydrogen chloride limit for existing HWC is 32 parts per million dry volume basis, corrected to 7% oxygen. HF is a Hazardous Air Pollutant (HAP) under the Clean Air Act, with a major source threshold of 10 tons/year. At the average HF emission rate measured during testing, annual emissions would be less than 100 pounds/year.

3. Question: Is there any evidence to suggest complete destruction of the spiked PFAS compounds occurred?

Response: There is a significant difference between "destruction" and "mineralization". Per the RCRA definition of destruction, a molecule is destroyed if it is chemically altered. This test program conclusively showed that >99.9999% destruction and removal efficiency could be obtained for a number of PFAS compounds if there was sufficient material in the feed to perform this demonstration, based on the analytical detection limit in the stack gas.

"Mineralization" requires showing that feed compounds are converted to stable end products including CO_2 and HF. Demonstrating complete PFAS mineralization would require performing a fluorine balance and verifying that all organic fluorine was converted to HF. This was not a goal of this program for the following reasons:

1) The plant was run under "normal" operating conditions, which included feeding solid waste (containers and shredded materials). Due to heterogeneity of these materials, there was no way to collect representative samples and analyze them for fluorine. Therefore, the total fluorine input to the system is not quantifiable for the solid waste materials. Hence, a complete fluorine balance is impossible for this type of system when feeding normal waste feed materials.
2) There may be multiple sources of fluorine in the feed material in addition to PFAS compounds. Examples include pesticides, pharmaceuticals, etc. There is no practical way to distinguish between the sources of fluorine in the feed materials that contribute to the HF produced in the offgas.

Follow-up response: No additional questions.

Section 1:

4. From report: PFAS are particularly challenging to degrade, both environmentally and thermally, due to the strength of the multiple carbon-fluorine (C-F) chemical bonds in these compounds.

Question / Response: There is growing evidence that the destruction of the C-4 through C-10 perfluorocarboxylates and C4-C10 perfluorosulfonates can be achieved at temperatures well below 1000 C. The destruction of lighter C1-C4 fluorocarbons derived as PICs from these parent compounds are likely to require higher temperatures, perhaps above 1000 C for CHxFy where x = 0 or 1 and y = 3 or 4, for complete destruction to CO2 and HF.

Response: No question asked, Clean Harbors agrees with the observation.

Follow-up response: None

5. From report: During the testing, the operating temperature of the RK ranged from 1,893 to 2,008 degrees Fahrenheit (F) and the operating temperature of the ABC ranged from 2,052 to 2,110 F.

Question: In Appendix B, minimum temperatures ranging from 1731 F (Test Condition 1) to

1773 F (Test Condition 3) were recorded for the RK. Are you reporting average temperatures in the statement from the report?

Response: The values cited in the text are the range of average temperatures for the nine test runs. They are not the absolute minimum and maximum values recorded in Appendix B.

Follow-up response: It is suggested that the text be modified as described in the response.

Response 2: Clean Harbors agrees that if the report is revised this statistical basis for the temperatures should be clarified.

6. From report: Combustion gas residence time in the ABC is estimated at 2 to 3 seconds.

Question: Are there calculations to back up this statement? I did not see any calculations in the report or the Appendices.

Response: Afterburner residence time cannot be measured directly; it can only be calculated from mass and energy balance calculations. Residence time is also not a regulatory parameter, therefore, there are no calculations of afterburner residence time in the report. However, based on mass and energy balance calculations that were performed for other purposes using the PFAS test data, the estimated average gas residence time in the afterburner during the PFAS tests was 3.1 seconds.

Follow-up response: No additional questions.

Section 2:

7. From report: This secondary test program goal was to demonstrate, to the extent practicable, an overall mass balance for the process and to calculate DREs for as many of the 49 target PFAS analytes as possible, based on PFAS feed rates and stack gas analytical detection limits.

Question: What mass balance are you referring to? The mass of PFAS compounds being fed? It is unclear on what is met by mass balance here. Mass balance can have several different meanings based on the context used.

Response: "Mass Balance" in the context of this report refers to calculating the mass of each individual PFAS compound in each process stream, including waste feed streams, reagent input streams, and process residual streams to the extent possible. The response to Question #3 explained the limitations on sampling and analysis of solid material, hence, PFAS materials in the solid waste feeds could not be included in the mass balance. Figures 6-1, 6-2, and 6-3 present a summary of the total PFAS mass balance data for each type of stream that was sampled and analyzed.

Please note that there are caveats that should be applied to these data because of how analytical detection limits were handled in calculations. For waste feed, reagent, and process residual streams, non-detects were assigned a value of zero in all calculations. For stack gas samples, all non-detects were assigned the detection limit in all calculations. This was done so that DRE calculations were done on the most conservative basis possible (i.e., likely omitting some PFAS mass in the feed and likely overestimating PFAS stack gas emission rates). Therefore, reported DRE values are likely underestimated.

Follow-up response: The wording here describing mass balance within the context of this report should be considered in a future revision of the report.

Response 2: Clean Harbors agrees that if the report is revised the use of the term “mass balance” should be clarified.

8. From report: Due to the high molar proportion of fluorine in PFAS chemicals, thermal treatment of these materials breaks the C-F bonds and generates byproduct HF, a HAP regulated under the Clean Air Act. Maximizing thermal breakdown of PFAS into products of complete combustion also maximizes the production of HF. Hence, current U.S. Environmental Protection Agency (EPA) guidance on PFAS thermal treatment emphasizes the importance of not only high PFAS DRE but also achieving low stack gas concentrations of HF. Stack gas samples for quantifying the presence of HF were withdrawn using an EPA Method 26A sampling train during each of the nine test runs to measure HF emission rates.

Question: Was PFAS destruction to HF measured directly in this study? This would be a direct and clear way to demonstrate a F mass balance and complete destruction of the PFAS in the feed.

Response: See response to Question #3.

Follow-up response: No additional questions.

<u>Section 3:</u>

9. From report: A detailed work plan was developed before conducting the tests to facilitate systematic execution of the field activities, including sampling, analysis, and quality control, to ensure that the project objectives would be met. Tests were run under each of three different process conditions typical of normal waste processing operations. Test Condition 1 (Test Runs 1-3) was intended to establish a baseline for results without adding additional PFAS spiking compounds to the waste feed. During Test Condition 2 (Test Runs 4-6), the feed rates of PFOA, PFOS, PFHxS, and HFPO-DA were augmented by spiking to facilitate calculation of DRE values for these compounds. During Test Condition 3 (Test Runs 7-9), AFFF concentrate was also fed to the incinerator.

Question: What was the purpose of test condition 3, how does it relate to test condition 1 and 2, and how was the data used to demonstrate PFAS DRE?

Response: The purpose of Test Condition #1 was to feed normal waste feed materials that were not known to specifically contain PFAS compounds (baseline conditions). The purpose of Test Condition #2 was to feed normal waste feed materials (similar to Test Condition #1) but to also spike four PFAS compounds at feed rates that had been calculated for each compound to be sufficient to demonstrate >99.9999% DRE based on the estimated analytical detection limit in the stack gas for each specific spiking compound. The purpose of Test Condition #3 was to feed a waste material (AFFF) that was believed to contain a significant concentration of PFAS and is also a commercial product that is likely to be processed though the incinerator on a routine basis.

DRE values were calculated for every target analyte for every run for each test condition. However, it should be noted that feed concentrations of many of the PFAS target analytes were too low to demonstrate the 99.99% DRE value required by RCRA regulations at the analytical detection limits that were achievable in the stack gas.

Follow-up response: No additional questions.

10. From report: The mass balance for the four spiked PFAS also included the spiked amounts.

Question: What is meant by this statement?

Response: For the overall mass balances as shown in Figures 6-1, 6-2, and 6-2 the amounts of PFAS spiked during Test Condition #2 make up a significant fraction of the overall PFAS mass fed to the system. Please see Appendix A, page 5, table titled “Total PFAS Input – Contribution from Waste Feeds and Spiked Materials”. For Runs 4, 5 and 6, the spiked materials make up 83, 76, and 92% respectively of the total mass of PFAS in the feed materials. This must be considered in comparing mass balance results between Test Conditions #1, #2 and #3.

Follow-up response: No additional questions.

11. From report: Table 3-1 presents the approach for calculating spiking rates for the four PFAS compounds to demonstrate a DRE > 99.9999% for each of the four spiked PFAS compounds. Demonstrating DRE > 99.9999% is equivalent to demonstrating that for every million mass units of a POHC introduced into an incinerator, only one mass unit is detected at the stack. Hence, it is necessary to work backwards from the achievable detection limit for the specific analyte in the stack gas. A sample calculation demonstrating the contribution of the spiking component inputs to the DRE calculation are presented in Table 3-1. Note that the example calculation presented below is actually based on achieving > 99.99995% DRE. This contingency factor is necessary to

account for uncertainty in the PFAS method detection limit (MDL) and stack gas flow rate.

Question: What is the accuracy of the PFAS feed rates and stack emission rates? To how many significant digits?

Response:
One key factor that affects the accuracy of the calculations of PFAS feed rates and stack emissions is how non-detect analytical values were handled in calculations. Please see response to Comment #7 for a discussion of this issue. As explained in that comment, the most conservative approach was taken to handling non-detects in performing DRE calculations.

Mass feed rates of waste materials are reported in units of lb/hr to five or six significant figures (i.e., XXX.XX or X,XXX.XX). Concentrations of PFAS in liquid feed materials are reported in concentrations of ng/l to three significant figures (X.XX). Stack gas sampling train fractions (4) are reported in units of ng/sample to four significant figures (X.XXX). Stack gas sample volumes are reported in units of dscf to five significant figures (XXX.XX). Stack gas flow volumes rates are reported in units of dscfm to five significant figures (XX,XXX).

Follow-up response: Given the accuracy stated above, are the DRE numbers stated in the report still correct? In other words, the report states the spiked PFAS was destroyed to a DRE greater than 99.9999%. Is this still correct given the low feed rates and the accuracy of the measurements?

Response 2: The calculations were performed following the protocol described in RCRA for hazardous waste incineration (40 CFR 264.343) and are believed to be correct. An error propagation test based on number of significant figures has not been performed nor is such a test required by RCRA.

It should be noted that part of the test planning included calculating the mass of each PFAS compound that was required to be spiked to demonstrate >99.9999% DRE based on the analytical detection limit in the stack gas. As noted in Table 6-2, the mass of PFAS in the waste feed materials was insufficient to demonstrate >99.9999% DRE for many of the PFAS target analytes.

12. From report: All of the temperatures recorded for samples on receipt at the laboratory were higher than 4 degrees Celsius (C). Interviews with EAL employees revealed that proper temperature measurement procedures were not observed. Further, it was confirmed through analysis of XAD media blank samples retained at the lab and the fact that PFAS are very thermally, chemically, and biologically stable, that XAD sample integrity was likely not compromised by temperatures that were above the target value. Other Test Method 45 (OTM-45) does not require refrigeration of the sample filter, which indicates there is a low level of concern with sample loss at ambient temperatures. Details of this reconciliation are summarized in a Technical Memorandum

provided in Appendix E.

Question: What is the basis for this statement (highlighted text)? I will provide calculations to test this assertion.

Response: Comment acknowledged, and Clean Harbors concurs that PFAS compounds do not have unusual thermal stability at typical combustion temperatures. However, the statement is made in the context of the temperatures that were recorded for various samples, which ranged from ~8 to ~24°C. The statement is believed to be true in that PFAS compounds would be thermally stable within this temperature range, but no data have been found to confirm this.

Follow-up response: Calculations are provided that give support for this assertion based on the prior work of Krusic et al, 2005.

Response 2: Based on telecon with Dr. Taylor, I understand that these calculations will be provided in a separate report that he is preparing and were not intended to be part of this document.

13. From report: The Test Plan was based on a comprehensive approach to sampling that included as many process inputs and outputs as practicable. The purpose of this was to develop as complete a PFAS mass balance as possible and to identify potential sources of PFAS entering the process and PFAS sinks for materials leaving the process. Sampling included waste feed streams, process treatment chemical inputs, process residue streams, and stack gas. The principal exclusions from sampling were the containerized, shredded and bulk solids waste feed streams. Due to their complexity and heterogeneity, it was considered infeasible to sample and perform PFAS analyses on these materials. Hence, any PFAS compounds contained in these waste streams were not included in the mass balance or DRE calculations.

Question / Comment: Once again, not sure what is meant by mass balance here.

Response: See response to Question No. 7.

Follow-up response: No additional questions.

14. From report: Field QC for PFAS in process samples included rinsate/equipment blanks and field blanks collected per the master sample matrix (Appendix G), and field duplicates collected at a rate of 10% of the total process samples. At the laboratory, for every extraction batch (≤ 20 samples), a method blank and a matrix spike were performed. Surrogates were spiked into the samples to verify extraction efficiency and internal standards were spiked into extracts to verify instrument drift. The Gas Chromatography-Liquid Chromatography instrument was calibrated using a minimum of five concentration levels. All assays were bracketed by passing continuing calibration verification standards. A maximum of 10 samples were assayed between continuing

calibration verifications. All laboratory QC procedures and results are documented in the EAL Report.

Question: Is this correct (highlighted text)? My understanding is that LC/MS/MS was used to analyze for PFAS.

Response: The analytical instrument was described incorrectly in the text, it was in fact LC/MS/MS.

Follow-up response: No additional questions.

15. From report: EPA Method 3A is an instrumental test method that was used to measure the concentration of O2 and CO2 in the stack gas, and nitrogen by difference. Three effluent gas samples were collected in Tedlar bags during each run. Following the completion of the test run, the contents of the bags were conveyed to continuous emissions analyzers that measured the concentration of O2 and CO2. The average of the three bags for each run was used for the O2 and CO2 concentration. The performance requirements of the method were met to validate data.

Question: Was CO measured in any of the test runs? PFAS are within a class of known flame inhibitors and may result in CO formation, depending on the concentrations fed. It would be good to verify that the PFAS had no effect on the combustion process.

Response: CO is continuously monitored and recorded as a condition of the plant's RCRA permit. The permit limit is 100 ppmv, dry basis, 1 hour rolling average. CO emissions were well within permit limits during all test runs. However, the CO emission concentrations are not reported within the PFAS report.

As reported in Appendix A, page 2, PFAS Mass Flow rate, the average total PFAS feed rate in all feed streams was 0.0132 lb/hr (excluding PFAS spiking chemicals). The average total PFAS spiking rate during Runs 4-6 was 0.348 lb/hr. Data in Appendix B shows that the average total waste feed rate during all runs was 12,818 lb/hr. Therefore, PFAS (without spiking) make up only 0.00001% of the total waste feed material. Including the spiking compounds, PFAS made up only 0.003% of the total waste feed. Clean Harbors believes it is unlikely that PFAS at these concentrations would have a significant effect as a flame inhibitor. However, Clean Harbors is not aware of any qualitative studies to support this assumption.

Follow-up response: No additional questions.

16. From report: Figure 3-1 and Table 3-2.

Question: Was the tubing within the OTM-45 sampling train rinsed and analyzed for PFAS? This includes all tubing from the particulate filter to the 5th impinger as shown in Fig. 3.1.

Response: Stack testing was conducted according to the procedures in OTM-45, which requires rinsing all sampling train glassware, including the sampling probe, impingers, and all connecting glassware.

Follow-up response: No additional questions.

Section 4:

17. From report: The laboratory performed data validation by comparing the final data deliverable/report to the project objectives, summarizing QC outliers in the final deliverable, and applying data validation qualifiers to associated results. The data were evaluated against project data quality objectives and measurement performance criteria, such as precision, accuracy, and completeness, as shown in Table 4-1.

Question: Was third-party data validation conducted?

Response: Third party data validation was conducted for all analytical data. This Data Validation Report is presented as Appendix J of the test program report.

Follow-up response: No additional questions.

Section 5:

No questions

Section 6:

18. From report: The secondary objectives of developing a mass balance for incidental PFAS in waste infeed and demonstrating high HF removal efficiency coincident with high PFAS DRE were also achieved.

Question / Comment: It is unclear that successful demonstration of the secondary objective was achieved. Specifically, high HF removal efficiency.

Response: HF removal efficiency was calculated using a procedure that is analogous to the procedure required by the RCRA Incineration Regulations to demonstrate HCl removal efficiency. This procedure is based on measuring the amount of organic chlorine in the waste feed materials and converting it to an HCl using a stoichiometric conversion factor (assuming 100% conversion efficiency). The amount of HCl in the stack gas is measured by capturing the chloride ion in impingers and converting it to HCl using a stoichiometric conversion factor. The formula for HCl removal efficiency is:

((HCl feed – HCl stack gas)/HCl feed) *100.

Calculated HF removal removal efficiency values for each test run are presented in Table 6 in the test report. Measured HF removal efficiencies were >99.6% in all cases.

Follow-up response: Is Clean Harbors still confident that the HF was removed to >99.6% given the large variance in the fluoride measurements in the residual streams (Attachment B)?

19. From report: Depending on the Test Condition, between 24 and 26 of the 49 target PFAS analytes were not detectable in the waste infeed and DREs for these could not be calculated. However, stack gas concentrations for all 49 target PFAS analytes were either not detectable, or if detectable, the mass emission rates from the stack were extremely low, generally ranging from 10-9 to 10-7 lb/hr. PFBA, PFHxA, perfluoropentanesulfonic acid (PFPeS), perfluoro-2-methoxyacetic acid (PFMOAA), N-EtFOSE, N-MeFOSE, and perfluoro(3,5,7,9,11-pentaoxadodecanoic) acid (PFO5DA) had reported emission rates between 10-7 and 10-6. PFBA, the compound with the highest calculated emission rate, was present in the method blank (XAD resin media blank). Therefore, the reported PFBA emission rate is likely biased high, and the DRE is biased low for at least some of the test runs by this blank contamination. Calculated stack emission rates for all 49 target PFAS analytes are presented in Table 6-3 and stack emission concentrations are presented in Table 6-4.

Question: What are the blank-corrected emission rates for PFBS in Table 6-3?

Response: See blank corrected emission rates in Attachment D.

Follow-up question: The DRE for PFBA is less than 99% for runs 1, 3, and 7 (Table 6-2). Did the blank-corrected data make a measurement improvement (order of magnitude) in the DRE numbers for runs 1, 5, and 7? Can you offer any explanation for the low DRE besides a low initial concentration in the waste feed?

Response 2: See revised Attachment D which shows blank corrected DRE calculations for PFBA. Blank correction generally results in a small increase in DRE, but far less than an order of magnitude for each run that was blank corrected.

Table 6-2 shows that there are several PFAS target analytes with DRE values <99.99%, even though the analyte was non-detect in the stack gas. This result is clearly caused by low concentrations of the PFAS target analyte in the feed material.

PFBA may also be a PIC. It is the lowest molecular weight (C4) carboxylic acid and would be expected to be a breakdown product of higher molecular weight carboxylic acids. Data presented by MacGregor (attached) also shows PFBA as residual product in multiple residual stream matrices (ash, water, stack gas) which may corroborate the PIC theory.

20. From report: The HF removal efficiency, based on the HF potential to emit and the and

measured HF in the stack gas, averaged 99.7% for the nine test runs.

Question: This statement assumes that you measured all the fluorine in the infeed. I don't think this is true. It also assumes that all fluorine fed into the incinerator was converted to HF. What basis do you have for this second assertion?

Response: Table 6-4 in the project report presents HF removal efficiency data and all values are reported as ">" values partially for the reason noted (fluorine was not sampled and analyzed in the waste feed). There were several reasons for reporting HF removal as a ">" value as explained in footnotes a, b, and c of Table 6-4. The statement in the text should also be qualified as a ">"value.

As described in the response to Question 18, HF removal efficiency was calculated is procedures analogous to those described in the RCRA incineration regulations for calculating HCl removal efficiency, which assumes that all chlorine in the feed material is converted to HCl. The point is acknowledged that there is a possibility that some fluorine could be converted to compounds other than HF. However, fluorinated products of incomplete combustion were not measured during this test program.

Follow-up response: I agree with the response. It is possible if not likely that some of the input F was converted to stable PICs such as CF4 and C2F6 in this testing. The report should reflect this current status of the science with respect to complete F mineralization.

Response 2: See initial response to Question #3.

21. From report: Table 6-5.

Question: How is Intermediate HF defined? A footnote should be added to this table providing that calculation. HF removal rate is calculated by subtracting HF stack emission rate from fluorine from waste feed with the difference divided by the fluorine from waste, correct? If so, what is the purpose of adding the Intermediate HF column? What does this data signify?

Response: HF removal percentage is calculated by converting all fluorine in the feed to HF and converting all fluorine in the stack gas to HF and then performing the calculation as describe above. "Intermediate HF" is the potential HF calculated by converting all of the fluorine in the waste feeds and spiking chemical to HF by using a stoichiometric equation (as shown in the table heading below the term "Intermediate HF". Clean Harbors agrees that the use of the term "Intermediate HF" is potentially confusing, and the term should be removed from the table.

Follow-up response: No additional questions.

22. From report: The technical memorandum also addresses the recorded temperatures of

the sample coolers upon receipt at the laboratory, which ranged from 6 °C to 13.3 °C except for one measurement of 19.4 °C recorded for three coolers containing non-hazardous stack gas samples. However, it is believed that this measurement was not made in accordance with standard procedures, as documented in the memorandum (Appendix E). The measured temperatures for the three coolers containing non-hazardous stack gas samples were noted as an exceedance relative to standard requirements, and associated sample data were qualified as estimated (J or UJ) per standard validation procedures. Additionally, the hazardous stack gas samples required shipment in specialized hazardous materials compliant fiberboard boxes, which precluded cooling during shipping; the temperatures of these samples upon delivery were greater than 23 °C.

Question: This data (highlighted text) is missing from Appendix J. Data for the non-hazardous waste samples is provided twice.

Response: Please confirm that the question references the proper Appendix. Temperature data for hazardous gas constituents is provided in Appendix E, Reconciliation of Sample Handling Deviations, pages 41-42 (Fed Ex documents).

Follow-up Response: In the current version of Appendix E, Attachment 2 (COCs for hazardous stack gas samples) is a duplicate of Attachment 3 (COCs for non-hazardous stack gas samples). Appendix E should be corrected with the appropriate COCs for Attachment 2.

Response: The term “Hazardous” refers to the DOT shipping classification of the samples, not the toxicological properties of the samples. The COCs in question refer to the OTM-45 samples. The “front-half rinse”, “back-half rinse”, and “impinger rinse” fractions are a 95% methanol/5% NH4OH solvent mixture that are defined as hazardous materials for DOT shipping purposes. These remaining four samples (front half filter, 1st XAD trap, Condensate, Breakthrough XAD) are considered non-hazardous per DOT regulations. These groups of samples should have been listed on separate COC forms and shipped separately. However, they were erroneously combined on a single COC form. This form is included in the referenced Attachment 2 (Hazardous Stack Gas Samples COCs) and Attachment 3 (non-hazardous Stack Gas Samples COCs) because the form contains information for samples in both hazardous and non-hazardous categories.

23. From report: Although the impact of temperature on the stability of PFAS in samples similar to those collected for this project has not been specifically documented, PFAS compounds are generally highly stable and resistant to degradation under normal environmental conditions. The stability of these compounds is reflected in Method OTM-45, which does not require refrigeration of sample filters. Therefore, although the data were qualified based on the temperature exceedances, the exceedances do not affect data usability.

Question: A calculation will be provided to test this assertion (highlighted text) using kinetic data from the literature.

Response: See response to Question #12.

Follow-up response: Calculations are provided that give support for this assertion based on the prior work of Krusic et al, 2005.

Response 2: See response to Question 12.

24. From report: The media blanks associated with the OTM-45 train were prepared and analyzed as method blanks. These blanks were collected in association with the XAD resin, the impinger solution, and the filter. The two blanks associated with the impinger solution were non-detect for all analytes. Analytical results for the filter blank were non-detect except for PFTeDA, which had a concentration of 0.061 ng/sample. Analytical results for the two XAD resin blanks were non- detect for all analytes except PFBA, PFHxA, and PFMOAA. The detected result for PFBA was 5.53 ng/sample, the detected results for PFHxA were 0.247 ng/sample and 0.234 ng/sample, and the detected results for PFMOAA were 1.35 ng/sample and 1.39 ng/sample.

Question: Is this consistent with footnote (d) in Table 6-4? The footnote seems to suggest that PFBA was detected in different components of the OTM-45 sampling train for different runs. It's confusing.

Response: See data in Attachment A. Footnote (d) refers to the concentration of PFBA in the Method Blank. The XAD-resin reagent blank was used as a method blank. Footnote (d) should be reworded as follows:

(d) Detected as a contaminant (5.53 ng/sample) in method blank No. MB-12020-PFAS. The XAD-2 resin reagent blank was used as the method blank. The PFBA mass in the following stack gas sample fractions exceeded the mass in the method blank:
Run 1 – Back-half
Run 5 – Back-half
Run 5 – Breakthrough XAD Resin
Run 7 – Back-half

Follow-up response: No additional questions.

Section 7:

25. From report: The results of testing conducted at Clean Harbors' Aragonite Incineration Facility from 17 to 19 June 2021 successfully demonstrate that the process can effectively destroy legacy terminal PFAAs such as PFOA, PFOS, and PFHxS, and the Gen-X

PFAS HFPO-DA, at DREs exceeding 99.9999%, when the feed rate of these materials is augmented and DREs are calculated using very conservative assumptions. It is worth noting that this is the required performance level for thermal destruction of polychlorinated biphenyls and dioxins/furans, which are demonstrably more hazardous and generally less thermally stable than currently (federally) unregulated PFAS.

Comment: The current, evolving scientific understanding does not support this statement. PFAS parent compounds are almost certainly less thermally stable that PCBs.

Response: Comment acknowledged. Clean Harbors is not aware of any published studies comparing the thermal stability of PFAS compounds with PCBs that were conducting using identical or similar test procedures. Therefore, this statement in the original report is unsubstantiated by any published data that is known to Clean Harbors and should be removed.

Follow-up response: No additional questions.

26. From Report: Section 7.2 Title: Incidental PFAS DRE and Mass Balance

Comment: Title is misleading. PFAS mass balance (as fluorine) was not reported. No evidence for the complete destruction of the spiked PFAS was provided.

Response: See responses to Question #3 and Question #7. Demonstrating a PFAS mass balance as fluorine was not a goal of the testing program and was technically impracticable for the reasons noted in the previously referenced responses.

Follow-up response: No additional questions.

27. From report: Mass balance results indicate that total PFAS input into the system in the treatment chemicals and process water are extremely low, with non-detect or close to non-detect concentrations of all analytes in the process water, TMT, and powdered activated carbon. The soda ash solution has a PFAS input into the system in the range of 10-6 to 10-5 lb/hr. This mass was comprised exclusively of FBSA, which was detected in all nine runs.

    Mass balance results indicate the total PFAS emitted from the system in the slag, spray dryer solids, baghouse dust, and stack gas are extremely low (10-8 to 10-4 lb/hr for each stream). Mass emission rates in the slag and stack gas are approximately equal and the mass emission rates in the spray dryer solids and baghouse dust are both about one order of magnitude less than the flow rates in the slag or stack gas.

Comment: The significance of these paragraphs is unclear to me. Are you saying there was little background PFAS in the incoming streams and unit operations (except for AFFF and the spiked PFAS in test condition 2) and little PFAS in the stack gas and air pollution control systems? I agree with the latter assertion but not so sure about the first; the report states that not all of the incoming streams were analyzed for PFAS or total organic fluorine.

Response: Comment is correct in that PFAS could not be analyzed in solids streams as described in response to Comment #3. The text should be qualified to clarify that it is based only on those streams that were sampled and analyzed and does not address any PFAS that may be in solid waste streams which were not sampled and analyzed.

Follow-up response: No additional questions.

28. From report: Given that laboratory standards enabling targeted analysis exist for only about 50 of the thousands of extant PFAS, other analytical tools such as non-targeted PFAS analysis and Total Organic Fluorine, combined with TOPA, could be employed in the future to more completely characterize the PFAS profiles in the waste and other process streams, as well as in the stack gas.

Comment: This statement (highlighted text) relates to both determination of complete PFAS destruction and the ability to perform a meaningful F balance. The need for this analytical capability could be further emphasized as such outcomes would be beneficial for both your industry and the general public.

Response: Not a question, comment acknowledged about analytical capability. However, as explained in the response to Comment #3, Clean Harbors does not believe it is possible to perform a meaningful fluorine balance on a commercial hazardous waste incinerator feeding a normal mixture of solid materials for the reasons previously noted.

Follow-up response: None.

29. From Report: Performing a fluorine balance, considering all fluorine inputs, could provide insights into how and where fluorine is removed from the system. Most (probably nearly all) of the organic fluorine is expected to be oxidized to form HF within the RK or ABC. This HF may then reactwith inorganic components of the slag, be neutralized and collected in the spray dryer solids, collected in the baghouse as an inorganic solid, or neutralized in the scrubber.

Question: What is the basis for this assertion (highlighted text)?

Response: The assertion is based on the typical operating temperatures in the rotary kiln and afterburner (~2,000°F) as described in Comment # 5, the gas phase residence time of 3.1 seconds as described in the response to Comment #6, and the oxygen content of the stack gas (~11%) as described in Appendix H of the test report. These operating conditions are believed to be sufficient to convert F to HF at a high efficiency. However, there is no publicly available data that is known to Clean Harbors to quantify the efficiency of the fluorine to HF conversion.

Follow-up response: No additional questions.

Appendices

Appendix A:

Fluorine Mass Balance Spreadsheet – The two tables entitled: Fluorine Feed Rate and Fluorine Mass Flow Rate in Residual Streams. Mass Balance Closure (%).

Comment: The mass balance closure for fluorine should be >100% if fluorine input in waste streams to incinerator is not fully characterized as repeatedly asserted in the final report. The data here do not provide strong support or corroboration for that claim as 6 of 9 test runs give only ~ 100% recovery (+/- 10%) and only one test run is well above 100% (130%). I suggest that the assertion in the final report that PFAS DREs are conservative be reconsidered in light of this data.

Response: The data in the Fluorine Mass Balance spreadsheet in Appendix A is incorrect, it is an obsolete version that uses assumed fluorine concentrations in Residual Streams rather than actual measured values. Actual measured values were not available when the spreadsheet was originally developed.

The corrected fluorine mass balance is attached (Attachment C, Fluorine Balance). The calculated fluorine mass balance closures ranged from approximately 2-10%. However, it is believed that the analytical method used to analyze fluorine in the spray dryer ash and baghouse dust was not appropriate for these matrices and therefore returned ND values for most of the samples. There is empirical evidence to support this, in that the mass flow rates of fluorine in the brine ranged from ~1.5 to 9.8 lb/hr. The brine is evaporated in the spray dryer, and this mass of fluorine should have been detected as fluorine in the spray dryer solids or the baghouse dust. It should be noted that there could be additional fluorine in these two streams if fluorine was initially removed from the flue gas as it passed through these two devices (which is highly likely).

A better indication of the fluorine mass balance closure is provided by the ratio of fluorine in the brine to the total fluorine in the feed. These values ranged from 105% to 457% for Runs 1-3 and from 52-65% for Runs 4-9. Ratios exceeding 100% may indicate that there was a significant amount of fluorine in the solid feed materials that could not be sampled and analyzed. This could have resulted in more fluorine being recovered in the brine than could be accounted for in the feed materials that were analyzed.

For Runs 4-9, the ratio of fluorine in the brine to fluorine measured in the feed materials was <100%. This could be the result of fluorine initially being removed from the flue gas as it passed through these spray dryer and baghouse, but not being detected because of analytical issues.

As noted in the response to Comment #3, PFAS DRE values and mineralization efficiency to HF are two totally different parameters. Clean Harbors believes assertions that calculated DRE values are reported on a conservative basis is correct because of how non-detects were used in DRE calculations for waste feed (ND assumed 0.0) and stack gas samples (ND assumed to be present at the ND).

Follow-up response: The large variance in the fluoride measurements in the residual streams suggest some significant analytical issues. This should be reflected in the report and additional testing and/or R&D is recommended to further investigate this issue.

Response: Clean Harbors agrees with this conclusion and acknowledges that there were likely analytical issues associated with the slag and spray dryer solids samples that need to be investigated in future test programs.

<u>Appendix E:</u>

Question: The 2nd page, last paragraph, states that "The sample temperature issues involved at the recording of 19.4 C of non-hazardous stack gas samples, and temperatures ranging from 23.4 to 24.1 C for hazardous stack gas samples . . ." The COC documents providing the temperatures for the hazardous stack gas samples is not provided in this Appendix.

Response: Temperature data for hazardous gas constituents is provided in Appendix E, Reconciliation of Sample Handling Deviations, pages 41-42 (Fed Ex documents). The shipment of the hazardous gas samples was not properly documented on a COC document.

Follow-up Response: In the current version of Appendix E, Attachment 2 (COCs for hazardous stack gas samples) is a duplicate of Attachment 3 (COCs for non-hazardous stack gas samples). Appendix E should be corrected with the appropriate COCs for Attachment 2.

Response 2: See response to Question 22.

Exhibit B

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Article

Pilot-Scale Thermal Destruction of Per- and Polyfluoroalkyl Substances in a Legacy Aqueous Film Forming Foam

Erin P. Shields,* Jonathan D. Krug, William R. Roberson, Stephen R. Jackson, Marci G. Smeltz, Matthew R. Allen, R. Preston Burnette, John T. Nash, Larry Virtaranta, William Preston, Hannah K. Liberatore, M. Ariel Geer Wallace, Jeffrey V. Ryan, Peter H. Kariher, Paul M. Lemieux, and William P. Linak

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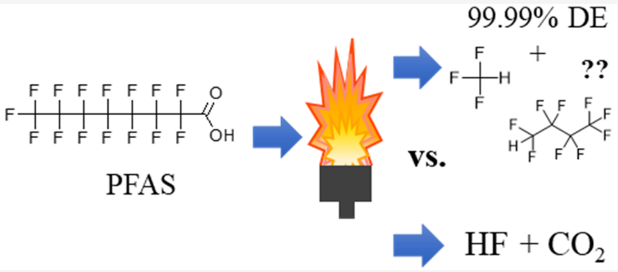

ABSTRACT: The destruction of per- and polyfluoroalkyl substances (PFAS) is critical to ensure effective remediation of PFAS contaminated matrices. The destruction of hazardous chemicals within incinerators and other thermal treatment processes has historically been determined by calculating the destruction efficiency (DE) or the destruction and removal efficiency (DRE). While high DEs, >99.99%, are deemed acceptable for most hazardous compounds, many PFAS can be converted to other PFAS at low temperatures resulting in high DEs without full mineralization and the potential release of the remaining fluorocarbon portions to the environment. Many of these products of incomplete combustion (PICs) are greenhouse gases, most have unknown toxicity, and some can react to create new perfluorocarboxylic acids. Experiments using aqueous film forming foam (AFFF) and a pilot-scale research combustor varied the combustion environment to determine if DEs indicate PFAS mineralization. Several operating conditions above 1090 °C resulted in high DEs and few detectable fluorinated PIC emissions. However, several conditions below 1000 °C produced DEs > 99.99% for the quantifiable PFAS and mg/m^3 emission concentrations of several nonpolar PFAS PICs. These results suggest that DE alone may not be the best indication of total PFAS destruction, and additional PIC characterization may be warranted.

KEYWORDS: *PFAS, AFFF, incineration, products of incomplete combustion, destruction efficiency*

■ INTRODUCTION

Per- and polyfluoroalkyl substances (PFAS) are a class of synthetic chemicals that possess strong carbon−fluorine bonds that give PFAS high stability and low surface energies.[1] These unique properties have made PFAS useful in heat resistant products, hydrophobic and oleophobic coatings, firefighting foams, and many other products and manufacturing processes.[1−3] The widespread use and stability of PFAS have led to the ubiquitous presence of PFAS in the environment and waste streams.[4−7] Even low levels of PFAS exposure can lead to bioaccumulation and has been associated with adverse health effects,[8−11] leading to low parts per trillion drinking water health advisory levels for several PFAS.[12] The current concentrations of PFAS in the environment have been determined to be near or over recent exposure guidelines,[13,14] indicating the need for PFAS emission reductions.[14]

Hazardous organic chemicals are often incinerated to destroy the compounds and prevent their release to the environment.[15,16] To ensure harmful emissions are not released into the atmosphere, the destruction efficiency (DE) or destruction and removal efficiency (DRE) of the parent organic molecule, or principle organic hazardous constituent (POHC), has been used to determine the destruction of the molecule.[15,17−19] Typically, a DE or DRE determined for a highly stable POHC (based on an incinerability index[20]) is used to ensure adequate destruction for all waste species.[15,18,20] The DE or DRE can be calculated using eq 1,

$$DE\ or\ DRE = [1 - (W_{out}/W_{in})] \times 100\% \tag{1}$$

where W_{in} is the mass feed rate of the molecule in and W_{out} is the mass emission rate of the POHC coming out of the incinerator for DE or out of the stack and into the atmosphere for DRE. The distinction between DE and DRE is that DRE includes credit for POHC removal in facility air pollution control devices (e.g., particulate control, acid gas scrubbers,

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activated carbon beds) where DE does not. Although this results in some transference of the POHC to the liquid and solid discharges from air pollution control devices, these discharges are themselves treated as hazardous wastes. The regulation, 40 CFR Part 63.1203, states that a DRE of 99.99% indicates complete destruction of most chemicals.[19] For perspective, a requirement of 99.99% DRE indicates that for every 1 kg of POHC introduced, 100 mg of the POHC could be released in the air emissions. When applied to an aqueous film forming foam (AFFF) containing ~2% PFAS, ~200 mg of PFAS could be emitted for every 100 kg of the AFFF incinerated.

Many PFAS of industrial importance are composed of a fluoroalkyl chain and a polar functional group. PFAS can easily be altered from their original form by the removal of the functional group thermally at temperatures as low as 100 to 300 °C[21−23] and by other mechanisms at ambient temperatures.[24,25] The removal of the functional group creates volatile PFAS, from the carbon−fluorine backbone, that are greenhouse gases;[26,27] most have unknown toxicity, and some can transform to perfluorocarboxylic acids in the atmosphere.[28] The complete destruction of PFAS, the breaking of all the carbon−fluorine bonds and mineralization to form hydrofluoric acid (HF) and carbon dioxide (CO_2), is necessary to ensure PFAS are not released into the environment during the thermal treatment of PFAS contaminated media.

The primary objective of this study was to evaluate whether DEs indicate complete destruction of PFAS during thermal treatment. As an indicator of incomplete destruction, volatile products of incomplete combustion (PICs) were quantified along with the DEs of the quantifiable PFAS. The study was performed using a pilot-scale natural gas-fired refractory-lined combustor. The PFAS mixture used was an AFFF predominantly containing legacy perfluorooctanesulfonic acid (PFOS).

AFFF was injected into the combustor at various locations experiencing different peak temperatures. The AFFF was atomized through the flame, with exposure to flame generated radicals and near adiabatic flame temperatures, and at postflame locations with peak temperatures ranging from 1180 to 810 °C. These temperatures span realistic high temperatures achieved in hazardous waste incinerators (HWIs), as well as lower temperatures that may be more typical of other thermal destruction systems such as sewage sludge or municipal waste incinerators.[29] To our knowledge, this study is the first to use a pilot-scale incinerator to examine AFFF destruction over a wide range of temperatures and include PIC measurements as an indicator of performance.

■ MATERIALS AND METHODS

Experimental Furnace. Experiments were performed using a small pilot-scale U.S. Environmental Protection Agency (EPA) research combustor named the Rainbow furnace that has been described in previous studies.[30−32] Here the furnace load and flame stoichiometric ratio (SR) were varied between 30 and 45 kW and 1.3 and 2.0, respectively. To provide similar mass flows and thorough mixing of the effluent, high amounts of excess air were used to reduce and vary furnace temperatures to those more typical of HWIs and other incineration systems. Figure 1 presents a cutaway drawing of the Rainbow furnace with AFFF injection locations (burner, port 4, port 8) and stack sampling locations identified. In this configuration, the combustor most closely resembles a hazardous waste incinerator injecting a low heating value liquid waste. Hazardous waste incinerators often introduce aqueous waste through lances downstream of the flame.

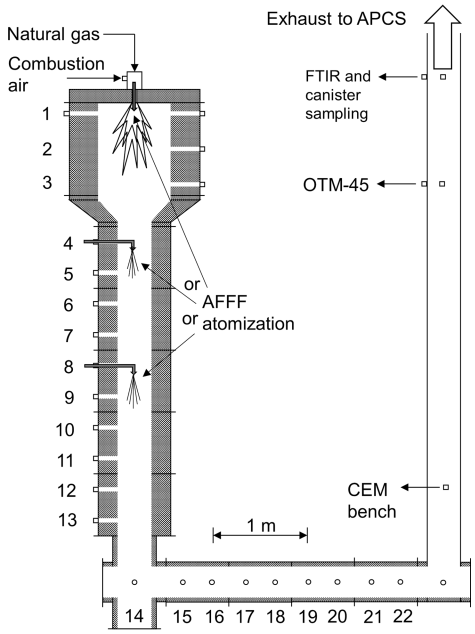

Figure 1. EPA refractory-lined natural gas-fired furnace showing the AFFF injection locations, through the flame with the natural gas and at ports 4 and 8 and the stack sampling locations indicated. Measurements are made prior to the facility air pollution control system (APCS).

AFFF Injection. One legacy AFFF formulation composed primarily of PFOS and perfluorohexanesulfonic acid (PFHxS) was used for these experiments. The AFFF was analyzed by a commercial laboratory for PFAS according to their liquid chromatography coupled to tandem mass spectrometry (LC/MS/MS) method derived from EPA Method 533.[33] The AFFF was added to a 19 L Cornelius keg placed on a scale to monitor mass loss and feed rate. The injection technique has been used previously[34] and is described here. AFFF was atomized through the burner or through one of two axial postflame access ports along the furnace centerline using twin fluid (air/AFFF) atomizers. The Cornelius keg was air pressurized (~584 kPa) to push the AFFF through a manually adjusted needle valve and 4−50 mL/min liquid rotameter (Brooks Instrument, Hatfield, PA) to the atomizer. Simultaneously, compressed air (584 kPa) was directed through a mass flow controller (Sierra Instruments, model Smart-Trak 50 L/min, Monterey, CA) to the atomizer. The AFFF and atomization air were combined at one end of a length of 0.1753 cm inside diameter, 0.3175 cm outside diameter stainless steel tubing. Within the tubing the atomizing air causes the liquid to form a thin film on the inner tube surface and shears the liquid film into droplets (~50 μm diameter for water) as it leaves the other end. The injector for the two postflame axial access ports included a 90-degree bend at the atomizer tip to direct the atomized AFFF downstream cocurrent with the combustion gases along the furnace centerline. In addition, to mitigate the potential for pyrolysis, the side port atomizer included two additional concentric outer tubes through which additional "sweep" air was introduced to keep the AFFF and atomizing air cool until the atomizer tip. The volumes of these two cooling flows were minor (~3%) compared to the combustion gas flow. The burner incorporated atomizer did not need cooling, and atomized AFFF into the natural gas at the center of the International Flame Research Foundation (IFRF) variable air swirl burner (using setting 4 of 0−8) where the combined natural gas AFFF mixture then burned as a diffusion flame with combustion air added annularly.

Figure S1 in the Supporting Information (SI) indicates Rainbow furnace temperature profiles, approximate residence times, and AFFF injection locations. One experiment introduced the AFFF through the flame where the AFFF would be exposed to near adiabatic flame temperatures (1963 °C for a methane−air diffusion flame at 101 kPa) and free radical chemistry characteristics of a natural gas diffusion flame. This was followed by five postflame experiments that varied the peak (injection) temperature from 1180 to 810 °C in approximate increments of 100 °C. The Rainbow furnace operating conditions for each injection experiment are listed in Table S1.

Real-Time Measurements. Figure 1 indicates stack locations where combustion exhaust samples were extracted for analysis. As previously described,[30] a Fourier transform infrared spectrometer (FTIR, Model 2030, MKS Instruments Inc., Andover, MA) and a continuous emission monitor (CEM, Model ZRE Analyzer, California Analytical, Orange, CA) measured furnace exhaust concentrations of oxygen (O_2), carbon monoxide (CO), and CO_2. These measurements are intended to verify combustion conditions and quantify small amounts of air in-leakage caused by the facility's induced draft blower and operation at a ∼1.27 cm H_2O draft. FTIR was also used to measure moisture (H_2O), HF, sulfur dioxide (SO_2), and nitric oxide (NO). Note that CEM measurements are dry (moisture removed), and FTIR measurements are wet. Where available, the CEM and FTIR values were compared, taking into account the water, to verify the FTIR's measurements.

Volatile Nonpolar PFAS. The volatile PFAS and fluorochemicals (vPFAS) were sampled using evacuated 6 L Silonite coated stainless steel canisters (Entech, Simi Valley, CA). The emissions were sampled with a heated probe, filter, and perfluoroalkoxy alkane (PFA) heated sample line at 120 °C and ∼3 L/min. A 1.0 L/min slip stream of the emissions was passed through three 0.1 M sodium hydroxide (NaOH) filled mini (∼30 mL) impingers and one empty impinger in an ice bath to remove acid gases and reduce the water content in the samples. The evacuated canisters (−101 kPa) collected stack gases after the impingers and were filled to ∼−34 kPa, resulting in an ∼4 L sample volume. Subambient pressure was maintained to minimize condensation inside the canister. For analysis, the canisters were pressurized with dry nitrogen to 207 kPa, and the injections were spiked with internal standards, d5-chlorobenzene, and 1,4-difluorobenzene.

The canisters were analyzed using a Markes International Unity-xr TD system and Markes BenchTOF-Select MS system (Bridgend, U.K.) integrated with an Agilent 7890B gas chromatograph (GC, Santa Clara, CA). Tetrafluoromethane was concentrated from 15 mL of sample to avoid trap breakthrough. Aliquots of 200 mL of the samples were trapped for other PFAS. Samples were concentrated using a Markes Greenhouse Gas trap at −30 °C and desorbed at 40 °C/s to 280 °C and held for 0.5 min. Analytes were separated using an Agilent GS-GasPro column (60 m × 0.32 mm inside diameter) starting at 50 °C, held for 1 min, increased at 5 °C/min to 130 °C, and then ramped at 10 °C/min to 240 °C and held for 37 min. Quantitation of 30 vPFAS were performed using a seven-point (0.5 to 20 ppbv, 50 to 200 ppbv for CF_4) calibration curve for each analyte.

Semi- and Nonvolatile Polar PFAS. The semivolatile and nonvolatile polar PFAS were sampled and analyzed according to the U.S. EPA's Other Test Method 45 (OTM-45).[35] Briefly, ∼ 3.0 m^3 was sampled over 3 h at a constant rate from the furnace exhaust. Due to the low pressure drop in the ductwork, isokinetic sampling could not be performed. OTM-45 creates four fractions (probe rinsate and filter, an XAD sorbent trap, impinger water, and a breakthrough XAD sorbent trap) for analysis using LC/MS/MS with a method based on Method 533 to quantify 49 polar PFAS, see Table S2 in the SI. The PFAS mass from each fraction was summed to give the total mass for each sample. A proof blank train was created by setting up and recovering an OTM-45 train with clean glassware near the sampling location. The sample extraction and analyses were performed by a commercial environmental laboratory, Eurofins TestAmerica (Knoxville, TN), according to OTM-45 and their standard operating procedures.

Calculation of Destruction Efficiency. To account for variable excess combustion air and any additional dilution caused by in leakage into the furnace, the DEs for the targeted PFAS in the AFFF were calculated using Method 19[36] as done previously.[30] The DE, or percent removal, was calculated using eq 1, but W_{out} was replaced with Method 19's E_{ao}, the mass emissions rate, and W_{in} was replaced with E_{ai}, the mass input rate. The mass emission rates are further defined in the SI.

Nontargeted PFAS. Nontargeted analysis (NTA) was performed with additional mass spectrometry analysis of the OTM-45 extracts using LC coupled to a high-resolution Thermo Orbitrap Fusion mass spectrometer (Thermo Fisher Scientific, Waltham, MA, U.S.A.) described elsewhere.[37,38] Extracts were diluted 1:3 with water and then analyzed with the LC/MS using a heated electrospray ionization source operated in negative mode. Data was generated using data dependent MS/MS acquisition with a scan range of 150−1500 *m*/*z* and Orbitrap resolutions of 60,000 and 15,000 for MS1 and MS2 acquisition, respectively. Instrument settings are detailed in the SI.

Raw instrument files were then processed with Thermo Compound Discoverer 3.3 to extract chemical features and tentatively matched against several databases (the USEPA's Distributed Structure-Searchable Toxicity (DSSTox), Thermo mzCloud, and Mass Bank of North America (MONA) mzvault library). The compounds' formula and potential names were generated by Compound Discoverer based on the MS1 molecular ion's mass. Some formulas and chemical names do not show fluorine, but the MS2 spectra possessed PFAS-like features. The PFAS-like features were manually identified based on a negative mass defect or predicted formula containing multiple fluorine atoms and fragmentation consistent with the fluorinated moieties listed in Table S3. Determining the presence of fluorinated molecules was the focus of this study; subsequent studies may focus on identification of unidentified compounds.

RESULTS AND DISCUSSION

Targeted PFAS Destruction. The AFFF was found to contain 10 PFAS from the targeted analyte list; see Table S4 in the SI. The quantitated PFAS consisted of C4 to C8 perfluoroalkyl carboxylic acids (PFCAs) and perfluoroalkyl sulfonic acids (PFSAs), and concentrations of the 10 PFAS were used to calculate the DEs for the PFAS in the AFFF. The

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Table 1. OTM-45 Results

Temperature (°C)	MB[a]	PBT[a]	Flame	1180	1090	970	870	810
Sample volume (dscm)[b]	-	-	3.12	3.71	3.71	3.72	3.74	3.74
Injection Port	-	-	burner	4	4	8	4	8
PFAS[a]	ng/sample	ng/sample	ng/sample	ng/sample	ng/sample	ng/sample	ng/sample	ng/sample
PFBA	ND	5.57	22.3	108	9.10[c]	628[c]	3950	116000
PFPeA	ND	3.32	17.6	56.0	7.42[c]	249[c]	741	63400
PFHxA	ND	6.59	26.1	100	13.8	490	1240	151000
PFHpA	0.40	1.55	6.32	29.8	5.23	65.5	475	36300
PFOA	ND	2.30	36.8	156	144[d]	452[d]	1430	78400
PFBS	0.11	0.41	0.61	6.66	0.57	0.67	28.8	1860
PFPeS	ND	ND	ND	4.58	0.14	0.54	23.4	1680
PFHxS	ND	1.25	0.92	21.6	1.36[d]	2.33[d]	118	8520
PFHpS	ND	ND	ND	1.84	ND	0.34	17.1	989
PFOS	ND	9.30[d]	3.08[d]	116	42.2[d]	18.6[d]	819	62200

[a]MB is laboratory method blank, PBT is the proof blank train, abbreviations are in Table S2 [b]Dry standard cubic meter. [c]Pre-extraction internal standards were above of acceptance criteria, >150% [d]Pre-extraction internal standards were below acceptance criteria, <20%

Table 2. DEs for Measured PFAS in AFFF with Gray Shading Indicating Less than Four Nines DE

Temperature, (°C)	Flame	1180	1090	970	870	810
PFAS	(%)	(%)	(%)	(%)	(%)	(%)
PFBA	99.9958	99.9725	99.9978	99.8443[b]	98.3336[b]	45.7362
PFPeA	99.9993	99.9971	99.9996	99.9876[b]	99.9372[b]	94.0300
PFHxA	99.9997	99.9984	99.9998	99.9925	99.9678	95.6188
PFHpA[a]	99.9997	99.9984	99.9997	99.9965	99.9566	96.3086
PFOA	99.9996	99.9978	99.9981	99.9938[b]	99.9663[b]	97.9522
PFBS[a]	>99.9999	>99.9999	>99.9999	>99.9999	99.9996	99.9704
PFPeS	>99.9999	>99.9999	>99.9999	>99.9999	99.9996	99.9671
PFHxS	>99.9999	>99.9999	>99.9999[b]	>99.9999[b]	99.9997	99.9768
PFHpS	>99.9999	>99.9999	>99.9999	>99.9999	99.9996	99.9766
PFOS	>99.9999[b]	>99.9999	>99.9999[b]	>99.9999[b]	99.9997	99.9751

[a]PFBS and PFHpA were detected in the analytical method blanks. [b]Pre-extraction internal standards were outside of acceptance criteria; DEs used estimated maximum concentrations.

PFAS found in the stack emissions from the OTM-45 sampling for all six AFFF injections are shown in Table 1, with compound abbreviations defined in Table S2. No other PFAS from the OTM-45 target list above method blank (MB) and reporting levels were detected in any of the sampling trains besides the original 10, with just perfluorononanoic acid (PFNA) being detected near blank levels in two samples and perfluorooctanesulfonamide (FOSA) being just above the detection limit in one sample. This is not surprising, as the 49 PFAS from OTM-45 are from methods for water analysis and are complex polar structures of industrial relevance that are more likely to be found in industrial discharges than to be formed via de novo synthesis during combustion processes. An exception to this may be the PFCAs which may form from fluoroalkyl fragments in the presence of water at postflame and stack conditions.

For these experiments, the train's glassware was cleaned according to OTM-45 for each test, so a field blank train was not run since the proof blank train (PBT) was the same as a field blank train. The PBT showed some near detection limit levels of contamination, mainly due to the XAD fractions of the train. The PFCAs, perfluorobutanesulfonic acid (PFBS), perfluorohexanesulfonic acid (PFHxS), and PFOS were all measured at trace levels in the proof blank train. The results are reported according to OTM-45, without any blank correction. The samples with low levels of PFAS are reported as near blank levels to indicate that the result may be biased high and the PFAS may be below the detection limit. The OTM-45 data were also impacted by the low recovery of the isotopically labeled extraction internal standard for some longer chain PFAS. This is likely due to the water that collects in the XAD decreasing the solubility of the long chain PFAS. The impacted PFAS are noted in the tables, and the values are the highest estimated value provided by the commercial laboratory.

The experimental sequence was flame, 1090, 970, 870, 810, and 1180 °C. It appears that there may have been some hysteresis due to contamination of internal furnace surfaces after the test at the lowest temperature. Experiments were performed on separate days with at least 18 h of operation at new combustion conditions without AFFF injection to achieve equilibrium. The experiment at 1180 °C was performed the

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Table 3. Volatile PFAS and Other Gases Quantified in the Emissions from AFFF Incineration

	Temperature (°C)					
	Flame	**1180**	**1090**	**970**	**870**	**810**
Canister Analytes ($\mu g/m^3$)						
tetrafluoromethane	ND	ND	ND	ND	ND	ND
hexafluoroethane	ND	ND	ND	11.4	9.36	6.51
chlorotrifluoromethane	ND	ND	ND	ND	ND	ND
fluoroform	ND	ND	ND	5.47	601	7530
octafluoropropane	ND	ND	ND	267	903	795
difluoromethane	ND	ND	ND	2.87	8.51	94.4
pentafluoroethane	0.70	1.35	0.65	3.99	276	8950
octafluorocyclobutane	ND	ND	ND	ND	ND	14.1
fluoromethane	ND	ND	ND	ND	ND	1.30
tetrafluoroethylene	ND	ND	ND	ND	1.16	149
hexafluoropropylene	ND	0.19	ND	0.31	4.96	567
1,1,1-trifluoroethane	ND	ND	ND	ND	ND	ND
hexafluoropropene oxide	ND	ND	ND	ND	ND	ND
chlorodifluoromethane	ND	ND	ND	ND	ND	ND
1,1,1,2-tetrafluoroethane	ND	ND	ND	3.39	1.84	64.2
perfluorobutane	ND	0.30	ND	ND	434	620
1*H*-heptafluoropropane	ND	0.99	ND	ND	86.8	2480
octafluourocyclopentene	ND	ND	ND	ND	5.15	235
trichlorofluoromethane	0.40	0.17	0.57	0.57	0.40	0.57
dodecafluoro-*n*-pentane	ND	ND	ND	ND	51.2	503
1*H*-nonafluorobutane	ND	0.64	ND	ND	59.8	1230
tetradecafluorohexane	ND	ND	ND	ND	1.41	307
1*H*-perflluoropentane	ND	ND	ND	ND	12.1	1000
E1[a]	ND	ND	ND	ND	ND	ND
hexadecaflluroheptane	ND	ND	ND	ND	ND	85.81
1*H*-perfluorohexane	ND	ND	ND	ND	6.65	1090
perfluorooctane	ND	ND	ND	ND	ND	291
1*H*-perfluoroheptane	ND	ND	ND	ND	ND	316
1*H*-Perfluorooctane	ND	ND	ND	ND	ND	203
E2[b]	ND	ND	ND	ND	ND	ND
FTIR Analytes						
CO (ppm)	7.2	3.6	4.5	5.7	109	1730
CO_2 (%)	6.2	6.3	5.2	5.0	4.4	4.0
HF (ppm)[c]	427	340	278	266	260	227
NO (ppm)[c]	86.7	91	63.5	38.1	4.9	0.4
SO_2 (ppm)[c]	60.9	41.7	34	31.4	35.2	35.4
Other Gas						
Oxygen, O_2 (dry, %)	7.9	7.2	9.0	9.2	11.8	12.0

[a] Heptafluoropropyl 1,2,2,2-tetrafluoroethyl ether. [b] 2*H*-Pefluoro-5-methyl-3,6-dioxanonane. [c] Values not verified with CEM data or certified transfer standard.

day after the lowest temperature injection experiment at 810 °C; Table 1 indicates slightly higher concentrations of some PFCAs than the experiment at 1090 °C, and the PFSAs had higher concentrations than the experiment at 970 °C. Even so, the concentrations were not far above the detection limits and still show very high DEs, but the potential for hysteresis is something to note. The apparent carryover could be due to the quartz probe not going through as extensive of a cleaning process as the other glassware and only being rinsed and brushed, or the furnace may not have fully desorbed PFAS deposited on refractory and ductwork surfaces during the previous 810 °C experiment. The 1180 °C experiment was not repeated due to the time to receive the analytical results and the high cost for each run. The possible contamination was relatively low, and the 1180 °C experiment measured most of the targeted compounds near the detection limit. As a result, the possible contamination did not impact the aim of these experiments to determine if DEs are an effective metric to verify treatment of PFAS. Future tests will involve more rigorous cleaning of the probe and a combustion blank to look for contamination in the system, and more time will pass between low temperature tests to allow more complete surface desorption.

The DEs for the 10 PFAS quantified in the AFFF as determined using Method 19 are shown in Table 2, with the values below four nines, <99.99%, emphasized using gray shading. The original PFAS concentrations (Table S4), AFFF feed rates and combustion parameters (Table S1), and AFFF stack emissions (Table 1) were used in the calculations. When reported PFAS emissions were not detected (ND), the detection limit was used as a conservative value for DE calculation. The lack of corrections for blank contamination as well as corrections for recoveries (including low recoveries) also serve to reduce DE values and provide more conservative values.

The DEs for all five PFSAs are >99.9999% for the four PFAS injection locations >970 °C. Even at 870 and 810 °C, DEs for all five PFSAs were >99.999% and >99.9%, respectively. DEs for the five PFCAs were also high (mostly >99.99%) for injection temperatures >1090 °C and mostly >99.9% for injection temperatures >870 °C. Even at the lowest AFFF injection temperature, 810 °C, DEs > 94% were measured for four PFCAs, except for perfluorobutanoic acid (PFBA). PFBA exhibited the lowest DEs, both with respect to AFFF injection temperatures and PFCA chain length. Lower than expected DEs for PFBA and PFCAs have been reported previously with various destruction technologies[25,39,40] and may suggest either that shorter PFCAs are relatively more stable species or shorter chained PFCAs are formed via hydrolysis of fluoroalkyl fragments in the postflame. Note that PFSAs do not indicate this same trend with calculated DEs for PFBS and PFOS approximately similar at corresponding temperatures. This trend for PFCAs might also suggest a pathway or intermediate through which PFAS transition during thermal destruction. PFAS might be affected by high concentrations of hydroxyl radicals (OH), H_2O, and CO_2 in the combustion gases that promote reformation of PFCAs from fluoroalkyl fragments. This has been reported to occur in the atmosphere[28] and experimentally,[41,42] and the formation of aldehydes and acyl fluorides that can react to create carboxylic acids has been predicted by several computational mechanisms.[43−46] If true, the conversion of PFSAs to PFCAs would reduce apparent DEs for PFCAs while the PFSAs would have higher DEs. These experiments, using a complex mixture of PFAS and other unknown components in the AFFF, do not represent the best approach for addressing mechanistic questions. Further experiments using neat solutions of specific PFAS in coordination with ongoing kinetic modeling efforts are needed to better address mechanisms.

Volatile Emissions. The generally high DEs (>99.99%) presented in Table 2 suggest PFAS are relatively fragile, at least with respect to losing their molecular identity even at temperatures <900 °C. High DEs, however, do not necessarily ensure the absence of emissions of fluoroorganic PICs. Evacuated canisters were used to look for some known[21−23] and suspected PICs. The current method under development at the EPA can measure the 30 vPFAS listed in Table 3. The reporting limits for 29 of these compounds is 0.5 ppbv, while tetrafluoromethane (CF_4) is limited to 50 ppbv. These are high values with respect to OTM-45 (~pptv concentrations), and current efforts are focused on lowering these limits of quantitation. This method was used during the AFFF incineration experiments, and the results, presented in $\mu g/m^3$, are shown in Table 3. At AFFF injection locations >1090 °C, the PIC data show very little vPFAS at the current detection limits, but as the AFFF injection temperatures fall below 1000 °C, the vPFAS increase considerably to mg/m^3 levels. The increase in vPFAS also coincides with elevated CO concentrations rising from single digit levels up to ~1700 ppmv (see Table 3). Increases in CO were the result of incomplete PFAS oxidation and not associated with the natural gas combustion, as the AFFF experiments with high CO were injected postflame long after natural gas combustion was complete.

An important finding from Table 3 is the notable emissions of relatively high concentrations (~mg/m^3) of all eight 1*H*-perfluoroalkanes (C1−C8) during the 810 °C injection experiment. These vPFAS are expected to be formed during the thermolysis of the PFCAs or PFSAs under both pyrolytic and oxidative conditions.[21−23,43,45,47] The fluorocarbon concentrations increase with decreasing fluoroalkyl chain length, with fluoroform (CHF_3) and pentafluoroethane (C_2HF_5) present at 810 °C, at concentrations of 7.5 and 9.0 mg/m^3, respectively. 1*H*-Perfluorooctane (C_8HF_{17}) and 1*H*-perfluoroheptane (C_7HF_{15}) concentrations were significantly lower (0.2 and 0.3 mg/m^3, respectively), possibly indicating a mechanistic pathway of incremental α or β carbon removal. Tetrafluoroethylene (C_2F_4) concentrations are relatively low (~0.15 mg/m^3), perhaps suggesting that a mechanism where C_2F_4 is formed[48,49] by β carbon scission is less important under oxidative conditions.

Note that similar results have been both experimentally and computationally derived under pyrolytic and oxidative conditions. Thermolysis often yields 1*H*-perfluorocarbons and 1-perfluoroalkenes with PFCAs,[21−23,47,50,51] with PFSAs forming the same compounds[52] as well as perfluorocarbons.[47,53] Computational studies predict similar products[43−46,48] using various computational methods. All the referenced models have a lactone or sulfone intermediate with HF elimination as the first step to the loss of the functional group. After the removal of the functional group, the steps to formations of nonpolar intermediates, including the breaking of carbon−carbon and carbon−fluorine bonds, are all relatively low energy steps. These steps involve unimolecular decomposition, hydrofluorination, hydrolysis, and fragmentation of the alkyl chain. A prominent and potentially important intermediate are acyl fluorides since these can readily be hydrolyzed to carboxylic acids, as suspected in this study. Altarawneh[43] examined the temperature sensitivity of PFBS destruction from 500 to 2000 K and indicated that PFBS is destroyed at low temperatures but can create fluorinated PICs at temperatures up to 1127 °C. These studies examined different conditions than the present study, but still the similarities are remarkable and provide further support that high DEs are not necessarily indicative of the absence of PICs.

HF concentrations presented in Table 3 were not validated because no accompanying CEM measurement was available. Subsequent attempts at Method 320 validation were unsuccessful due to poor HF transport efficiencies and subsequent poor calibration gas recoveries. Additionally, the measured HF concentrations were typically observed to rise throughout the duration of an experiment indicating the HF was not yet at equilibrium with the reactive surfaces of the furnace. The HF values are included for perspective to indicate approximate HF concentrations based on the amounts of AFFF introduced. Note that NO values decrease with decreasing AFFF injection temperatures. This behavior is not fully understood but may be related to selective noncatalytic reduction (SNCR) technologies used for the control of nitrogen oxides.[54−56] SNCR decreases NO concentrations in combustion effluents by reactions with added ammonia, ammonia derivatives, or urea to the combustion gases at temperatures between 700 and 1000 °C. AFFF is known to contain percent levels of amines, sulfonamides, and amides, and these may be acting to reduce the NO concentrations as the AFFF injection temperatures fall below 1000 °C. Efforts to improve confidence in FTIR measurements including HF and NO are ongoing.

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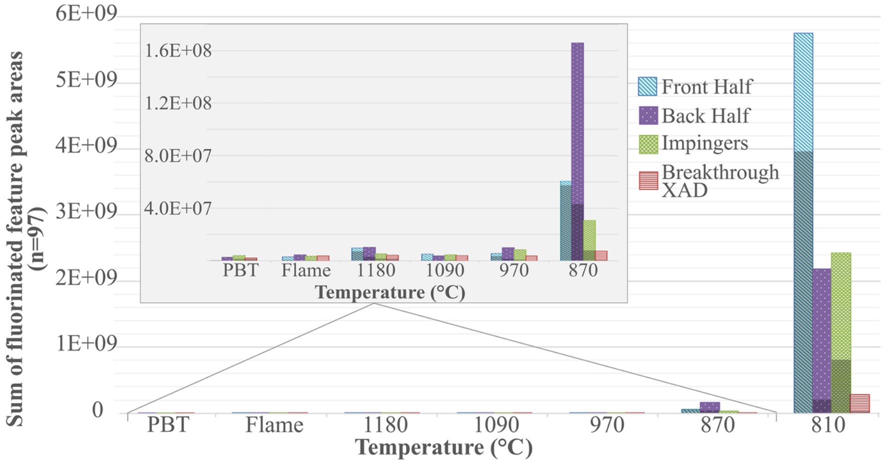

Figure 2. Sums of the peak areas of fluorinated features observed with nontargeted analyses of the OTM-45 extracts. Each fraction of the sampling train is shown for each temperature. The darkened portion of each bar is the sum of the targeted compounds' peak areas, included to show how well the targeted list covers the observed PFAS.

Nontargeted PFAS Emissions. Additional mass spectra analysis of the OTM-45 extracts revealed there were up to 92 features that indicated the presence of different semivolatile polar PFAS. Figure 2 presents the sum of the peak areas for these 92 fluorinated species for the six combustion experiments and the PBT. Where the peak area of a feature was very low, an arbitrary value was given to the peak to allow for statistical analysis by the software. This artificially makes the peak areas for fluorinated features in the blanks and some low detection samples higher than what they may actually be. Figure 2 does not correct for this, and again near blank levels may indicate the nontargeted peak areas are below detection limits. Figure 2 presents separate analysis for four OTM-45 sample fractions: front half (filter and probe rinse), back half (XAD-2 sorbent), impinger solutions, and a second volume of XAD-2 sorbent to quantify the potential for sample breakthrough. The NTA peak areas in Figure 2 are separated between those corresponding to 36 targeted PFAS (lightly shaded) and 56 nontargeted (unidentified) PFAS found. The tentative formulas and chemical names for the nontargeted PFAS are listed in Table S5. These formulas and names are based on the MS1 molecular ion; the software occasionally picked compounds that do not contain fluorine. The MS2 spectra did show PFAS-like features and are included in Table S5. The 36 targeted PFAS are part of the other OTM-45 targeted list of PFAS shown in Table S2, and Figure 2 shows how much the total PFAS present are made up of these targeted compounds. It is apparent many of the compounds sampled during these experiments are not found in the OTM-45 list. As the temperature decreases the peak area of the OTM-45 fractions shift from the back half XAD having the most area to the front half, or filter, fraction having the most area at 810 °C. This is due to the large increase of sulfonates in the emissions, see Table 1, that preferentially adsorbed on the filter, and to a lesser extent an increase of PFCAs on the filter too.

Figure 2 presents these data on two linear scales. The larger plot includes the 810 °C experiment, and the inset excludes these data to allow better comparison of the other experimental results. NTA indicates additional unidentified semivolatile polar PFAS mass in addition to the 36 targeted PFAS in all sample fractions. However, like the volatile nonpolar PIC measurements, injection temperatures > 1000 °C do not result in NTA PFAS mass significantly above blank levels. Note that the NTA also shows the suspected hysteresis effect of performing the 1180 °C experiment after the 810 °C experiment. The NTA indicates increasing PFAS emissions at AFFF injection temperatures < 1000 °C and that unidentified PFAS comprise a portion of these emissions.

■ CONCLUSIONS

The functional groups of many PFAS, and perhaps many PFAS of industrial importance, can be removed at temperatures which do not fully mineralize the fluorinated chain. This would classify many industrial PFAS as Class 3 to Class 5 compounds on the U.S. EPA's Thermal Stability Index, where Class 1 is the most stable and Class 7 compounds are the least stable.[45] Despite the ranking of parent PFAS, subsequent fluorinated PICs formed are stable,[57] and the simple use of DEs as the sole indicator of complete PFAS destruction may be misleading. For some PFAS, relatively low energies are needed to remove the polar functional group, with the first step being the loss of the terminal C or S likely through a lactone or sulfone intermediate, leaving a nonpolar fluoroalkyl chain. If conditions prevent continuation of the destruction mechanisms, this may result in high DEs, >99.99%, but not necessarily the mineralization of the PFAS molecule. Here, complete destruction is defined as mineralization, which for a C, F, O, H system results in CO_2, HF, and H_2O. In these experiments, combustion conditions were examined that produced high DEs and measurable PICs. However, when AFFF was exposed to temperatures ≥1090 °C (including exposure to flames and near adiabatic flame temperatures), high DEs and near detection limit concentrations of relatively few vPFAS PICs were observed. Based on these experiments, high destruction of PFAS can be shown only by considering both high DEs and the absence of PICs.

Finally, note that these experiments focused on steady-state combustor operations. This was done to simplify the fluid dynamics and mixing behavior and allow a focus on the kinetic aspects. However, except for thermal oxidizers and some other steady-state liquid injection applications, HWIs (often rotary kilns) introduce wastes in multiple ways, including batch solids and contained liquids. These cause transient release of organics to the vapor phase that may temporarily overwhelm available oxygen and depress temperatures. For most HWIs, the afterburner is intended to dampen and smooth this transient behavior, but it is likely that the time dependent behavior of PFAS in HWIs and other batch fed systems will depend on the system's ability to smooth these transients and maintain high temperatures. More research into rotary kiln systems and full-scale incinerators is needed.

■ ASSOCIATED CONTENT

Supporting Information

The Supporting Information is available free of charge at https://pubs.acs.org/doi/10.1021/acsestengg.3c00098.

> Additional combustor conditions, sampling setup, method information, analytical data, destruction efficiency calculation method, and analytical methods for nontargeted analysis (PDF)

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Notes

The research described in this article has been reviewed by the U.S. EPA Center for Environmental Measurement and Modeling and approved for publication. The contents of this article should not be construed to represent Agency policy nor does mention of trade names or commercial products constitute endorsement or recommendation for use.

The authors declare no competing financial interest.

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■ NOTE ADDED AFTER ASAP PUBLICATION

This paper published ASAP on June 1, 2023 with errors in Table 2. The errors were corrected and the paper reposted on July 7, 2023.

Exhibit C

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SIERRA CLUB EARTHJUSTICE

Incineration is not a safe disposal method for PFAS

Incineration is not proven to safely destroy per- and polyfluoroalkyl substances (PFAS). Commercial incinerators do not, and often cannot, measure their PFAS releases, and the limited laboratory testing that has been conducted does not reflect real-world incineration conditions. PFAS chemicals' carbon-fluorine bond is particularly resistant to combustion, making PFAS unusually difficult and dangerous to incinerate. Yet, despite an acknowledged lack of data, the federal government has already incinerated millions of gallons of PFAS-containing waste, placing the communities surrounding incinerators at risk.

Under the National Defense Authorization Act for Fiscal Year 2020, the Department of Defense cannot incinerate PFAS unless it first establishes that the incineration is "conducted at a temperature range adequate to break down PFAS chemicals while also ensuring the maximum degree of reduction in emission of PFAS, including elimination of such emissions where achievable" and is "conducted in accordance with the requirements of the Clean Air Act, including controlling hydrogen fluoride."[1]

The National Defense Authorization Act for Fiscal Year 2022 imposed a federal moratorium on PFAS incineration until DOD "issues guidance implementing" the foregoing requirements, as well as the recommendations in the Environmental Protection Agency's interim guidance on the destruction and disposal of PFAS and materials containing PFAS.[2] The information that would be required to inform and support that guidance does not currently exist, as there is no proof that existing incinerators are capable of breaking down PFAS chemicals without generating additional PFAS emissions or other harmful products of incomplete combustion.

We reviewed published studies related to PFAS incineration. Scientists are plagued by measurement challenges—studies have unacceptably high detection limits and/or analyze for just a limited number of potential breakdown products, or analyze the incineration of tiny amounts of PFAS compounds. Indeed, the sentinel study done for 3M on PFAS incineration used a bench scale burner and incinerated about an ounce of PFAS. As EPA itself has recognized, "the effectiveness of incineration to destroy PFAS compounds and the tendency for formation of fluorinated or mixed halogenated organic

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[1] National Defense Authorization Act for Fiscal Year 2020, Pub. L. 116-92, § 330, 133 Stat. 1198 (enacted Dec. 20, 2019),

[2] National Defense Authorization Act for Fiscal Year 2022, Pub. L. No. 117–81, § 343(a), 135 Stat. 1643 (enacted Dec. 27, 2021).

byproducts is not well understood" and "[e]mission studies … have been incomplete due to lack of necessary measurement methods suitable for the comprehensive characterization of fluorinated and mixed halogenated organic compounds."[3] Instead of returning to an unproven and dangerous PFAS disposal technology, the Department of Defense should heed EPA's recommendation of "interim storage" of PFAS-containing waste "until identified uncertainties are addressed and appropriate destruction and disposal technologies can be recommended."[4]

1. *PFAS may not be eliminated in the operating conditions of a hazardous waste incinerator*

Two original industry studies of PFOS breakdown products lack the sensitivity to ensure a high level of thermal destruction. Destruction efficiencies of 99.9999% are usually required for highly toxic, persistent wastes, like PCBs and PFAS.[5] The 3M-sponsored studies from 2003 and 2005 didn't detect PFOS and PFOA in waste gasses, but had a detection limit of 0.1%, which means concentrations of up to 1,000 parts per million of PFOS or PFOA in air would not be detected under the conditions of this study.[6],[7] Indeed, given the large stockpiles that DOD holds of PFOS-based AFFF, allowing 0.1% of the PFAS to escape unreacted from incinerators could result in a massive amount of PFAS entering the environment.

EPA is developing methods to measure individual PFAS chemicals at a higher level of sensitivity in air samples, but until these methods are perfected it will be impossible to accurately gauge how much of the PFAS in military waste passes through into the atmosphere.

a. *Thermal breakdown of PFAS can form a range of harmful breakdown products.*

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[3] United States Environmental Protection Agency, 2020a. Per- and Polyfluoroalkyl Substances (PFAS): Incineration to Manage PFAS Waste Streams. https://www.epa.gov/sites/default/files/2019-09/documents/technical_brief_pfas_incineration_ioaa_approved_final_july_2019.pdf

[4] United States Environmental Protection Agency, 2020b. Interim Guidance on the Destruction and Disposal of Perfluoroalkyl and Polyfluoroalkyl Substances and Materials Containing Perfluoroalkyl and Polyfluoroalkyl Substances. https://www.epa.gov/system/files/documents/2021-11/epa-hq-olem-2020-0527-0002_content.pdf

[5] United States Environmental Protection Agency, 2019. Guidance for Applicants Requesting to Treat/Dispose of PCBs Using Incineration or an Alternative Method. https://www.regulations.gov/docket?D=EPA-HQ-OLEM-2018-0305

[6] Philip Taylor & Tak Yamada, Final Report – Laboratory-Scale Thermal Degradation of Perfluoro-Octanyl Sulfonate and Related Precursors (May 2003), https://clu-in.org/download/contaminantfocus/pfas/UDR-TR-03-00044.pdf.

[7] Tak Yamada et al., Thermal Degradation of Fluorotelomer Treated Articles and Related Materials , 61 Chemosphere 974–84 (Nov. 2005), https://doi.org/10.1016/j.chemosphere.2005.03.025.

Even if the carbon-fluorine bonds in PFAS could be broken by incineration, the resulting, highly reactive fluorine molecules can form a range of harmful breakdown products with varied physical and chemical qualities. Much of the published incineration research for PFAS has been done at bench scale using just milligrams of starting materials, and in optimized temperature and handling protocols. These findings are not reflective of actual incineration conditions, and they have not been replicated at an operational scale.

As many scientists have acknowledged, “There are no proven analytical technologies which have been demonstrated to detect all potential fluoro-organic by-products.”[8] Of particular concern are PFAS that get volatilized or transformed into volatile organofluorine compounds and escaped detection.[9]

Independent studies detect a range of concerning breakdown products in bench scale incineration studies. They include:

Greenhouse gasses - The original 3M studies measured several potent greenhouse gases and other breakdown products.[4,5] In Taylor (2003) PFOS byproducts include: fluorobenzene, one- and two- carbon fluoroalkanes (tetrafluoromethane, fluoroform, and hexafluoroethane), and fluoroalkenes (1,1-difluoroethene and 1,2-difluoroethene). Yamada (2005) heated PTFE (a polytetrafluoroethylene polymer) to a maximum of 1000C with a 2 second residency time, and detected one- and two- carbon fluorochemicals (fluoroform ion and fluoropropene ion). Concentrations of these breakdown products were estimated to be less than or equal to 1,000 parts per million or 0.1%. Garcia (2007) detected one-, two- and three-chain fluorochemical formation from the thermal degradation of PTFE at temperatures between 750 to 1050C.[10]

The global warming potential of fluorine-containing byproducts is thousands of times more potent than carbon dioxide.[11]

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[8] Horst, et al. 2020. Understanding and Managing the Potential By-Products of PFAS Destruction. Groundwater Monitoring & Remediation. https://ngwa.onlinelibrary.wiley.com/doi/abs/10.1111/gwmr.12372

[9] Watanabe, et al. 2018. Thermal mineralization behavior of PFOA, PFHxA, and PFOS during reactivation of granular activated carbon (GAC) in nitrogen atmosphere. Environ. Sci. Pollut. Res. Int. 25 (8), 7200e7205. https://doi.org/10.1007/s11356-015-5353-2

[10] García, et al. 2007. Products obtained in the fuel-rich combustion of PTFE at high temperature. J. Anal. Appl. Pyrol. 80 (1), 85e91. https://doi.org/10.1016/j.jaap.2007.01.004

[11] Greenhouse Gas Protocol. 2016. Global Warming Potential Values. https://www.ghgprotocol.org/sites/default/files/ghgp/Global-Warming-Potential-Values%20%28Feb%2016%202016%29_1.pdf

Fluorinated acetic acids - Mono-, di-, and tri-fluoroacetic acids are common thermal breakdown products of PTFE, particularly at lower temperatures (Ellis 2001). They are toxic to aquatic ecosystems and widely detected in the atmosphere and in precipitation. Some scientists suggest they may be partially responsible for pulmonary edema seen in workers at PTFE plants.[8]

Dioxins and furans - Dioxins and furans can be formed in municipal solid waste incinerators when PFAS are incinerated alongside other wastes.[12] Methodological constraints hinder monitoring for dioxins and furans in other PFAS incineration studies.[13]

Un- or partially-reacted PFAS - EPA lists "shorter chain PFAS, partially fluorinated PFAS, and defunctionalized perfluorinated carbon chains" as other potential thermal by-products.[2] Short-chain polyfluorinated alkyl acids require higher temperatures to achieve thermal destruction than long-chain acids.[14] Wang tested for PFAS in air at two municipal solid waste incinerator facilities in China. They reporting higher concentrations of PFOA in air at the incinerator sites compared to an upwind site, while fluorotelomer concentrations were comparable across all samples.[15]

Hydrogen fluoride - The complete liberation of fluorine from carbon sources in the incinerator would produce hydrogen fluoride, an acutely toxic and corrosive gas. Hydrogen fluoride has to be managed to ensure it doesn't impact machinery of the incinerator itself.[16] As the ITRC reports in its PFAS destruction guidance related to incineration, "there have not been sufficient pilot studies to determine the validity of this concern. This could pose serious health and safety issues and could compromise equipment components."[17]

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[12] Merino, et al. 2016. Degradation and removal methods for perfluoroalkyl and polyfluoroalkyl substances in water. Environ. Eng. Sci. 33 (9), 615e649. https://doi.org/10.1089/ees.2016.0233

[13] Aleksandrov et al. 2019. Waste incineration of Polytetrafluoroethylene (PTFE) to evaluate potential formation of per- and Poly-Fluorinated Alkyl Substances (PFAS) in flue gas. Chemosphere. 226. 898-906.

[14] Watanabe et al. 2016. Residual organic fluorinated compounds from thermal treatment of PFOA, PFHxA and PFOS adsorbed onto granular activated carbon (GAC). Journal of Material Cycles and Waste Management. 18:625-630. https://link.springer.com/article/10.1007/s10163-016-0532-x

[15] Wang, et al. 2013. Mineralization behavior of fluorine in perfluorooctanesulfonate (PFOS) during thermal treatment of lime-conditioned sludge. Environ. Sci. Technol. 47 (6), 2621e2627. https://doi.org/10.1021/es305352p

[16] United States Environmental Protection Agency, 2020. Thermal Treatment of PFAS in Environmental Media: A review of the state-of-the-science. Mark Mills, Diana Bless Environmental Protection Agency; Kavitha Dasu, Dinsuah Siriwardena, Amy Dindal Battelle Memorial Institute.

[17] ITRC. 2020. PFAS - Per- and Polyfluoroalkyl Substances: Treatment Technologies. Interstate

Chemours, under a consent decree with the federal government and the state of North Carolina, has developed a non-target analytical method which will help map the “dark matter” of PFAS breakdown products. One recent study to develop non-target methods examined a sample of waste gasses from the thermal oxidizer at Chemours Fayetteville facility in North Carolina and found a number of unidentifiable fluorochemicals and GenX (HFPO-DA) in waste gasses. Ninety-nine percent of the waste fluorine gases were unidentified chemicals, and 1 percent was GenX.[18]

b. *Current monitoring methods aren’t able to determine exactly what is coming out of incinerator stacks*

EPA is working to develop and validate the analytical methods that will allow it and others to reliably measure PFAS and breakdown products in air and other media. Such tools are essential to allow regulators to determine whether the extremely strong carbon-fluorine bonds in PFAS can be broken in the conditions of a hazardous waste incinerator, and whether emissions controls can trap and remove byproducts. Until these methods are available there is no way to substantiate the degree of breakdown and removal of PFAS and other organic-fluorine compounds from incinerator stacks. These methods are listed as “coming soon” on the EPA website.[19]

2. Hazardous waste incinerators and other kilns and thermal oxidizers do not operate in compliance with existing permits

There is no evidence that any incinerator operating in the United States can safely destroy concentrated PFAS waste such as AFFF. In part this is because neither EPA nor any other agency has established the temperatures and other operating conditions required to destroy PFAS without the formation of harmful products of incomplete combustion, and it is in part because incinerators do not conduct the monitoring required to determine the effects of their PFAS incineration. But even if minimum temperatures and operating conditions could be established, several of the hazardous waste incinerators on the Defense Logistics Agency’s Qualified Facilities List have a long track record of environmental non-compliance, raising questions about their ability to maintain those temperatures and other operational requirements.

HERITAGE THERMAL SERVICES, INC. – EAST LIVERPOOL, OHIO

Technology Regulatory Council. https://pfas-1.itrcweb.org/12-treatment-technologies/

[18] Alexandria Forester, et al. Development of Total Organic Fluorine Method for the Analysis of Progress Wastewater Streams and Air from Fayetteville Works (NC). Final report. December 31, 2021.

[19] EPA. 2022. PFAS Analytical Methods Development and Sampling Research. https://www.epa.gov/water-research/pfas-analytical-methods-development-and-sampling-research

Publicly available records indicate that, since the beginning of 2018, the facility reported at least ***25*** instances where it exceeded the emissions standard for total hydrocarbons. Of these, at least two seem to coincide with violations of the minimum temperature limits for the combustor. Several of the THC exceedances were quite severe, with records showing THC levels at over three times the MACT emission standard. The facility also documented ***2*** exceedances of its opacity limits over this span.

The facility has been under heavy scrutiny from state regulators, the EPA, and the general public. Documents filed by the U.S. Department of Justice ("DOJ") indicate that there have been "numerous" documented violations of the minimum combustion temperature OPLs for the rotary kiln and the secondary combustion chamber at the Heritage East Liverpool incinerator.[20] In comments on the facility's draft permit, Save Our County, a local community group, noted 13 violations of the minimum combustion temperature OPLs from January 2015 through March of 2016.[21] In a March 2015 Finding of Violation, EPA documented an additional 13 violations of the facility's minimum combustion temperature OPLs from January 2011 through April 2014.[22] DOJ also notes "numerous" violations of the maximum flue gas flow rate OPL,[23] which, as discussed above, reflects poor operating conditions that increase the propensity for PIC formation.

CLEAN HARBORS ENVIRONMENTAL SERVICES – DEER PARK, TEXAS

Publicly available records indicate that, since the beginning of 2018, the facility reported at least ***20*** deviations from OPLs. At least ***2*** of these deviations appear to relate to exceedances of the opacity standard, indicating emissions of particulate matter from the facility that could reflect inefficient combustion.

Records maintained by the state regulatory agency – the Texas Commission on Environmental Quality ("TCEQ") indicate that the most recent Semi-Annual Excess Emissions Report was filed in April of 2017, for the reporting period from April through September 2016. That report shows that the facility's two incinerator trains reported excess emissions of opacity for 13.5 minutes and of total hydrocarbons for just over 1

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[20] Complaint ¶¶ 92, 101, *USA v. Heritage Thermal Servs., Inc.*, No. 4:18-cv-2419 (E.D. Ohio Oct. 18, 2018), ECF No. 1.

[21] Save Our County, Inc., Comment on Heritage Thermal Services, Inc.'s Draft Hazardous Waste Renewal Permit and Draft Title V Permit at 7 (Aug. 18, 2017), https://static1.squarespace.com/static/52d06637e4b03daab13b67f6/t/5a2ed345ec212d1fdd6093bf/1513018190690/SOC+Comment+on+Heritage+RCRA+and+Title+V+permit+renewal.pdf

[22] Finding of Violation ¶ 59, *In re Heritage Thermal Servs., Inc.*, No. EPA-5-15-OH-12 (EPA Mar. 23, 2015).

[23] Complaint, *supra* note 20, ¶ 108.

hour. That same report documented that one of the incinerators was in an upset mode (resulting in a startup/shutdown event) for 1 hour and 39 minutes.

VEOLIA TECHNICAL SOLUTIONS – PORT ARTHUR, TEXAS

Publicly available records indicate that, since the beginning of 2018, the facility reported at least ***86*** violations of emission limits or OPLs. There were **40** unique exceedances of the emissions standard for carbon monoxide, and an additional ***6*** exceedances of the facility's minimum combustion chamber temperature OPL.

TCEQ has issued notices of violation ("NOVs") and cited the facility for these and other violations related to its hazardous waste incineration. In responding to a recent NOV, the facility acknowledged that "compliance with the [CO] authorized emission limit requires precise timing and control by highly skilled [o]perators to balance the fuel to oxygen ratio to achieve optimal combustion and control of CO emissions."[24] The facility has suggested that they will be able to limit CO exceedances through additional training. But state records indicate that the facility's struggles in minimizing CO emissions are longstanding, dating back at least a decade.

CLEAN HARBORS ENVIRONMENTAL SERVICES – KIMBALL, NEBRASKA

Publicly available records indicate that, since the beginning of 2019, there were at least ***105*** total violations of emission limits, OPLs, or other permit terms. The facility reported at least ***57*** instances where it exceeded the emissions standard for THC. Of these, two were expressly linked in the facility's reports to problems maintaining adequate minimum temperature for the combustor. There was ***1*** additional reported violation during this span where the facility violated its minimum temperature requirement. The facility also documented ***10*** exceedances of the particulate matter standard.

However, these reports may actually undercount the compliance problems at the facility. A separate report related to leak-detection also requires reporting of startup/shutdown events; the list presented in such reports includes incidents that are not reflected in the list of OPL and emission limit violations reported for 2019.

Summary reports filed by the facility show that, during 2019, the facility was in "upset" mode and reporting excess THC emissions for a total of 45.7 hours. Of this total, 27.25 hours were attributable to "startup/shutdown" events with the remaining being attributable to "process problems." The facility reported an additional 0.4 hours of excess emissions related to O_2-related upset conditions.

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[24] Tex. Council on Envtl. Qual., Investigation Report: Veolia ES Technical Solutions, Investigation No. 1591996 at 9–10 (Sept. 2019).

Another permit term violation related to the incineration of prohibited waste. In issuing the facility a NOV, the state regulatory agency – the Nebraska Department of Environmental Quality ("NDEQ") – classified the violation as a "high-priority violation" of its RCRA permit. The facility also reported two other incidents in 2019 that led to fires igniting on the premises. And in September of 2019, the facility received a notice of violation from EPA related to deficiencies in its processing and storage of hazardous wastes; similar violations were noted in a May 2019 notice of violation issued earlier by NDEQ.

Conclusion - PFAS incineration is unnecessary as new and promising destruction technologies on their way.

While PFAS incineration is fraught with technical and operational challenges and poses a serious threat to the communities surrounding incinerators, new destruction technologies could provide a safer and more effective disposal alternative. These novel technologies use heat, pressure, enzymes or other forces to deconstruct PFAS in confined systems. This means that breakdown products can be contained and studied to ensure destruction was complete before waste products are released in the environment. Among the most promising technologies are Super Critical Water Oxidation (SCWO) which EPA has said appears to be a promising alternative to incineration for AFFF waste.[25] Instead of returning to PFAS incineration, DOD and other federal agencies should be leading the transition to safer and more effective PFAS destruction technologies.

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[25] EPA. 2021. Supercritical water oxidation as an innovative technology for PFAS destruction. https://cfpub.epa.gov/si/si_public_record_Report.cfm?dirEntryId=354238&Lab=CEMM

Exhibit D

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Review

A critical review of perfluoroalkyl and polyfluoroalkyl substances (PFAS) landfill disposal in the United States

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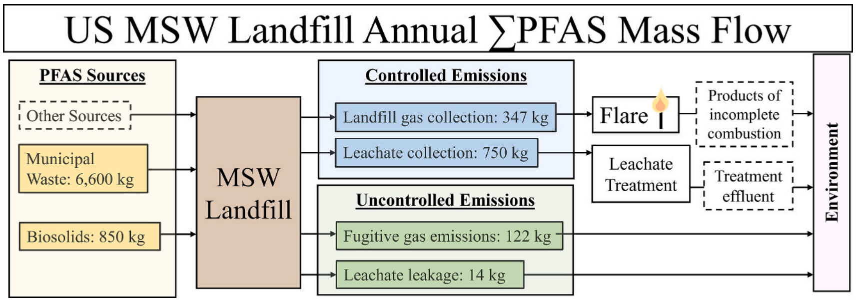
HIGHLIGHTS

- Solid waste management strategies impact PFAS emissions.
- PFOA has the highest ratio to its respective RSL in C&D and MSW landfill leachates.
- Unlined C&D landfills present a significant source of PFAS to the environment.
- An estimated 7.5 metric tons of PFAS enter MSW landfills annually.
- Annually, 460 kg of PFAS emitted via landfill gas, 750 kg via landfill leachate.

GRAPHICAL ABSTRACT



ARTICLE INFO

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ABSTRACT

Landfills manage materials containing per- and polyfluoroalkyl substances (PFAS) from municipal solid waste (MSW) and other waste streams. This manuscript summarizes state and federal initiatives and critically reviews peer-reviewed literature to define best practices for managing these wastes and identify data gaps to guide future

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Abbreviations: μg, Microgram; AFFF, Aqueous film-forming foams; C&D, Construction and demolition; diPAP, Polyfluoroalkyl phosphoric acid diesters; FASA, Perfluoroalkane sulfonamide; FASE, Perfluoroalkane sulfonamido ethanol; FTAc, Fluorotelomer acrylate; FTCA, Fluorotelomer carboxylic acid; FTO, Fluorotelomer olefin; FTOH, Fluorotelomer alcohol; H_2S, Hydrogen sulfide gas; HAL, Health Advisory Limit; kg, Kilogram; L, Liter; LFG, Landfill gas; MCL, Maximum Contaminent Level; MeFBSAA, Methyl-n-perfluorobutanesulfonamidoacetic acid; MeFOSAA, Methyl-n-perfluorooctanesulfonamidoacetic acid; mg, Milligram; Mg, Megagram (metric ton); MPCA, Minnesota Pollution Control Agency; MSW, Municipal solid waste; MSWI, Municipal solid waste incineration; NEBRA, North East Biosolids & Residuals Association; NWRA, National Waste & Recycling Association; PFAA, Perfluoroalkyl acids; PFAS, Per- and polyfluoroalkyl substance(s); PFBS, Perfluorobutane sulfonate; PFCA, Perfluoroalkyl carboxylic acids; PFHxA, Perfluorohexanoic acid; PFHxS, perfluorohexane sulfonate; PFOA, Perfluorooctanoic acid; PFOS, Perfluorooctane sulfonic acid; PFPeA, Perfluoropentanoic acid; PFSA, Perfluoroalkyl sulfonic acids; PIC, Product of incomplete combustion; RCRA, Resource Conservation and Recovery Act; RNG, Renewable natural gas; RO, Reverse osmosis; RSL, Regional Screening Limit; SI, Supplementary information; US EPA, United States Environmental Protection Agency; WWTP, Wastewater treatment plant.

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research. The objective is to inform stakeholders about waste-derived PFAS disposed of in landfills, PFAS emissions, and the potential for related environmental impacts. Furthermore, this document highlights data gaps and uncertainties concerning the fate of PFAS during landfill disposal. Most studies on this topic measured PFAS in liquid landfill effluent (leachate); comparatively fewer have attempted to estimate PFAS loading in landfills or other effluent streams such as landfill gas (LFG). In all media, the reported total PFAS heavily depends on waste types and the number of PFAS included in the analytical method. Early studies which only measured a small number of PFAS, predominantly perfluoroalkyl acids (PFAAs), likely report a significant underestimation of total PFAS. Major findings include relationships between PFAS effluent and landfill conditions – biodegradable waste increases PFAS transformation and leaching. Based on the results of multiple studies, it is estimated that 84% of PFAS loading to MSW landfills (7.2 T total) remains in the waste mass, while 5% leaves via LFG and 11% via leachate on an annual basis. The environmental impact of landfill-derived PFAS has been well-documented. Additional research is needed on PFAS in landfilled construction and demolition debris, hazardous, and industrial waste in the US.

1. Introduction

Per- and polyfluoroalkyl substances (PFAS) include thousands of unique manufactured chemical compounds with a hydrophobic carbon-fluorine chain and a functional group that may be hydrophilic or hydrophobic. PFAS provides beneficial properties for many consumer products and industrial applications, mostly stick- and stain-resistance and surfactant qualities. PFAS's usefulness has led to a nearly ubiquitous presence in our lives, and PFAS's stability, due to the strength of carbon-fluorine bonds, result in long half-lives and the nickname “forever chemicals.”

Human exposure to PFAS has been linked to detrimental health effects which impact all systems, including reproductive effects such as decreased fertility or increased high blood pressure in pregnant women, developmental effects or delays in children, including low birth weight, accelerated puberty, bone variations, behavioral changes, increased risk of some cancers, including prostate, kidney, and testicular cancers, reduced ability of the body's immune system to fight infections, including reduced vaccine response; interference with the body's natural hormones and increased cholesterol levels and risk of obesity (reviewed by Fenton et al., 2021). In response to the growing body of evidence identifying PFAS as a significant threat to human health and the environment, the United States Environmental Protection Agency (US EPA) is undertaking research to determine the impact of PFAS via a risk paradigm approach: (1) determine toxicity, (2) understand exposure, (3) assess risk, and (4) find and innovate effective treatment and remediation techniques and strategies. Because PFAS-containing products are disposed of at the end of their useful lives, significant PFAS quantities are managed with solid waste in the US and elsewhere. Properly managing solid waste via containment, treatment, and destruction is essential to protecting our environment and reducing the risk of harmful exposures.

Recognizing the impact of PFAS on human health and the environment, the US EPA released its first provisional Health Advisory Levels (HALs) for PFAS in drinking water in 2009. As analytical capabilities and scientific understanding of PFAS health impacts have improved, the Agency has promulgated additional guidance and risk-based thresholds. For the first time, in 2023, the US EPA proposed enforceable drinking water regulatory limits to reduce human exposure to PFAS (US EPA, 2022d). In April of 2021, the US EPA released the PFAS Strategic Roadmap, which outlines the EPA's commitments to action for 2021 through 2024. Information about US EPA PFAS initiatives is summarized in ***Table S1*** of the Supplementary information (SI), and applicable limits are included in Table 1. The US EPA has also proposed designating PFOA and PFOS as hazardous substances under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) and is considering adding certain PFAS to the Resource Conservation and Recovery Act (RCRA) list of hazardous constituents (US EPA, 2022b).

At the State level, all the US states except Arkansas, Louisiana, Mississippi, Nebraska, Texas, and Wyoming have dedicated websites providing PFAS-specific information. Some states have banned PFAS-containing products, as summarized in ***Table S2*** (SI). In contrast, others have initiated their own regulatory limits and advisory guidelines, as presented in ***Table S3*** (SI). Eight states have undertaken specific actions and introduced or passed bills targeting PFAS in solid waste (see ***Table S4***, SI). Notably, PFAS regulations are rapidly evolving, and any documentation of state-level PFAS initiatives will likely be outdated quickly.

Confronted with significant quantities of PFAS managed in landfills, the solid waste community struggles to understand the best means to manage PFAS-containing waste streams. Many studies have evaluated PFAS in landfills. However, there is a need for a critical review of the literature that would define the best methodologies for managing these wastes and identify data gaps to guide future research. This manuscript aims to inform the public and stakeholders from the solid waste industry

Table 1
Average concentrations (ng L^{-1}) of select PFAS in landfill leachate and US EPA risk-based thresholds.

Leachate matrix		PFOA		PFOS		PFNA		PFBS		PFHxS		PFHxA	5:3 FTCA
		Mean (n)	DF	Mean (n)	DF	Mean (n)	DF	Mean (n)	DF	Mean (n)	DF	Mean (n)	Mean (n)
MSW		*1400 (284)*	*23*	260 (284)	6.6	69 (234)	1.2	910 (234)	0.1	540 (234)	1.4	2800 (225)	3500 (86)
CDD		*1100 (17)*	*19*	660 (17)	17	50 (17)	0.8	530 (17)	0.1	2200 (17)	5.7	1600 (17)	1400 (17)
MSWI Ash		*800 (40)*	*13*	400 (40)	10	59 (40)	1.1	1400 (40)	0.2	510 (40)	1.3	1300 (40)	700 (40)
HW (Primary)		4900 (24)	81	*4100 (24)*	*102*	530 (24)	8.7	6500 (24)	1.1	12,000 (24)	32	12,000 (24)	NM
HW (Secondary)		*100 (5)*	*1.7*	14 (5)	0.4	40 (5)	0.7	57 (5)	0.01	86 (5)	0.2	440 (5)	NM
EPA limit (ng L^{-1})	Tapwater RSL (HQ = 1.0)	60		40		59		6000		390		n/a	n/a
	Lifetime HAL	0.004		0.020		n/a		2000		n/a		n/a	n/a
	Proposed MCL	4		4		n/a		n/a		n/a		n/a	n/a

(HAL = health advisory level; MCL = maximum contaminant level; RSL = regional screening level; HQ = hazard quotient; DF = average dilution factor required to meet RSL; NM = not measured).
Italicized values represent the controlling dilution factor.

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about PFAS entering the waste stream and being disposed of in landfills, potential landfill PFAS emissions, and the related environmental impacts. Furthermore, this document highlights data gaps and uncertainties concerning the fate of PFAS during landfill disposal. Data were compiled and summarized, as described in the Methods section of the SI (***Section S2*** and ***Table S5***), to provide a concise critical review of this evolving research topic.

2. Solid waste management in the United States

A detailed discussion of solid waste management in the US is included in the SI (Section S3). Residents, businesses, and industries in the United States (US) generate significant amounts of solid waste; overall municipal solid waste (MSW) generation in 2018 was 265 million metric tons (US EPA, 2020b). In addition to MSW, significant amounts of construction and demolition (C&D) waste (545 million metric tons), wastewater treatment plant (WWTP) biosolids (2.5 million metric tons), and varied amounts of industrial waste and disaster debris enter the US solid waste management system every year (US EPA, 2020b). Over time, MSW generation in the US has increased. While the fraction of MSW which is landfilled has decreased from over 90% in 1960 to 50% in recent years, the mass of MSW disposed of in landfills reached its highest recorded level at 133 million metric tons in 2018 (see Fig. S1 in the SI). The US's landfill design, monitoring, and classification are identified and regulated according to the RCRA described in the SI's RCRA section. RCRA and its regulations provide requirements for landfill engineering controls based on the type of waste the landfill receives (MSW (Subtitle D), Hazardous (Subtitle C), industrial, construction, and demolition (C&D) debris) as outlined in the SI.

2.1. Sources of PFAS in solid waste

While extensive research has been undertaken to measure PFAS in effluent from waste management activities (particularly landfill leachate), fewer studies have attempted to estimate the PFAS load entering the waste management sector. Coffin et al. (2022) estimated an extractable ∑PFAS concentration in MSW of 50 μg kg^{-1} based on concentrations in MSW screenings reported by Liu et al. (2022a). Estimating PFAS loading to landfills is not only complicated by analytical challenges and the diversity of measurable PFAS, but also by the heterogeneity of MSW and other waste streams (e.g., household products, building materials, industrial waste, and "other wastes"). The following subsections focus on waste representing suspected high PFAS load or a significant fraction of the waste stream. Fig. 1 presents PFAS concentrations measured in various products and the environment compared to those measured in landfill leachate, compost, and biosolids from WWTPs.

2.1.1. Municipal solid waste

In the US, household waste is among the most significant fractions of MSW. Few studies measured the PFAS concentration of suspected PFAS-containing consumer products in the context of direct exposure during product use (Buck et al., 2011; Favreau et al., 2017; Glüge et al., 2020; Guo et al., 2009; Herzke et al., 2012; ITRC, 2022; Kotthoff et al., 2015; OECD, 2022; US FDA, 2022; Ye et al., 2015). These findings indicate a significant load of PFAS remaining in products at the end of their useful life. Household waste consists of two main categories: the biodegradable fraction and the non-biodegradable fraction. Both types of waste streams contain PFAS, but the fate of their PFAS may differ.

2.1.1.1. Biodegradable fraction. Paper and paperboard are the most

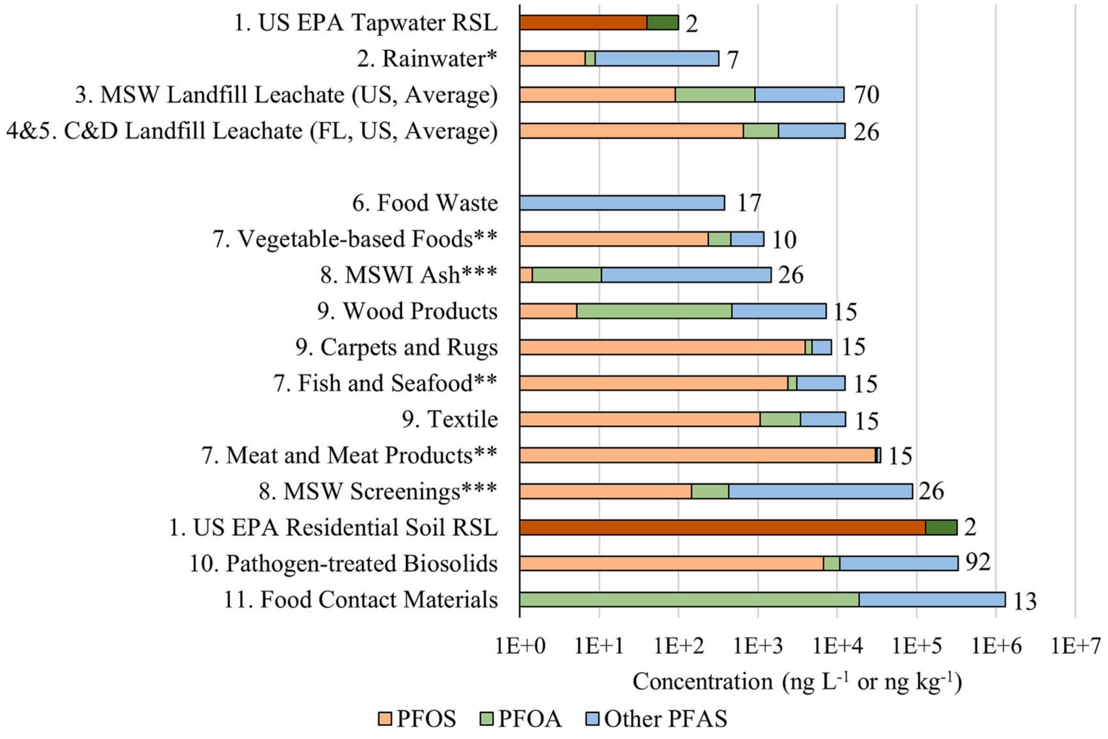

Fig. 1. PFAS concentrations and compositions measured in various products, wastes, and the environment compared to MSW landfill leachate.
* includes ultra-short chain PFAS, TFA.
** upper bound of the mean.
*** minimum total PFAS based on leachable fraction.
Note: numbers prior to matrix type refer to sources. Numbers to the right of the bars are the number of PFAS analytes. RSLs refer to risk-based screening levels, not enforceable regulatory limits. Sources: 1. US EPA (2022d) 2. Pike et al. (2021) 3. Lang et al. (2017) 4. Solo-Gabriele et al. (2020) 5. Chen et al. (2023) 6. Thakali et al. (2022) 7. European Food Safety Authority (2012) 8. Liu et al. (2022b) 9. Bečanová et al. (2016) 10. Thompson et al. (2023a, 2023b) 11. Siao et al. (2022).

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abundant components of MSW, representing 23% of the US MSW generation in 2018 (US EPA, 2021a). PFAS are often added to paper products to improve stick and stain resistance, which results in paper products (including food packaging) consistently reported as a significant source of PFAS for human exposure and in the waste stream (Curtzwiler et al., 2021; D'eon et al., 2009; Ramírez Carnero et al., 2021; Robel et al., 2017; Seltenrich, 2020; Yuan et al., 2016; Zabaleta et al., 2016). In a review of studies that measured PFAS in food-contact materials, Siao et al. (2022) reported concentrations of $\sum_{13}$PFAS in food packaging as high as 8500 μg kg^{-1}; at these concentrations, paper and paper products likely contribute significantly to the overall PFAS loading in MSW, as well as contamination of food and food waste. Sapozhnikova et al. (2023) used targeted and total oxidizable precursor (TOP) assays to measure PFAS migration from food packaging into food products among 88 packaged food samples. TOP analysis identified a significant portion of total PFAS in packaging came from unknown precursor PFAS; average $\sum_8$PFAA was 28 μg kg^{-1} before oxidation and 380 μg kg^{-1} after oxidation. Migration from the packaging into food was found to increase over the course of the ten-day study. Unfortunately, many new products marketed as environmentally-friendly alternatives to plastic products have been found to contain PFAS (Timshina et al., 2021), and advocacy groups in the US and beyond have moved to revise compostable labeling to preclude PFAS-containing products (BioCycle, 2020). Disubstituted polyfluoroalkyl phosphates (diPAPs) have been found to represent a significant fraction of the PFAS used in paper products. However, most studies do not include diPAP as an analyte (D'eon et al., 2009; Thompson et al., 2023a). These findings suggest the concentration of $\sum$PFAS in paper products may be significantly higher than current estimates.

Another large fraction of biodegradable household waste is food waste, accounting for 22% of the MSW generated in the US in 2018 (US EPA, 2021a, 2021b, 2021c). Unlike paper products, PFAS are not intentionally added to food; contact with PFAS-containing equipment, packaging, water, feed, or soil amendments may result in residual PFAS. Several studies have been published describing the potential migration of PFAS from PFAS-impregnated food packaging (Ramírez Carnero et al., 2021). Up to 33% of extractable PFAS on the surface of food contact materials have been reported to migrate to simulated foods – the migration efficiency depends on the food type and PFAS class (Yuan et al., 2016). Additionally, some PFAS are known to bioaccumulate in the food chain. A European Food Safety Authority (2012) report lists seafood and meat as the food categories most frequently reported containing measurable concentrations of PFAS, with PFOS and PFOA quantified most commonly in 29% and 9% of samples, respectively. The same study estimated mean overall dietary exposure for PFOS and PFOA ranging from 0.07 to 32 ng kg^{-1} body weight per day, with lower exposure rates for 14 additional PFAS. Exposure was highest among toddlers and children due to higher food consumption for body size. Among 25 samples of food waste analyzed for PFAS by Thakali et al. (2022), 17 contained PFAS (mean $\sum_{17}$PFAS $= 0.38$ μg kg^{-1}); PFOS and PFOA were not detected in any of the samples.

Wood and yard trimmings represent approximately 18% of the US MSW generation (US EPA, 2020b). While natural wood and plant matter are unlikely to contain significant concentrations of PFAS (Thompson et al., 2023b), engineered wood building materials may be coated with PFAS to enhance performance. In a study of PFAS content in consumer and building materials, 100% of oriented strand board and wood products analyzed contained measurable PFAS concentrations, with median and maximum Σ_{15}PFAA of 5 and 18 μg kg^{-1}, respectively (Bečanová et al., 2016).

2.1.1.2. Non-biodegradable fraction. In the non-biodegradable category of household waste, carpets, and textiles have been consistently found to contain intentionally added PFAS that provide stick and stain resistance and waterproof properties (Kallee and Santen, 2012; Kim et al., 2015; Lang et al., 2016; Peaslee et al., 2020; van der Veen et al., 2022). A review of Σ_{15}PFAA in various household and consumer products found textiles, floor covering, and car interior materials represented the three highest maximum concentrations (78, 38, and 36 μg kg^{-1}, respectively); the highest non-biodegradable median PFAS concentration was from insulation (3.6 μg kg^{-1}) (Bečanová et al., 2016). PFAS and fluoropolymers are also used in non-stick cookware (Sajid and Ilyas, 2017) and electronics to provide smudge resistance, insulation, and other properties. An estimated 114 separate PFAS have been identified in electronic production (Garg et al., 2020). PFAS contamination and exposure through e-waste management have been the subject of several studies (Garg et al., 2020; Tansel, 2022; B. Zhang et al., 2020). Notably, the measurement of PFAS in e-waste itself (as opposed to through leachate, environmental contamination, or dust) is limited. A range of 0.07–0.43 μg kg^{-1} PFOS among all electronic products is provided by Garg et al. (2020). Σ_{15}PFAA reported by Bečanová et al. (2016) ranged as high as 11.7 μg kg^{-1} (median: 0.4 μg kg^{-1}) in electronic and electrical equipment (EEE) and as high as 2.2 μg kg^{-1} (median: 1.4 μg kg^{-1}) in waste EEE.

2.1.2. *Industrial waste*

Industrial processes generate waste and effluent in large volumes; processes that use PFAS, such as the leather tannery, chrome plating, and textile industries, represent a significant contribution of PFAS to the solid waste stream (ITRC, 2022) which are often disposed of in landfills. Other types of industrial processes which generate PFAS-containing waste involve the management of PFAS-contaminated materials, including the separation of wastewater biosolids as part of municipal wastewater treatment, the management of MSW incineration residuals (MSWI ash), and the disposal of PFAS-contaminated soils and other residuals generated as part of environmental cleanup processes.

2.1.2.1. Biosolids. WWTPs manage residential, commercial, and industrial wastewater, including landfill leachate, and have been the subject of many PFAS studies (Lenka et al., 2022). Biosolids account for a significant fraction of WWTP effluent (Fredriksson et al., 2022) and impact PFAS loading to the environment and landfills (Johnson, 2022; Thompson et al., 2023b). Reported PFAS concentrations in biosolids vary with the number of PFAS included in the analytical method. Gallen et al. (2018) reported mean $\sum_9$PFAS of 45 μg kg^{-1} of biosolids; Thompson et al. (2023a, 2023b) reported mean $\sum_{92}$PFAS of 500 μg kg (dry)$^{-1}$ in untreated biosludge and 330 μg kg(dry)$^{-1}$ in biosolids (biosludge treated for pathogen removal), indicating that early studies of PFAS in biosolids which measured fewer PFAS, and predominantly PFAAs, did not capture a significant portion of the total PFAS. Over 5.8 million dry metric tons of biosolids were managed in the US in 2018, of which 30% was managed in landfills, 15% was incinerated, and over 50% was used as a soil amendment (NEBRA, 2022).

2.1.2.2. MSW incineration ash. The incineration of MSW for energy recovery (MSWI) produces two solid waste streams – bottom ash, the material that does not burn, and fly ash, fine particulate matter collected in the air pollution control system. Approximately 13% of MSW in the US is managed through incineration (US EPA, 2021a, 2021b, 2021c), resulting in an estimated 7.5 million tons of MSWI ash (Liu et al., 2019). Few studies have measured PFAS in MSWI ash. Liu et al. (2021b) reported $\sum_{21}$PFAS in fly and bottom ash from three facilities in China, with concentrations ranging from 1.5 to 88 μg kg^{-1} in fly ash and from 3.1 to 77 μg kg^{-1} in bottom ash. Based on the concentrations of PFAS in a laboratory leaching study, the average minimum $\sum_{26}$PFAS in MSWI ash from a US facility was 1.5 μg kg^{-1} (Liu et al., 2022b); this represents a conservative estimate of total PFAS. These concentrations are in the same range as MSW. Incineration temperatures may not be sufficiently high to mineralize or destroy PFAS, and operational strategies likely play a significant role in the fate of PFAS during incineration. The impact of temperatures on PFAS leaching from MSWI is discussed in greater detail in the context of MSWI ash monofill leachates.

2.1.2.3. Manufacturing wastes. There is extensive use of PFAS in some industries, as PFAS is added intentionally to products (i.e., to produce stain-resistant properties in textiles and paper products) and as part of the manufacturing process (i.e., to facilitate demolding). This results in unintentionally contaminated materials through contact. The Interstate Technology Review Committee (ITRC) thoroughly lists PFAS uses in the industrial and manufacturing sectors (ITRC, 2022). PFAS-laden manufacturing waste is often sent to landfills for disposal across industries.

Among specific industries and industrial wastes which have been the subject of PFAS analysis, high-concentration effluents from electronic industries have been described in the literature; photolithographic effluent in Taiwan contained 130,000 ng L^{-1} each of PFHxS and PFOS (Lin et al., 2009); liquid effluent from television and circuit board manufacturing contained 1600 ng L^{-1} of $\sum_{11}$PFAS (Kim et al., 2016); sludge effluent collected from an electronics industry location in South Korea contained 91 μg kg^{-1} of $\sum_{11}$PFAAs (Kim et al., 2016). PFAS are used commonly in paper processing and treatment; a case study in Norway identified PFAS impacts downstream of a landfill used for paper factory waste disposal (Langberg et al., 2021). Chrome plating industry waste sludges are designated hazardous wastes (F006), which contain high concentrations of PFAS (ITRC, 2022) and are therefore managed in Subtitle C hazardous waste landfills. A study of chrome sludge in China identified PFOS as the most predominant PFAS at concentrations as high as 2435 μg kg^{-1} (Qu et al., 2020). The chrome plating industry consumes an estimated 6500 kg of PFOS annually (Garg et al., 2020).

2.1.2.4. PFAS remediation residuals. Sites with high levels of PFAS contamination from the historical use of PFAS-containing aqueous film-forming foams (AFFF) or other releases are frequently remediated, and the contaminated media is commonly disposed of in landfills (either with the waste or used as daily cover). Remediation approaches include mobilization of PFAS and collection of the leachate, sorption of PFAS using activated carbon or other sorbents, or soil excavation for landfill disposal (Bolan et al., 2021; Ross et al., 2018). Brusseau et al. (2020) reviewed PFAS concentrations measured in soils from contaminated sites, reporting median PFOA and PFOS concentrations of 83 and 8700 μg kg^{-1}, respectively, with concentrations as high as 50,000 μg kg^{-1} for PFOA and 460,000 μg kg^{-1} for PFOS.

3. Fate of PFAS in landfills

The fate of solid waste-derived PFAS within landfills is dominated by transformation and partitioning. Many PFAS species are persistent in the environment and PFAS that are degradable can transform into more recalcitrant, typically more environmentally mobile PFAS (Bolan et al., 2021). The partitioning behavior of PFAS are related to the chemical structure of individual species, both according to PFAS class, functional groups, and chain length among homologous species. In turn, the ongoing transformation will impact partitioning behavior (Robey et al., 2020; Zhang et al., 2020a, 2020b; Smallwood et al., 2023). In landfills, PFAS may partition to the liquid phase (leachate) and gaseous phase (landfill gas; LFG), remain sorbed to the waste, and/or interact with the engineering controls of the landfills (e.g., leachate collection systems, gas collection, and control systems). PFAS that are resistant to degradation and minimally soluble or volatile, such as certain polymeric PFAS, have historically been presumed to remain immobile and sequestered in landfills, although more recent studies have called this assumption into question (Lohmann et al., 2020).

3.1. PFAS transformation

Many studies observed the transformation of PFAS precursors into terminal species under abiotic and microbially active aerobic and anaerobic conditions. While this section briefly reviews these processes to provide context to PFAS in landfills, the aim is not to conduct an exhaustive review of the topic, which is available in other reviews (Lu et al., 2023).

3.1.1. Abiotic transformation

PFAS transformation pathways under abiotic conditions include oxidation, photolysis, and thermal degradation (ITRC, 2020; Washington and Jenkins, 2015). While the bulk of PFAS transformations in organic-rich landfills are likely a result of biodegradation, these abiotic processes play an essential role in solid waste management systems. PFAS such as fluorotelomer alcohols (FTOHs) can volatilize under temperatures typical in landfills (35–55 °C). Once in the atmosphere, FTOH can transform via photolysis or other chemical reactions into perfluorocarboxylic acids (PFCAs) which are then deposited on land and waterbodies (Esfahani et al., 2022; Martin et al., 2006). Other abiotic processes include thermal degradation. An increase in the temperature of waste may facilitate PFAS transformation. Wastes within landfills may be exposed to temperatures insufficient to mineralize or defluorinate PFAS but which may cause precursor transformations. Thompson et al. (2023a, 2023b) measured higher concentrations of diPAPs in biosolids that had undergone any form of heat treatment, including heat drying as well as higher temperature vector reduction treatment, indicating the presence and transformation of unidentified precursors.

3.1.2. Aerobic transformation

Aerobic environments exist at the early stages of landfill decomposition. The waste still contains atmospheric oxygen in its void space and likely contributes to the transformation of PFAS in waste. Thompson et al. (2023a, 2023b) observed a proportional increase in PFCAs after aerobic biosolids composting, especially short-chain (perfluoropentanoic acid, PFPeA, and perfluorohexanoic acid, PFHxA). Similarly, Li et al. (2022) found significant increases among short-chain PFAAs (including PFBS and PFOS) in aerobically treated anaerobic digestor sludge. These findings are significant because short-chain PFAS are more mobile in the environment, more likely to be uptaken by plants (Ghisi et al., 2019), and more challenging to treat (Ross et al., 2018). Multiple studies have shown that aerobic decomposition facilitates the transformation of precursor PFAS to shorter-chain terminal PFAS, such as PFOA and PFOS (Hamid et al., 2020; Lee et al., 2010a; Liu et al., 2010; Lott et al., 2023; Rhoads et al., 2008; Schultz et al., 2006; Wang et al., 2009, 2011; Zhao et al., 2013).

3.1.3. Anaerobic transformations

Comparatively, fewer studies have documented PFAS transformation under anaerobic or methanogenic conditions similar to landfills. Liu et al. (2021a) compared 52 PFAS in leachate from waste collection vehicles to anaerobic MSW landfill leachate and concluded the vehicle leachate contained proportionally more precursor PFAS and short-chain PFAAs compared to the landfill leachate as a result of the transformation in the anaerobic landfill environments. Studies of anaerobic precursor transformation identified FTCAs as the predominant by-product of FTOH degradation. Allred et al. (2015) reported increased MeFBSAA and FTCA leaching over abiotic reactors in biologically active landfill microcosm reactors, indicating that methanogenic biological transformation was responsible for the increase. Zhang et al. (2013) observed the accumulation of FTCAs in landfills over time, concluding that FTCAs are indicators of FTOH transformation, while Lang et al. (2016) and Weber et al. (2022) reported PFOA accumulation in leachate as a result of precursor transformation under anaerobic experimental conditions. Lang et al. (2016) attributed this to the longer experimental duration, with PFOA appearing as a significant degradation by-product only 200+

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days into the 550-day experiment.

3.2. PFAS partitioning in landfills

3.2.1. PFAS partitioning to the liquid phase

PFAS concentrations in landfill leachate are a function of multiple factors, including the PFAS profile of the incoming waste stream and conditions within the landfill, which, in turn, correspond with waste composition, stage of decomposition, and environmental factors, especially rainfall precipitation. These factors also affect the physical-chemical aspects of the leachate quality, and any discussion of PFAS in leachate should also include matrix contextualization. The number of PFAS that can be detected and quantified in landfill leachate has grown. Early methods were able to quantify 24 PFAS compounds in three classes (Huset et al., 2011), but improvements have been made; more recent studies attempted to measure 92 PFAS and detected 53, as presented in Table 2.

3.2.1.1. PFAS in landfill leachate by type

3.2.1.1.1. MSW landfills. The vast majority of PFAS landfill leachate data are measured from MSW landfills (Allred et al., 2014; California Water Boards, 2023; Chen et al., 2022, 2023; Huset et al., 2011; Lang et al., 2017; Liu et al., 2022a; Masoner et al., 2020; NWRA, 2020; Solo-Gabriele et al., 2020). The ∑PFAS content of MSW landfill leachate in published US studies ranges from BDL - 125,000 ng L^{-1} with an average of 10,500 ng L^{-1} and a weighted average of 12,600 ng L^{-1}. The weighted average is notably similar to the estimated average ∑PFAS concentration reported by Lang et al. (2017) using Monte Carlo simulation. Often, the ∑PFAS content heavily depends on the number of unique PFAS measured in the study, which ranged from two to 70 for MSW landfill leachate (see SI ***Fig. S2***). For comparison among studies, we will focus on PFAS with corresponding US EPA tapwater Regional Screening Levels (RSL) (i.e., PFOA, PFNA, PFBS, PFHxS, PFOS, and Gen-X), as presented in Table 1. Except for Gen-X, which has only been quantified in a single sample of landfill leachate from a North Carolina MSW landfill with a history of accepting PFAS manufacturing wastes (NWRA, 2020), the remaining five PFAS are reliably quantified in all published landfill leachate studies. Other PFAS which reliably contribute significantly to ∑PFAS in landfill leachates, PFHxA and 5:3 FTCA, are also included in Table 1.

PFAS concentrations have also been reported for leachates from MSW landfills in other countries, including Australia (Gallen et al., 2016, 2017), Europe (Ahrens et al., 2011; Busch et al., 2010; Eggen et al., 2010; Fuertes et al., 2017; Kallenborn et al., 2004; Knutsen et al., 2019; Perkola and Sainio, 2013; Woldegiorgis et al., 2005), and Asia (Huang et al., 2022; Liu et al., 2022b; Yan et al., 2015; Yin et al., 2017; Zhang et al., 2014). International differences in waste composition, sample collection, and analytical processes can impact reported PFAS concentrations, making a direct comparison of the overall PFAS content challenging. Concentrations of PFOS and PFOA, which have been reliably measured in most or all studies, are included for eight countries in ***Table S6*** and described by Travar et al. (2020).

Table 2

Number of PFAS measured and ∑PFAS among published landfill leachate studies.

Matrix	Number of samples	Number of PFAS detected (in Method)	Average ∑PFAS (ng L^{-1})	∑PFAS range (ng L^{-1})	Country	Reference
MSW LL	1	38 (51)	9700	9700	USA	Liu et al. (2021a)
	1	32 (51)	9400	9400	USA	Robey et al. (2020)
	78	25 (26)	12,700	300–58,000	USA	Chen et al. (2023)
	4	10 (11)	17,200	15,000–18,000	USA	Solo-Gabriele et al. (2020)
	6	24 (24)	4700	2700–7400	USA	Huset et al. (2011)
	40	30 (70)	12,200	2000–29,000	USA	Lang et al. (2017)
	11	2 (2)	840	330–2600	USA	Clarke et al. (2015)
	19	28 (28)	5400	230–29,000	USA	Helmer et al. (2022)
	39	2 (2)	1500	47–3400	USA	EGLE (2019)
	9	22 (25)	24,300	1400–125,000	USA	NWRA (2020)
	131	31 (40)	17,500	BDL – 104,000	USA	California Water Boards (2023)
	17	14 (14)	3000	33–15,000	Australia	Gallen et al. (2016)
	94	9 (9)	6100	210–46,000	Australia	Gallen et al. (2017)
	22	15 (15)	7000	Not reported	Australia	Simmons (2019)
	6	25 (43)	6100	31–13,000	Germany	Busch et al. (2010)
	11	24 (24)	9800	2500–36,000	Canada	Benskin et al. (2012)
	31	16 (18)	2700	700–6400	Canada	Li (2009)
	10	2 (2)	*	50–2300	Canada	Gewurtz et al. (2013)
	2	16 (27)	4200	2200–6100	Norway	Eggen et al. (2010)
	5	7 (8)	770	200–1500	Norway	Kallenborn et al. (2004)
	2	4 (4)	400	210–610	Finland	Perkola and Sainio (2013)
	48	7 (10)	2400	14–17,500	Ireland	Harrad et al. (2019)
	4	8 (16)	1100	640–1400	Spain	Fuertes et al. (2017)
	12	28 (30)	1700	320–11,000	Norway	Knutsen et al. (2019)
	10	17 (26)	490	0.3–1300	Sweden	Gobelius et al. (2018)
	5	11 (14)	82,100	7300–290,000	China	Yan et al. (2015)
	9	33 (57)	42,900	3040–109,000	China	Liu et al. (2022b)
	6	17 (17)	14,200	1800–43,300	China	Huang et al. (2022)
	12	18 (18)	4060	1270–7660	Singapore	Yin et al. (2017)
CDD LL	5	8 (9)	6000	4200–11,000	Australia	Gallen et al. (2017)
	13	24 (26)	9500	270–30,500	USA	Chen et al. (2023)
	2	11 (11)	15,500	14,000–16,000	USA	Solo-Gabriele et al. (2020)
MSWIA LL	2	9 (11)	3100	2800–3400	USA	Solo-Gabriele et al. (2020)
	31	26 (26)	7300	39–54,500	USA	Chen et al. (2023)
MSW GC	21	26 (26)	12,200	199–80,900	USA	Chen et al. (2023)
	12	53 (92)	19,000	3000–50,000	USA	Smallwood et al. (2023)
HW LL (Primary)	24	17 (28)	68,000	570–377,000	USA	California Water Boards (2023)
HW LL (Secondary)	5	13 (24)	1800	25–3700	USA	California Water Boards (2023)

(LL = landfill leachate; MSW = municipal solid waste; CDD = construction and demolition debris; MSWIA = MSW incineration ash; GC = gas condensate).

[*] Gewurtz et al. (2013) do not provide detailed data to calculate average ∑PFAS.

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3.2.1.1.2. C&D landfills. PFAS were detected in all C&D landfill leachate samples analyzed across three studies with $\sum$PFAS ranging from 270 to 30,500 ng L^{-1} (weighted average 10,300 ng L^{-1}). Solo-Gabriele et al. (2020) and Chen et al. (2023) found no significant difference in the total measured PFAS between leachate from MSW and C&D landfills. The analytical method used by Chen et al. (2023) included 18 terminal PFAS (PFAAs) and eight precursors (FASAs, FTCAs, and FTSs). The study, however, reported a significant difference in the fraction of $\sum$Terminal and $\sum$Precursor species between MSW and C&D landfill leachates. C&D leachate contained, on average, 86% terminal PFAS, while MSW leachate contained 64% terminal PFAS (Chen et al., 2023). This could be attributed to the different types of PFAS present in each waste stream and the type of biological activity prevalent in each landfill type. Because C&D landfills contain proportionally less food waste and more concrete and gypsum drywall, the prevailing landfill conditions result in higher pH leachate and proportionally more sulfate chemical species in the leachate as opposed to ammonia, which is typically at higher concentrations in MSW landfill leachate (Townsend et al., 1999). Further, due to those differences in leachate conditions, microbial differences result from presence of different carbon sources as well as electron donors and acceptors. Generally, sulfur-reducing bacteria are found in higher concentrations at C&D landfills due to higher amounts of sulfate, while methanogens are more prevalent at conventional landfills (Meyer-Dombard et al., 2020).

Fig. 2 includes the range of concentrations for PFAS with RSLs for MSW and C&D landfill leachate; average PFHxS concentrations were higher in C&D landfill leachate than in MSW landfill leachate, and PFBS concentrations were lower in C&D landfill leachate. Waste composition is highly variable between landfills as well as over time at an individual landfill, so, while limited studies may suggest potential sources of select PFAS in C&D debris (e.g., higher concentrations of PFHxS may be attributed to their use in carpeting and other building materials (Beesoon et al., 2012; Jin et al., 2011), generalizations about specific sources may not be appropriate. Gallen et al. (2017) measured nine terminal PFAS in Australian C&D landfill leachates (n = 5), reporting average $\sum_9$PFAS concentrations of 6000 ng L^{-1} (compared to 6100 ng L^{-1} in 94 MSW leachates from the same study).

Unlike MSW landfills, at the US federal level, C&D landfills do not require a bottom liner and leachate collection systems. This contributes to the lower number of studies describing PFAS in C&D relative to MSW landfill leachate and an increase in the probability of groundwater contamination from C&D compared to MSW landfills. Average concentrations of PFOA, PFOS, PFNA, PFBS, and PFHxS, along with corresponding US EPA risk-based thresholds (HALs, MCLs, and RSLs), are included in Table 1. PFOA poses the most significant challenge as its concentration in C&D landfill leachate would have to be diluted by 19 to meet the tapwater RSL or by 287 to meet the US EPA proposed MCL.

3.2.1.1.3. MSWI Ash monofills. Solo-Gabriele et al. (2020) and Chen et al. (2023) found leachate from MSWI ash monofills to have lower $\sum$PFAS concentrations than leachate from MSW landfills. Solo-Gabriele et al. (2020) reported $\sum_{11}$PFAS in MSWI ash monofill leachates ranging from 2800 to 3400 ng L^{-1} and inversely correlated with incineration temperature. $\sum_{11}$PFAS in leachate from MSWI ash that underwent incineration at 800 °C was almost three times higher than after incineration at 950 °C. The decrease indicates loss of measurable PFAS via mineralization (i.e., destruction), volatilization (i.e., air emission), or transformation to PFAS species which are not measured in standard analytical methods (e.g., products of incomplete combustion or PICs). Leachates from MSWI ash which had undergone incineration at 950 °C, still contained >2000 ng L^{-1} of PFAS, indicating PFAS are not fully mineralized at these operating conditions. Liu et al. (2021b) reported substantially higher $\sum_{21}$PFAS in MSWI ash leachate from three facilities in China, with concentrations ranging from 127,000–450,000 ng L^{-1}. The study did not report incineration temperatures or other operating conditions.

However, when MSWI ash was co-disposed with other wastes, such as MSW or biosolids, $\sum$PFAS concentration in the leachate was on par with that in MSW landfill leachate (Solo-Gabriele et al., 2020; Liu et al., 2022a). Liu et al. (2022a) found the co-disposal of a small fraction (e.g., 4%) of MSW, including biosolids, with MSWI ash resulted in leachate concentrations that were comparable to MSW landfill leachate, suggesting liquids are preferentially flowing through and leaching PFAS from the non-incinerated waste as opposed to the ash. While MSWI ash-derived leachates have lower concentrations of PFAS, these studies suggest care should be taken to dispose of MSW and MSWI ash separately, and more research is needed to understand the fate of PFAS during MSW incineration.

3.2.1.1.4. Industrial landfills. Unlined industrial landfills that received residuals from manufacturing PFAS and PFAS-containing products have been linked to contamination of local groundwater sources. Notable examples include the House Street landfill in Belmont, Michigan which received tannery waste (US EPA, 2022e); Crown Vantage landfills in Parchment, Michigan (MPART, 2020), that were used to dispose of paper mill waste from the production of laminated paper

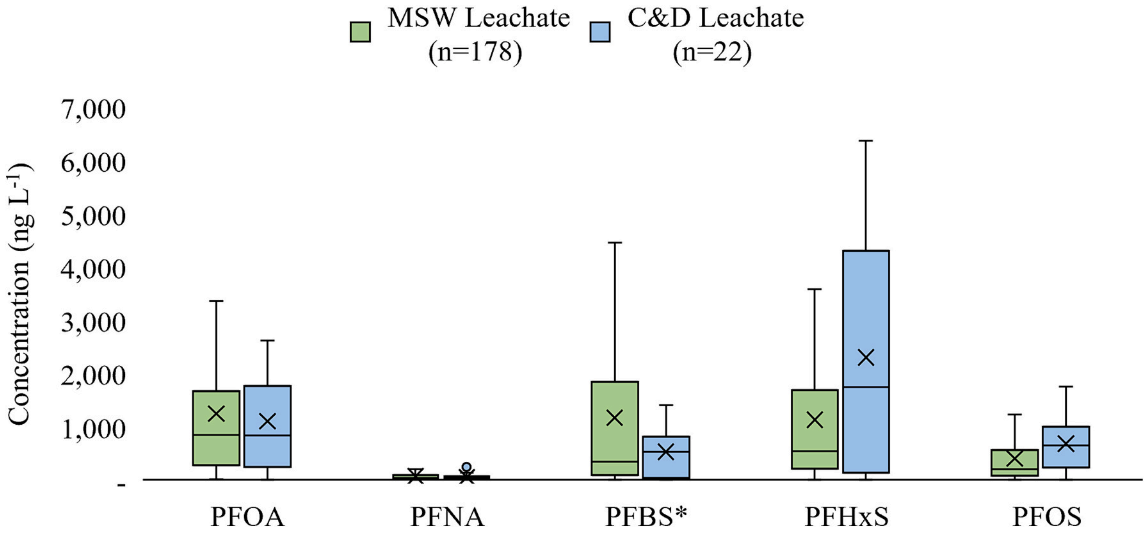

Fig. 2. Average concentrations of five PFAS with US EPA tapwater RSLs.
Data from Gallen et al. (2017), Solo-Gabriele et al. (2020), and Chen et al. (2023).
* Gallen et al. (2017) did not include PFBS analysis.

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products; and the 3M Woodbury disposal site in Washington County, Minnesota, that was used to dispose of PFAS production waste. As part of this literature search, no leachate PFAS concentration data from industrial landfills in the US were located. However, Kameoka et al. (2022) measured PFAS in leachate from three industrial landfills in Japan; $\sum_{17}$PFAA concentrations averaged 45,000 ng L^{-1}.

3.2.1.1.5. Hazardous waste landfills. Although PFAS are not federally regulated as listed hazardous wastes, some solid wastes managed in Subtitle C hazardous waste landfills contain PFAS (as discussed in Section 2.1.2, e.g., chrome-plating sludge), while other PFAS-containing wastes may meet hazardous waste characteristic criteria (e.g., flammable, corrosive, etc.). Some hazardous waste landfills have also reported receipt of AFFF waste at their sites. No peer-reviewed studies have evaluated PFAS concentrations in leachate collected from hazardous waste landfills; however, California Water Boards have released PFAS concentrations for landfill leachate, including two hazardous waste landfills in California (California Water Boards, 2023). The data for these sites are included in the SI ***Table S7***. Among 29 samples from the two sites, $\sum_{24}$PFAS and $\sum_{28}$PFAS concentration was as high as 377,000 ng L^{-1} (average 68,000 ng L^{-1}), substantially higher than MSW, C&D debris, or MSWI ash landfill leachates (see Table 2). In the US, hazardous waste landfill disposal requires waste pre-treatment to minimize contaminant mobility – land disposal restrictions for hazardous waste are described in the Code of Federal Regulations (CFR; 40 CFR § 268). Leaching studies have shown minimal PFAS immobilization using traditional solidification techniques (Barth et al., 2021), which may explain elevated PFAS concentrations in the leachate.

US hazardous waste landfills must also use secondary leachate collection systems; California's database includes five samples of secondary hazardous waste landfill leachate from one site, with $\sum_{24}$PFAS averaging 1800 ng L^{-1} (see Table 2). Without exception, for all sampling locations with both primary and secondary leachate PFAS data, concentrations for individual and $\sum_{24}$PFAS were higher in the primary compared to the secondary leachate. While the absence of biological decomposition in hazardous waste landfills may minimize the microbially-mediated precursor transformation to PFAAs, waste treatment methods (e.g., lime treatment) may also impact transformation and partitioning, possibly oxidizing precursor PFAS. Hazardous waste pretreatment standards are designed to minimize traditional hazardous waste constituent leaching (e.g., lime treatment stabilizes metals and neutralizes acidic waste) and have not been optimized for PFAS stabilization; PFAS fate, transport, and transformations under hazardous waste pretreatment processes are not well understood. Because of the strict Subtitle C landfill operation requirements and the pre-treatment of wastes, leachate generation in these landfills is typically minimal, and any leachate which is produced is often managed as hazardous waste (i.e., not discharged to WWTP, as other landfill leachates often are).

3.2.1.2. Other factors impacting PFAS concentrations in leachate

3.2.1.2.1. Waste age. As waste degrades under the anaerobic conditions of biologically active landfills, the overall PFAS concentrations in the leachate and the ratio of the terminal to precursor species have been found to increase. Lang et al. (2017) reported leachate from waste older than ten years had significantly lower concentrations of PFNA, 8:2 FTCA, 5:3 FTCA, PFBS, MeFBSAA, and MeFOSAA than leachate from younger waste. These differences could be attributed to changes in the PFAS formulations in commercial products and/or the conversion of PFAA precursors. Liu et al. (2021a) measured PFAS in leachate from waste collection vehicles alongside leachate from the receiving MSW landfill. The study found significantly higher $\sum_{51}$PFAS concentrations in landfill leachate which had undergone further biological decomposition. Furthermore, Liu et al. (2021a) also reported a difference in PFAS profiles likely caused by the transformation of precursor PFAS in landfill environments.

3.2.1.2.2. Leachate quality. Although most PFAS behavior and solution chemistry studies focus on remediation technologies, generalizations regarding PFAS phase partitioning also apply to landfill leaching (Z. Du et al., 2014). Comparatively, fewer studies have explored PFAS partitioning in the context of leachate chemistry. In a landfill simulator study, Allred et al. (2015) observed increases in longer-chain PFCA and perfluoroalkyl sulfonic acids (PFSA) concentrations when biodegradation reached the methanogenic stage. At this stage, increased methanogenic and secondary fermentation and decreased volatile fatty acid concentrations from the acidogenic stage result In increased pH, more neutral pH, which is theorized to deprotonate waste surfaces, resulting in less sorption of PFAS to the degrading organic matter. This theory is supported by the results described by Solo-Gabriele et al. (2020), where a significant positive correlation was reported between PFAS concentrations and increasing leachate pH. This effect has also been observed in several previous landfill leachate sampling studies (Benskin et al., 2012; Gallen et al., 2017; Hamid et al., 2018; Yan et al., 2015).

In addition to partitioning behavior, the PFAS profile of landfill leachate is a function of PFAA precursor transformation resulting from biodegradation. Biological activity is catalyzed by landfill moisture, resulting in higher landfilled waste temperatures and more PFAS transformation. In a study of WWTP biosolids pathogen removal, precursor transformation and apparent increases in $\sum_{92}$PFAS, driven by increased PFAA content, resulted after aerobic composting and increased diPAP concentrations from heat treatment (Thompson et al., 2023b). Based on a nationwide study of 95 leachate samples collected from 18 landfills, leachate from MSW landfills in US regions with high annual precipitation showed significantly greater $\sum_{19}$PFAS than comparable landfills in arid locations (Lang et al., 2017); see Table 2 for all US-based studies included in this review. Further, leachate generation volume is significantly higher in regions that experience more precipitation. As a result, landfills in arid regions are estimated to contribute <1% of the nationwide landfill leachate PFAS mass load (Lang et al., 2017). When studies have evaluated the short-term impacts of precipitation on PFAS in landfill leachate, however, leachate PFAS concentration decreased within a day of a precipitation event due to dilution (Benskin et al., 2012; Gallen et al., 2017). Normalization of PFAS concentrations to bulk parameters such as chloride or total dissolved solids may be able to account for such dilution.

3.2.2. PFAS partitioning to the gas phase

MSW contains a proportionally more biodegradable organic matter which undergoes anaerobic decomposition in landfill environments compared to other waste streams (e.g., C&D). The decomposition of organic matter produces MSW LFG, which is, on average, about 50% methane (CH_4), and 50% carbon dioxide (CO_2), with a small fraction consisting of other gaseous and volatile constituents (Wang et al., 2021). LFG at MSW landfills is collected and managed according to the requirements of the US EPA New Source Performance Standards (US Clean Air Act, 40 CFR § 60). According to the US EPA's Landfill Methane Outreach Program (LMOP) August 2022 database, 1230 of the 2635 MSW landfills in the US have gas collection systems in place, and 1157 have flares in place (US EPA, 2022a). C&D LFG is rarely collected in the US, as C&D landfills contain less biodegradable organic matter and produce less LFG than MSW landfills. Additionally, C&D LFG contains proportionally more $H_2S_{(g)}$ produced by sulfur-reducing bacteria and the decomposition of gypsum disposed of as drywall.

Gas generation and composition at other landfill types has yet to be the subject of significant research. MSWI ash monofills are not expected to generate LFG because there is minimal biodegradable matter in the ash; however, the co-disposal of WWTP biosolids, MSW, or any degradable organic matter with MSWI ash will produce biogas as a result of decomposition. Gas generation at industrial landfill sites is primarily a function of the type of waste deposited. Organic waste like pulp and paper mill sludges will likely generate gas requiring management. In general, Subtitle C hazardous waste landfills in the US do not contain

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putrescible organic waste and do not generate biogas.

3.2.2.1.1. PFAS in MSW landfill gas. PFAS volatilization and release from MSW landfills within the gaseous phase is receiving an increased focus driven by advances in volatile PFAS measurement (Riedel et al., 2019) and an improved understanding of PFAS chemistry. The partitioning coefficients (e.g., Henry's constant) for ionizable PFAS are significantly lower than neutral PFAS (Abusallout et al., 2022), making ionizable PFAS less likely to volatilize under typical MSW landfill conditions. Experimental measurement of PFAS vapor pressures similarly suggests FTOHs (i.e., neutral PFAS) are more readily volatilized than PFCAs (i.e., ionizable PFAS) and that vapor pressure decreases logarithmically with carbon chain length in homologous species (M. Zhang et al., 2020). Measurement and data of PFAS in actual MSW LFG are still minimal.

In a 2007 analysis of landfills that accepted PFAS-containing industrial wastes, the MPCA detected several PFAS (12 PFAAs and perfluorooctane sulfonamide, PFOSA) in MSW LFG with $\sum_{13}$PFAS ranging from 4.1 to 18.7 ng m^{-3} (MPCA, 2010). Titaley et al. (2023) measured neutral PFAS in LFG of three active MSW landfills (n = 12 samples) and reported concentrations of four n:2 FTOHs (n = 6, 8, 10, and 12), one fluorotelomer acrylate (6:2 FTAc), and one fluorotelomer olefins (12:2 FTO). Concentrations for individual PFAS range from 270 to 4900 ng m^{-3}, and the total measured neutral PFAS for each landfill was, on average, between 4600 and 14,000 ng m^{-3} (weighted average across all samples: 10,200 ng m^{-3}). Smallwood et al. (2023) reported FTOH in LFG condensate, which, when normalized to gas volume, was three orders of magnitude lower than the gaseous phase concentrations reported by Titaley et al. (see SI ***Table S8*** for calculations), indicating FTOHs preferentially partition to the gas phase; FTOHs may transform in the atmosphere into PFCAs, such as PFOA, which have known and suspected toxic effects.

3.2.2.1.2. PFAS in C&D landfill gas. While no data exist on the concentration of PFAS in C&D LFG, it can be conservatively assumed, based on data from MSW LFG measurements, that PFAS also leave C&D landfills via gas effluent. As previously described, PFAS-containing wastes are disposed of at C&D landfills, and it is highly likely C&D debris contains volatile PFAS, such as FTOHs, which readily transform into FTCAs and PFCAs as a result of biodegradation and environmental oxidation, respectively. Lower rates of biological activity in C&D landfills may result in slower biodegradation of PFAS like FTOH (and other volatile precursors) may persist longer in C&D compared to MSW landfills and therefore have more opportunity to volatilize and leave the landfill via LFG. This is likely offset by the lower volume of LFG generated overall at C&D landfills compared to MSW. Nonetheless, this read-across should be validated by experimental data.

3.3. Fate of PFAS in traditional landfill leachate and gas management systems

Most landfills compliant with New Source Performance Standards (Clean Air Act) and RCRA must capture gas effluent and leachate to minimize environmental impacts. Leachate is often intercepted using a low-permeability bottom liner made of high-density polyethylene, collected, and may be transported off-site to a WWTP, disposed of using deep well injection, or otherwise managed and treated on-site.

PFAS interactions with low-permeability landfill liners have been the subject of limited studies. Most landfill liners are constructed from polyethylene geomembranes. Laboratory studies of PFAS diffusion through linear low-density polyethylene report below detection diffusion rates (Di Battista et al., 2020). Diffusion through high-density polyethylene has yet to be reported but maybe even lower due to differences in material structure. Landfill liner integrity – the absence of flaws or holes – is the most critical factor in preventing PFAS transmission through geomembrane and composite liners (Di Battista et al., 2020). An analysis of landfill liner performance reported median leakage rates of 44 and 33 L ha^{-1} day^{-1} for geomembrane and composite liners, respectively, with an overall liner collection efficiency of 98% (Jain et al., 2023). Compacted clay liners, which are more common in older landfills and C&D landfills, do not adsorb PFAS, which are reported to pass through bentonite clay at the same rate as other mobile leachate constituents like chloride (Li et al., 2015). PFAS profile, leachate quality, and soil characteristics all play a role in soil interaction, and decisions should be made on a site-specific basis (Li et al., 2019; Gates et al., 2020; Mukhopadhyay et al., 2021).

Management of leachate in the US is dependent on climate – in dry regions, leachate generation is minimal, and many facilities use atmospheric evaporation. In contrast, in wet regions, leachate management presents a significant challenge (US EPA, 2021c). A nationwide survey found approximately 60% of US Subtitle D landfills conveyed their leachate to WWTPs for off-site treatment, 28% recirculated leachate or use other techniques resulting in no necessary leachate treatment, and 12% used on-site treatment (US EPA, 2021c). A breakdown of on-site leachate treatment strategies is included in SI ***Fig. S3***. Traditional leachate treatment typically targets non-PFAS leachate constituents of concern, such as ammonia and chemical oxygen demand (COD). The fate of PFAS in existing leachate treatment systems and wastewater treatment systems that manage leachate have been the subject of several studies and have been reviewed previously (Appleman et al., 2014; Lu et al., 2023; Meegoda et al., 2020; Travar et al., 2020; Zhang et al., 2022). To generalize, the treatment of ammonia and COD relies on chemical or biological oxidation, which do not effectively treat PFAS but often have the unintended effect of transforming precursor PFAS to terminal PFAS (US EPA, 2021b). Furthermore, during treatment, PFAS may partition into solids (e.g., biosolids) to a limited extent, which results in additional management challenges (Thompson et al., 2023b). Studies have recommended PFAS removal prior to such treatment (Lott et al., 2023). The targeted treatment of PFAS via removal or destruction in landfill leachate has been the subject of multiple reviews (Bandala et al., 2021; Berg et al., 2022; Lu et al., 2023; Ross et al., 2018; Travar et al., 2020) which have thoroughly discussed the effectiveness of different technologies and which are, here, summarized in Table 3.

PFAS separation technologies typically rely on adsorption over materials, such as activated carbons and ion exchange resins (US EPA, 2022c; Chow et al., 2022; Crone et al., 2019; Appleman et al., 2013), the use of high-pressure membrane separation (US EPA, 2022c; Lipp et al., 2010; Steinle-Darling and Reinhard, 2008), and newer technologies such as ozo- and foam-fractionation with the aim of concentrating the PFAS into a smaller volume of either a solid phase or concentrated liquid residual to either be disposed or destroyed via a subsequent high-energy destructive treatment method (Du et al., 2021; Labiadh et al., 2016). Several novel technologies are being investigated for the destructive treatment of landfill leachate – most require large amounts of energy in the form of chemical reactions or localized high temperatures to break the C—F bond. MSWI for energy recovery is not currently optimized to target PFAS destruction. Additional research is ongoing to define the conditions needed for PFAS destruction in MSWI and other incineration approaches, such as sewage sludge incineration.

Flaring and combustion are common LFG management techniques. Flaring is typically carried out in an open (candle) or enclosed flare. Combustion processes can generate energy on-site (e.g., a combustion engine) or off-site in a gas-fired power generation system. MSW LFG regulations target the destruction of nonmethane organic compounds (NMOCs), not PFAS. Flares generally operate at ~650 °C to 850 °C and temperatures in combustion engines or boiler systems could be lower (Wade, 2022). PFAS separation treatment has not been applied to LFG, however, laboratory-scale thermal PFAS destruction experiments indicate that temperatures higher than 1000 °C are necessary to achieve the mineralization of PFAS (Winchell et al., 2021). MSW LFG flare temperatures and the time that gaseous PFAS are in the presence of high

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Table 3
Summary of treatment methods for PFAS in landfill leachate (Bandala et al., 2021; Berg et al., 2022; Lu et al., 2023; Ross et al., 2018; Travar et al., 2020; Wei et al., 2019).

	Technology	Pros	Cons	Matrix	References
Separation technologies	Activated carbon (GAC, PAC)	• High maturity level • Highly effective for long-chain PFAS	•Generates large quantities of spent sorbent that need additional treatment and disposal	GW	Busch et al. (2010); McCleaf et al. (2017), Pan et al. (2016), Ross et al. (2018), Bao et al. (2014), Pan et al. (2016); Malovanyy et al. (2023)
	Ion exchange resins	• High maturity level • Can remove compounds such as GenX	•Needs secondary treatment and disposal	GW, LL	Gao et al. (2015); Dixit et al. (2021); McCleaf et al. (2017); Ross et al. (2018); Boyer et al. (2021); Park et al. (2020); Ellis et al. (2022); Malovanyy et al. (2023)
	Membranes (RO, UF, NF)	• High maturity level and commonly practiced • 2-stage RO most effective on raw leachate	• Membrane fouling • Secondary stream with high PFAS concentrations and volume requires treatment • UF might not be effective	GW, LL	Das and Ronen (2022); Enzminger et al. (1987); Wei et al. (2019); Ross et al. (2018); Boo et al. (2018); Malovanyy et al. (2023)
	Foam/ ozofractionation	• High maturity level and commercially available pilot-scale technology • Potentially low cost	• Pretreatment of leachate might be required • Secondary treatment of concentrated PFAS required	GW, AFFF, LL	Smith et al. (2022); Robey et al. (2020); Malovanyy et al. (2023)
Destruction technologies	Incineration	• Highly effective method • Can be used for regeneration of spent materials	•As a standalone method, not practical for large volumes of leachate		
	Chemical Oxidation	•Controllable by varying pH and temperatures	• Uses additional chemicals for treatment • Low effectiveness of removal • Needs to be paired with other methods such as UV for higher effectiveness	LL	Abu Amr et al. (2013); Lin et al. (2012)
	Electrochemical	• 98–99.7% effectiveness demonstrated • Operates at ambient temperatures • No chemicals required • Lower energy consumption compared to incineration	• Expensive electrode materials • Perchlorates could be formed	LL	Labiadh et al. (2016); Du et al. (2021); Gomez-Ruiz et al. (2017); Witt et al. (2020); Krause et al. (2021)
	Photocatalysis	• 94–99% degradation reported • Can also potentially mineralize PFAS	• Slow kinetics • Lab-scale testing only • Difficult to scale for larger volumes		Esfahani et al. (2022)
	Sonolysis	• Can destroy short-chain and long-chain molecules • Effective for high concentration samples • Can be combined with chemical oxidation to lower costs	•High capital costs		Moriwaki et al. (2005); Vecitis et al. (2008); Babu et al. (2016)
	Microwaves	• Can be used to regenerate GACs • Catalytic microwave treatment could result in ~65–67% effectiveness	•Expensive for large-scale use		Gagliano et al. (2021); Lee et al. (2010b); Liu et al. (2020)
	Subcritical water oxidation	•Effective for short-chain PFAS	• Additional chemicals (e.g., zero-valent iron) needed for higher effectiveness • Slower kinetics		Hori et al. (2006)
	Supercritical water oxidation	• High maturity and close to commercialization • Low residence times required	• Full fluorine balance needed • High-pressure and temperature processes can be energy intensive	GW, AFF, LL	Pinkard et al. (2021); Hori et al. (2006); Krause et al. (2022)
	Wet Air Oxidation	•No demonstrated benefits for PFAS treatment	Converts FTOH precursors to PFCAs	LL	Travar et al. (2020)
	Biological processes	•Limited aerobic and anaerobic degradation of PFOS by bacteria and fungi reported	• Laboratory demonstrations only and thus low technology readiness level • Slow kinetics • Longer-chain PFAS converted to shorter-chain; no mineralization		Berhanu et al. (2023); Huang and Jaffé (2019)
	Constructed wetlands	•No demonstrated benefits for PFAS treatment	• Unlikely to be effective • Does not result in a concentrated PFAS stream that can be adequately managed • Environmental release of PFAS	LL	Yin et al. (2017, 2019); Awad et al. (2022); Lott et al. (2023)

(GAC = granular activated carbon; PAC = powder activated carbon; RO = reverse osmosis; UF = ultrafiltrations; NF = nanofiltration; GW = groundwater; LL = landfill leachate; AFFF = aqueous film-forming foam).

temperatures are too low to completely mineralize PFAS, but may result in the transformation of volatile PFAS into products of incomplete combustion (PICs). Notably, several PICs have been identified as significant greenhouse gases (Ahmed et al., 2020; Hong et al., 2013; Longendyke et al., 2022).

4. Environmental impact of PFAS emissions from landfills

Waste-derived PFAS may be emitted from landfills through multiple pathways, primarily in leachate or LFG effluent. While most RCRA-compliant landfills are operated to minimize environmental impacts, controls have yet to be designed to manage PFAS, and there is a subclass of small landfills in the US that are not required to install bottom liners as they are exempt from RCRA requirements (40 CFR § 258.1(f)(1)).

PFAS may be released into the atmosphere via fugitive gas emissions or gas flares. No data were found on PFAS concentrations in the ambient air surrounding C&D landfills, hazardous waste landfills, or industrial landfills; however, PFAS concentrations in the ambient air close to MSW landfills have been the subject of studies in the US, Germany, and China. Ahrens et al. (2011) reported average total FTOH concentrations of 2.6 and 26 ng m^{-3} at two US MSW landfills, representing 93% and 98% of total gas phase PFAS, with the remaining fraction consisting of perfluoroalkane sulfonamide (FASAs), perfluoroalkane sulfonamido ethanols (FASEs), and PFAAs. Weinberg et al. (2011) reported average total FTOH concentrations at two German landfill sites of 0.086 and 0.271 ng m^{-3}, representing 80% and 92% of total gas phase PFAS. Tian et al. (2018) measured PFAS in air sampled on-site at two landfills as well as downwind. The PFAS profile of the on-site air samples was more evenly split among classes. Total FTOHs were 0.61 and 2.1 ng m^{-3} at the two sites, representing 42% and 76% of $\sum_6$PFAS, with PFAAs representing the bulk of the remaining fraction. PFAS concentrations downwind of the two landfill sites were lower than on-site but elevated relative to control sites, indicating atmospheric transport of PFAS. Lower concentrations downwind may indicate dilution or deposition of volatile PFAS. Neutral PFAS readily transform in the environment – studies have shown the degradation of FTOHs into PFCAs via photooxidation (Esfahani et al., 2022; Martin et al., 2006). Tian et al. (2018) reported elevated neutral and ionizable PFAS in dry deposition samples on-site and downwind of landfills, driven primarily by PFBA and PFOA. Ahmadireskety et al. (2020) reported PFAS concentrations in landfill cover soils of approximately 8 μg kg^{-1}, similarly driven by PFCAs.

Deposition of PFAS from landfill-impacted air may also contribute to PFAS measured in surface water on landfill sites. Chen et al. (2023) reported $\sum_{26}$PFAS concentrations in stormwater at MSW landfill sites averaging 470 ng L^{-1}, significantly lower than leachate concentrations from the same study but significantly higher than groundwater samples, which averaged 140 ng L^{-1} of $\sum_{26}$PFAS. PFAS may be present in both surface and groundwater due to leachate contamination. At the same time, particulate transport from the working face or atmospheric transport and deposition of PFAS are more likely to impact surface water. The MPCA (2010) reported PFAS contamination in groundwater impacted by landfills accepting PFAS-laden industrial waste. Hepburn et al. (2019) measured PFAS and other landfill leachate indicators in groundwater impacted by legacy landfills in Australia, where PFOA represented >10% of total PFAAs, likely associated with legacy landfills.

Using the landfill liner collection efficiency reported by Jain et al. (2023) and overall leachate leakage rate of 1.9% with the leachate generation rate reported in Lang et al. (2017) (61 billion L $year^{-1}$), approximately 1.2 billion L of MSW landfill leachate enter the groundwater directly as a result of liner imperfections every year (14.3 kg of total PFAS using the average $\sum_{19}$PFAS from Lang et al. (2017)). This represents a conservative estimate, as Lang et al. (2017) note that most but not all landfills contributing to the total estimated leachate generation are lined. Although C&D leachate generation rates are not readily available, using leachate generation rates calculated for 17 MSW landfills in six US states, Jain et al. (2023) reported an average collection rate of 6900 L ha^{-1} day^{-1}. Assuming similar leachate generation rates for C&D landfills, this corresponds to approximately 2.5 million L of C&D leachate entering the groundwater per hectare of C&D landfill annually, representing a $\sum$PFAS mass of 26 g of PFAS per hectare of C&D landfill (see Table S9 in the SI for more calculation information). In 2012, the US EPA inventoried 1504 active C&D landfills (US EPA, 2012).

In the US, most landfill leachate generated from RCRA-permitted landfills is managed off-site (again, many C&D landfills are not required to collect leachate and thus operate without a bottom liner). This represents a significant flux of PFAS leaving the landfill. Multiple studies in the US and Australia have estimated the contribution of PFAS to municipal WWTP from landfill leachate and the environmental impact of PFAS in WWTP effluent. Masoner et al. (2020) estimated the PFAS load in landfill leachates and receiving WWTPs. They reported that landfill leachate while representing, on average, <2% of WWTP influent by volume across three sites, contributed 18% of influent PFAS. Gallen et al. (2017) reported similar contributions of PFAS to WWTPs from landfill leachates. PFAS are not effectively treated with traditional WWTP processes and are released to the environment via WWTP liquid effluent, land-applied biosolids, landfills, and possibly incineration of biosludge (Barisci and Suri, 2021; Coggan et al., 2019; Gallen et al., 2018; Helmer et al., 2022; Tavasoli et al., 2021).

5. Estimate of US MSW landfill PFAS mass balance

Estabrooks and Zemba (2019) evaluated landfill PFAS mass balance at an MSW landfill in Vermont, identifying the PFAS load from targeted waste types suspected to contain PFAS, not including residential MSW, and found that approximately 7% of the PFAS load entering landfills is emitted via leachate annually, and hypothesize the majority of PFAS remain in the waste mass within the landfill. Coffin et al. (2022) propose an estimated extractable $\sum$PFAS load in MSW entering landfills of 50 ng g^{-1} based on the findings in Liu et al. (2022a). This, combined with US EPA estimation of landfilled MSW in 2018 (the most recent year for which MSW generation data is available for the US), corresponds to 6600 kg of extractable PFAS entering MSW landfills in 2018 with MSW (US EPA, 2020b). Biosludge and biosolids also contribute a significant fraction of PFAS loading in MSW landfills. Using $\sum_{92}$PFAS in treated biosolids reported by Thompson et al. (2023b) and biosolids management statistics reported by NEBRA (2022), the 1.74 million dry metric tons of biosolids landfilled each year contribute an additional estimated 850 kg of PFAS to MSW landfills. Based on our calculations, a conservative estimate of 7480 kg of extractable PFAS entered US MSW landfills in 2018. This estimate does not include PFAS polymers.

As described earlier, PFAS can be emitted from landfills via the gaseous and liquid phase. MSW landfills in the US collect approximately 93.5 million m^3 of gas daily according to the US EPA LMOP database. This translates to nearly 1 kg of neutral PFAS emitted via MSW LFG per day (347 kg annually) based on the concentrations reported by Titaley et al. (2023). The US EPA estimates MSW LFG collection efficiency of approximately 75% (US EPA, 2020a), indicating an additional 31.2 million m^3 of LFG are released via fugitive emissions from MSW landfills annually. Leachate generation in the US, estimated by Lang et al. (2017), is 61.1 billion L $year^{-1}$ which corresponds to 750 kg of PFAS emitted from MSW landfills via leachate annually (using the weighted average $\sum$PFAS concentration of 12,300 ng L^{-1} calculated in this study). See Fig. 3 for a flowchart representing PFAS sources, controlled emissions, and uncontrolled emissions to the environment corresponding to MSW landfills, and Fig. 4 for a graphical presentation of the fraction of PFAS entering landfills from MSW and biosolids and corresponding emissions; the majority of PFAS entering landfills remain in the waste (84% annually) and significant a mass of PFAS have likely accumulated since PFAS use in consumer products began. Detailed calculations for Fig. 3 are included in the SI ***Table S10***.

One can estimate the total PFAS released via the gaseous phase per ton of MSW based on the potential methane generation capacity (L_o) of

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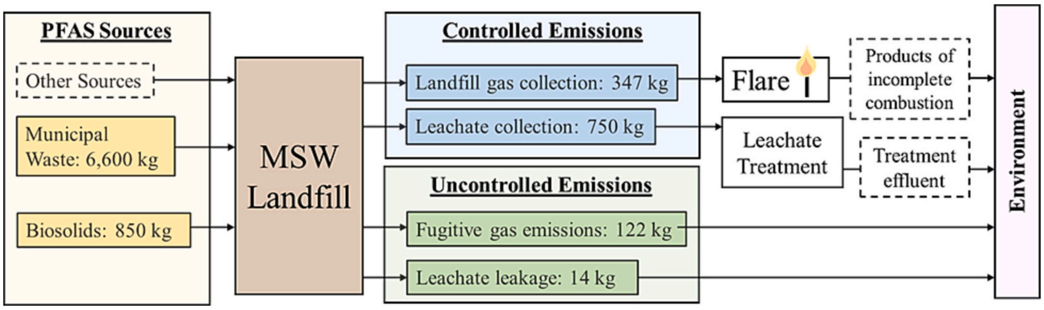

Fig. 3. Flowchart depiction of annual ∑PFAS loading and release at MSW and C&D debris landfills based on current understanding in the literature. Dashed lines represent PFAS streams which have not been quantified to any extent in the literature.

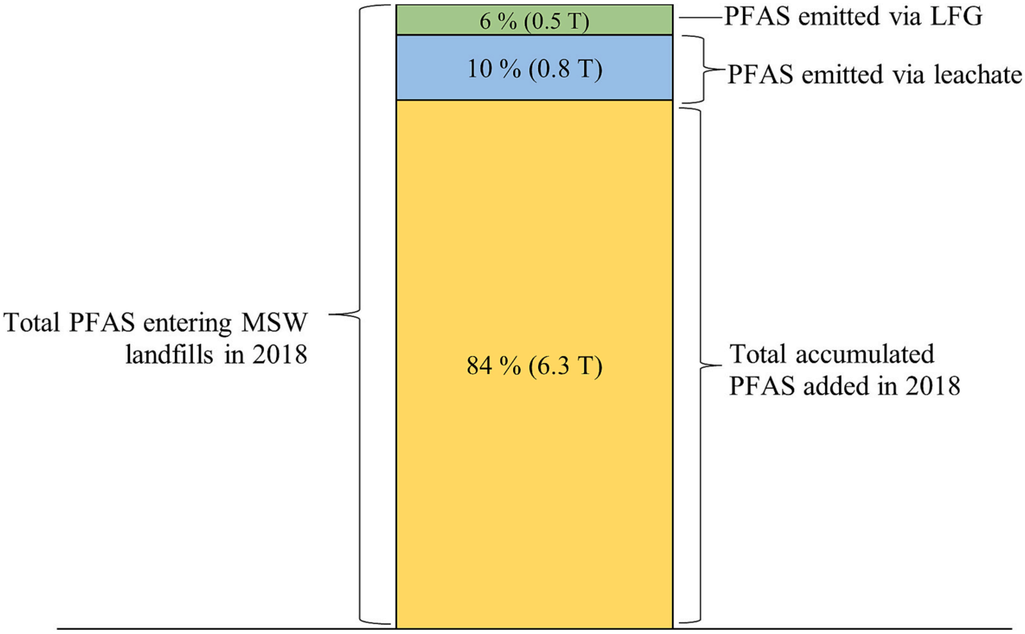

Fig. 4. Estimated PFAS mass balance for US MSW landfills.

MSW. Jain et al. (2021) estimated MSW methane emissions of 68 m^3 of methane per metric ton (Mg) of waste, or approximately 136 m^3 of LFG per Mg of waste; using these values and the Titaley et al. (2023) LFG PFAS concentrations suggest 1.38 mg of PFAS are released, cumulatively, via LFG for every Mg of MSW.

5.1. Limitations

The estimated PFAS mass loading and emissions presented here are based on multiple assumptions and, in some cases, limited data, resulting in significant uncertainty. We have not provided additional data quality assurance in this review process. A small number of studies have explored changes in landfill leachate PFAS profile over time, and no studies have looked for similar relationships in LFG; for this critical review, it was assumed that ∑PFAS reported in leachate and gas are representative of a range of waste ages and stages of decomposition and, overall, are expected to remain consistent over time. Even fewer studies have looked at C&D debris landfills in the US, and those studies are limited to Florida landfills. This critical review of previous analyses provides perspective, not precise values, which should be derived through additional empirical studies.

6. Conclusions and data gaps

The bulk of studies of PFAS in solid waste and landfills focus on MSW landfill leachate, with comparatively fewer studies estimating overall PFAS loading in other types of landfill leachate, in the solid waste itself, or gaseous effluent. Regardless of the type of landfill, in all studies across all locations, PFAS were quantified in all leachate samples. PFAS concentrations in leachates vary across studies, which may be a function of waste type, leachate qualities, climate, and the analytical method.

US MSW and C&D landfill leachates have similar ∑PFAS concentrations. However, C&D leachate contains proportionally more terminal PFAS. This is likely due to the PFAS present and the conditions within each landfill type. Concentrations of the five PFAS which have been the subject of proposed US EPA regulations (i.e., PFBS, PFHxS, PFOS, PFOA, and PFNA) consistently exceed US EPA tapwater RSLs in both MSW and C&D landfill leachates by a factor as high as 20 (PFOA) and in HW landfill leachates by a factor as high as 104 (PFOS); as presented in Table 1 and Fig. 2.

MSWI ash leachates have lower PFAS concentrations than other leachates, however, co-disposal of ash with other wastes results in disproportionately high PFAS concentrations in leachate. To minimize PFAS leaching from MSWI ash landfills, care should be taken to dispose of unburned waste which contains higher concentrations of PFAS separately from MSWI ash. No peer-reiviewed studies have reported

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PFAS concentrations in effluent from hazardous waste (Subtitle C) landfills, although hazardous waste management methods are likely to reduce PFAS leaching. Since some hazardous waste landfills likely accept PFAS-laden industrial waste at relatively high levels, it would be helpful to have more information on effluent generated from these facilities.

Traditional leachate treatment methods that use oxidation (e.g., a treatment that targets ammonia, COD) are likely to increase the transformation rate of precursor PFAS to terminal PFAS, such as regulated PFAAs. Treatment that relies on volatilization, such as evaporation, likely contributes significant quantities of PFAS to the atmosphere and surrounding environment, increasing off-site transport. Separating PFAS from leachate prior to additional treatment would avoid these issues. Though there are many aqueous treatment technologies for the targeted removal or destruction of PFAS, few have been tested for effectiveness on landfill leachate. Those tested on leachate and have shown promise include supercritical water oxidation, electrochemical oxidation, reverse osmosis, and foam separation. Assuming treatment efficacy is comparable across PFAAs, reducing PFOA concentration to its limit (e.g., MCL) will reduce all other PFAS to below their respective limits. PFAS treatment of liquid wastes often produces a secondary residual waste requiring additional management.

PFAS are expected to be present in LFG as a product of volatilization and the anaerobic decomposition of biodegradable waste but have been quantified only in MSW LFG. PFAS have not been measured in C&D LFG. However, based on PFAS profiles in C&D landfill leachate, similar PFAS concentrations are likely present in C&D LFG, although LFG generation rates from C&D debris is lower. To reduce gaseous emissions of PFAS, biodegradable waste should be disposed of separately from other PFAS-containing waste. Data do not exist on the effectiveness of PFAS destruction from LFG combustion within flares and internal combustion engines or PFAS removal from LFG to RNG conversion processes. However, the temperatures reached in LFG flares are expected to transform volatile PFAS into terminal PFAS and possible PICs, with minimal mineralization.

Based on our estimate of the PFAS entering and leaving landfills, significant quantities of PFAS are emitted in both LFG and leachate; however, the bulk of PFAS remains within the waste mass on a per-year basis (see Fig. 3). This suggests landfills will be a source of PFAS emissions for the foreseeable future. Studies have demonstrated down-gradient impacts on groundwater from landfills. C&D landfills pose the highest risk of environmental contamination since they are not required (at the federal level) to install liners to collect leachate. Even among lined landfills, the average liner collection efficiency is approximately 98%, corresponding to an annual flux of 14.3 kg PFAS entering groundwater via liner imperfections.

Elevated PFAS concentrations were measured in ambient air at landfills across several studies. The highest concentrations were found among FTOHs, which transform into PFAAs in the environment. Atmospheric PFAS may deposit and contribute to soil and surface water concentrations. Even if LFG collection systems were equipped to operate at temperatures and residence times sufficient to destroy PFAS, current MSW LFG collection efficiency is only 75%, and landfills not required to collect LFG will continue to emit PFAS into the atmosphere. The fate of PFAS in LFG that passes through landfill cover soil should be analyzed in future studies.

This review has identified several data gaps for PFAS emissions from US landfills. Data are needed from hazardous waste landfill sites and relevant industrial waste landfills. Furthermore, US C&D landfill leachate data are limited to Florida landfills, and additional efforts should be made to collect information from other states. C&D waste streams may vary due to regional construction requirements. The measurement of PFAS in LFG and other gaseous emissions is an area of emerging study. More research is needed on both controlled and uncontrolled landfill gaseous emissions. A closer evaluation of the fate of PFAS during leachate treatment and LFG management is needed to help decision-makers guide the solid waste community. Geomembrane liners are the most effective tools for the protection from and collection of PFAS-containing liquids, such as landfill leachate. More research is needed to understand long-term interactions between PFAS and liner systems, especially in complex matrices such as landfill leachate. More research is needed to evaluate the long-term implications of PFAS in the landfill environment since the bulk of PFAS remains within the solid waste mass. This review focused on landfilling as a management option for solid waste; evaluation of PFAS fate during other solid waste management processes (e.g., anaerobic digestion, thermal treatment, composting, and recycling) is needed.

CRediT authorship contribution statement

Thabet Tolaymat: conceptualization, approach, methodology, writing-reviewing, editing, funding, **Nicole Robey**: data curation, methodology, calculations, writing-original draft, writing and editing. **Max Krause**: writing and editing, **Judd Larson, Keith Weitz, Sameer Parvathikar**: data curation, original draft preparation, editing, **Lara Phelps, William Linak, Susan Burden, Tom Speth, Jonathan Krug:** writing and editing

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.scitotenv.2023.167185.

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Org-9-1

Geosyntec Consultants, Inc.

Thank you for the opportunity to provide comments on the AFFF Collection and Disposal Program: DEIS prepared by the Hazardous Waste and Toxics Reduction Program, Washington State Department of Ecology (Ecology).
Our comments on the draft guidance are attached.

Thanks,

Vanessa Maldonado.
Geosyntec Consultants, Inc.

Org-9-1

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consultants

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February 05, 2024

Sean Smith
Department of Ecology
P.O. Box 330316
Shoreline, Washington 98133

Subject: Comments on Aqueous Film-Forming Foam (AFFF) Collection and Disposal Program: Draft Programmatic Environmental Impact Statement (DEIS)

Dear Mr. Smith:

Thank you for the opportunity to provide comments on the *AFFF Collection and Disposal Program: DEIS* prepared by the Hazardous Waste and Toxics Reduction Program, Washington State Department of Ecology (Ecology).

Our comments on the draft guidance are provided on the following pages. If you have any questions, please do not hesitate to reach out.

Sincerely,

Vanessa Maldonado, Ph. D., EIT
Senior Staff Engineer

Cindy Bartlett, LG
Principal Geologist

Geosyntec
consultants

COMMENTS ON THE AFFF COLLECTION AND DISPOSAL PROGRAM: DEIS

CHAPTER 2. Project Description and Alternatives

Subsection 2.2.1: Alternative 1 Approved Hold in Place, page 2-20

It is mentioned that AFFF would be held in place at participating fire stations until acceptable advanced treatment technology becomes available.

- What is the anticipated or expected timeline for advanced treatment technologies to become available?
- Who will Ecology be relying on to determine the availability and qualification of advanced treatment technologies approved for use?

We recommend adding an expected timeline and guiding documents (e.g., Guidance on Destruction and Disposal of Per and Polyfluoroalkyl Substances [PFAS]) The only guidance document we are aware of is the Environmental Protection Agency (EPA)'s Interim Guidance on the Destruction and Disposal of PFAS. The EPA's guidance document was expected to be finalized by the end of 2023 and should be finalized soon. Will Ecology consider this document as a basis for decision-making regarding technologies available to treat AFFF held in place? The criteria for decision-making should be included in the DEIS.

Also, Alternative 1 is not legally supported for large quantity generators (LQGs). If Alternative 1 is selected, a policy change to allow LQGs to hold AFFF in place would be required. How will the Department of Ecology address this issue? What is the strategy to overcome this challenge?

Subsection 2.2.2: Alternative 2 Incineration, page 2-21

Although incineration has shown to destroy 99.9999% of legacy PFAS, the incineration of PFAS requires reaching a temperature of approximately 1100 °C. If the required temperature is not met, multiple PFAS can be converted to other PFAS at lower temperatures, resulting in high destruction efficiencies (e.g., 99.9999%) without full mineralization and the potential release of the remaining fluorocarbon portions to the environment. Further, although working temperatures below 1000 °C produce high destruction efficiencies for quantifiable PFAS, several nonpolar PFAS are emitted as products of incomplete combustion (Shields et al., 2023). Thus, the destruction efficiency alone is not the best indicator of total PFAS destruction. With this preamble, the following should be clarified in the DEIS:

1. How is the complete destruction of PFAS warranted with incineration without relying on the destruction efficiency?
2. How will the required operating conditions (e.g., temperature of at least 1100 °C) in approved incineration facilities be warranted and proven to comply?
3. How are the potential emissions of PFAS byproducts (e.g., products of incomplete combustion) going to be captured and monitored? What is the strategy to control air emissions in approved facilities? EPA's OTM-50 sampling technique for quantification of

volatile fluorinated compounds is now available. The combination of OTM-50 and OTM-45 would provide a more complete analysis of the potential PFAS in emission byproducts. The DEIS should clarify the intent to monitor/control these air byproducts if this Alternative 2 is selected.

4. If Alternative 2 is selected, does Ecology intend to cover 100% of the costs for incinerating thousands of gallons of AFFF? How is the cost feasibility considered?

Subsection 2.2.3: Alternative 3 Solidification and Landfilling, page 2-22

Solidification and landfilling should not be considered as an alternative for AFFF foam disposal/treatment for the following reasons:

1. There is currently little to no research investigating the rates at which PFAS may leach from concrete into surrounding environmental matrices (Douglas et al., 2023) and potentially impact the receiving landfill(s).
2. Leachability studies have shown the presence of multiple PFAS (e.g., 6:2 FTS, PFBA, PFPeA) in the leachate that results from solidification/stabilization (Sörengård et al., 2019). We understand that generated leachate could be collected, treated, and disposed of in a landfill, however, as of today there are no treatment technologies that have been demonstrated to fully destroy PFAS in such complex matrix as landfill leachates (Berg et al, 2022).
3. It has been shown that the stabilization efficiency depends on the PFAS chain length, and it is less effective for perfluorocarboxylates (e.g., PFOA) and short-chain PFAS (Sörengård et al., 2019).
4. Stabilization/solidification studies have been conducted and even field-tested to treat soil and sediments with carbon-based amendments. While this stabilization/solidification has been employed to treat soils, sediments, and liquid waste (e.g., groundwater with low PFAS concentrations) containing a variety of chemical pollutants, the process applied to AFFF mixtures (liquid matrices with high concentrations of PFAS, [e.g., 3% PFOS]) has not been evaluated. The applicability of a technology does not necessarily translate between matrices and concentration ranges. Further research is necessary to prove the solidification/stabilization of PFAS would be feasible to stabilize pure AFFF foams.
5. The description of this alternative does not consider the real and negative implications of landfilling PFAS even if solidified in a neutral matrix such as concrete. Leachates containing landfill leachates emit volatile PFAS (e.g., 6:2 FTOH) which have negative environmental impacts. Thus, landfilling solidified PFAS is not just a leachate issue. The

potential for emitting volatile PFAS should be included in the draft EIS and should be considered as a high-risk factor for the selection of such an alternative.

6. Although this alternative captures a high percentage of PFAS, it transfers part of the problem (PFAS) from one place to another. It does not seem to be solving it since not destructive and could create additional problems (e.g., volatilization, leaching).

Subsection 2.2.4: Alternative 4 Deep Well Injection, page 2-23

Although this is a relatively simple alternative, the potential for future groundwater contamination should be considered in this alternative evaluation, including future migration of PFAS from the depth injected to other aquifers. Although the selected locations for deep well injection are remote and planned beneath current drinking water aquifers, there is always a potential for migration and eventual contamination of other aquifers. Deeper aquifers are becoming more important for future water supplies in the face of climate change and the depletion of aquifers. Potential risks such as the risk of seismic effects from injection also should be accounted for and considered in the alternative description and selection.

General Comments/Questions:

- Although airports, military sites, and industrial sites are not within the scope of the EIS, will the collection and disposal program be limited to municipal fire departments or expanded to more participants with AFFF inventory (e.g., airports) once approved?
- Will Ecology accept rinse water from municipal fire departments who are cleaning their systems when transitioning for fluorine free products? If not, how should this be disposed of?
- The potential issues associated with transportation of AFFF (e.g., potential for spills and emissions during the transportation process) should be considered in the selection of the alternatives, as it is for non-vehicle transport (Section 2.2.6.2)
- The Alternatives Assessment in Section 2.2 does not appear to address technology costs. It is important to consider the economic feasibility of alternatives due to significant differences. For instance, the cost for incineration of PFAS is significantly higher when compared to any of the other alternatives selected.

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Org-10-1

February 5, 2024

Mr. Sean Smith
Hazardous Waste & Toxics Reduction
Northwest Regional Office
Washington State Department of Ecology
3190 160th Avenue SE
Bellevue, WA 98008-5452

Re: Aqueous film forming foam (AFFF) Collection and Disposal Program - Draft Programmatic Environmental Impact Statement, Publication 23-04-064 (December 2023)

Dear Mr. Smith:

The American Chemistry Council (ACC) supports the Department's efforts to collect waste aqueous film forming foam (AFFF) and appreciates its analysis of alternative approaches to disposal of this material. ACC previously supported the Department's 2020 Determination of Non-Significance for its proposal to send the foam to the existing Clean Harbors Incineration Facility in Aragonite, Utah. As part of the draft Environmental Impact Statement (EIS), the Department has expanded its review to include solidification and landfill and Class 1 deep well injection as disposal options. ACC agrees with the Department's assessment that these two additional disposal options also do not present significant adverse effects on human health and safety or the environment.

Based on its assessment, we encourage the Department to consider all three of these alternatives (incineration, solidification/landfill, deep well injection) as safe and effective approaches to the disposal of waste AFFF. This conclusion is the same reached by the US Department of Defense (DOD) as part of guidance issued in July 2023.[1] In its guidance, DOD noted that hazardous waste incinerators, hazardous waste landfills, and solid waste landfills[2] are available options "that maximize reduction of PFAS releases or emissions to the environment and human health exposures."[3]

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[1] DOD. Interim Guidance on Destruction or Disposal of Materials Containing Per- and Polyfluoroalkyl Substances in the United States. Memo from Brendan M. Owens, Assistant Secretary of Defense for Energy, Installations, and Environment (July 11, 2023). (Enclosed)

[2] Those including a composite liner and gas and leachate collection and management to control the migration of PFAS into the environment.

[3] Although the DOD assessment concluded that deep well injection maximizes reduction of PFAS releases, it noted that the limited number of wells currently receiving PFAS means that it "will rarely be an available option for DOD."

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ACC is very concerned, however, about the inclusion of "Approved Hold in Place" of AFFF at participating fire stations as an alternative in the Department's assessment. The EIS identifies issues associated with regulations controlling long-term storage of waste and permitting, but does not consider the increased risk of environmental release at numerous locations that such storage presents. While treatment technologies may continue to advance, it is neither correct nor a clarification to suggest that long-term storage of AFFF waste is an appropriate method for handling PFAS waste when effective methods currently exist.[4] We urge the Department to reassess the ranking of long-term storage as an appropriate alternative to handling AFFF waste that runs counter to the intent of solid and hazardous waste regulatory structures and that may encourage stockpiling of material. This could lead to more environmentally detrimental effects than the other alternatives. Additionally, this method increases the cost of materials management due to the required handling and storage cell construction and maintenance for all regulated entities.

Please do not hesitate to contact me at srisotto@americanchemistry.com or at (202) 249-6727 if you have any questions about the above information.

Sincerely,

Steve Risotto

Stephen P. Risotto
Senior Director

Enclosure

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[4] Notably, the other destruction technologies considered as alternatives in the EIS do not suggest a level of destruction that exceeds the 99.9999 percent destruction efficiency that is achieved at the Clean Harbors Aragonite incinerator (Draft EIS, at 2-15).

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ASSISTANT SECRETARY OF DEFENSE
3400 DEFENSE PENTAGON
WASHINGTON, DC 20301-3400

ENERGY, INSTALLATIONS,
AND ENVIRONMENT

7/11/23

MEMORANDUM FOR ASSISTANT SECRETARY OF THE ARMY (INSTALLATIONS, ENERGY AND ENVIRONMENT)
ASSISTANT SECRETARY OF THE NAVY (ENERGY, INSTALLATIONS AND ENVIRONMENT)
ASSISTANT SECRETARY OF THE AIR FORCE (INSTALLATIONS, ENVIRONMENT AND ENERGY)
DIRECTOR, DEFENSE LOGISTICS AGENCY (LOGISTICS OPERATIONS)

SUBJECT: Interim Guidance on Destruction or Disposal of Materials Containing Per- and Polyfluoroalkyl Substances in the United States

The DoD Per- and Polyfluoroalkyl Substances (PFAS) Task Force issues this interim guidance to help DoD make informed decisions in the evaluation of existing destruction and disposal options, and to comply with section 343 of the FY 2022 National Defense Authorization Act (NDAA). Section 343 requires DoD to prohibit the incineration of covered DoD PFAS-containing materials[1] until DoD issues guidance implementing the U.S. Environmental Protection Agency (EPA) "Interim Guidance on the Destruction and Disposal of Perfluoroalkyl and Polyfluoroalkyl Substances and Materials Containing Perfluoroalkyl and Polyfluoroalkyl Substances," December 18, 2020 (hereinafter referred to as the EPA guidance), and section 330 of the FY 2020 NDAA.

Concurrent with its compliance with these requirements on PFAS destruction and disposal, DoD is transitioning to a PFAS-free firefighting agent for land-based applications over the next few years. DoD has determined that this transition, which requires the removal of PFAS-containing firefighting foam (i.e., Aqueous Film Forming Foam (AFFF)) from installation fire protection inventories, will generate large quantities of PFAS-containing concentrate and rinsate for which DoD must find a safe disposal solution. In addition, quantities of PFAS-containing material are generated from DoD's nationwide cleanup program, and recovery of emergency use discharges or spills of AFFF. Given these combined quantities, DoD's long-term storage capabilities will be exceeded and thus DoD requires a comprehensive destruction and disposal strategy.

In choosing among disposal options, one of the most significant factors for DoD was the additional oversight and controls provided at disposal and destruction facilities with

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[1] PFAS-containing materials covered under this guidance includes all "covered material" under Section 343 of the FY 2022 NDAA, which means "any [Aqueous Film Forming Foam] AFFF formulation containing PFAS, material contaminated by AFFF release, or spent filter or other PFAS-contaminated material resulting from site remediation or water filtration that—

(A) has been used by the Department of Defense or a military department;
(B) is being discarded for disposal by the Department of Defense or a military department; or
(C) is being removed from sites or facilities owned or operated by the Department of Defense."

environmental permits. In issuing this guidance to comply with section 343 of the FY 2022 NDAA, DoD continues to recognize the statutory authority and responsibility of the EPA and State environmental regulatory agencies to regulate the disposal of wastes that may threaten human health or the environment.

Based on the analysis contained in Attachment 1 and consistent with the EPA guidance, DoD has identified the following four commercially available options to destroy or dispose of DoD PFAS-containing materials, in the order of consideration:

- Carbon reactivation units with environmental permits (for used granular activated carbon only).
- Hazardous waste landfills with environmental permits.
- Solid waste landfills with environmental permits that have composite liners, and gas and leachate collection and treatment systems.
- Hazardous waste incinerators with environmental permits.

In addition to these four DoD-wide options, the DoD Components are directed to consider onsite hazardous waste storage on a site-specific basis, for storage over ninety days. The DoD Components may also consider underground injection control on a site-specific basis. Third, the DoD Components, upon notification to the Office of the Assistant Secretary of Defense for Energy, Installations, and Environment (OASD(EI&E)), may also consider other existing and developing PFAS treatment or destruction technologies that are accepted/permitted by the appropriate State or Federal regulator, instead of utilizing hazardous waste incinerators, on a site-specific basis. The DoD Components, when selecting one of the options above for the destruction or disposal of PFAS-containing materials, including AFFF, must continue to make informed, fact-based decisions to mitigate the risk of PFAS releases to the environment for the protection of human health, consistent with the attached guidance and decision tree.

DoD continues to evaluate existing and developing PFAS destruction and disposal technologies, monitor studies on those technologies' effectiveness and potential environmental effects, and collaborate Administration-wide on best practices.For example, DoD's Strategic Environmental Research and Development Program has ongoing projects to develop an improved understanding of the effectiveness and sustainability of thermal destruction technologies for treatment of PFAS-containing materials. Of particular interest is the assessment of the fate and behavior of PFAS throughout the thermal treatment process. DoD also anticipates that EPA will be updating its guidance by December 2023. OASD(EI&E) will update this guidance annually to reflect changes as technologies mature, EPA updates its guidance, and additional data becomes available. The point of contact for this guidance is Ms. Alexandria Long, OASD(EI&E), at 703-571-9061 or alexandria.d.long.civ@mail.mil.

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Date: 2023.07.11 18:11:14 -04'00'

Brendan M. Owens

Attachments:
As stated

Attachment 1 — DoD Guidance on Options for the Destruction and Disposal of PFAS-Containing Materials and Implementation of Section 343 of the FY 2022 NDAA

1. *DoD Implementation of the EPA's "Interim Guidance on the Destruction and Disposal of Perfluoroalkyl and Polyfluoroalkyl Substances and Materials Containing Perfluoroalkyl and Polyfluoroalkyl Substances," December 18, 2020*

The EPA issued the "Interim Guidance on the Destruction and Disposal of Perfluoroalkyl and Polyfluoroalkyl Substances and Materials Containing Perfluoroalkyl and Polyfluoroalkyl Substances," on December 18, 2020, (referred to as "the EPA guidance" in this document).[2] In the EPA guidance, EPA evaluated destruction and disposal technologies that are commercially available and have the potential to control the migration of PFAS to the environment and identified three destruction or disposal options: landfilling, thermal treatment, and underground injection. DoD reviewed the EPA guidance and is implementing that guidance through this interim policy. Specifically, DoD is using the EPA guidance to help DoD make informed decisions in the evaluation of existing destruction and disposal options, including the relative uncertainty associated with each technology's capability to control releases to the environment for the protection of human health. DoD is also implementing EPA's guidance on environmental justice considerations in disposal and destruction of PFAS-containing materials.

A. EPA Interim Guidance on Destruction and Disposal of PFAS and Materials Containing PFAS

EPA's guidance recognizes that interim storage is not a destruction or disposal method, but asserts that storage "may be an option" if the immediate destruction or disposal of PFAS-containing materials is "not imperative."[3] EPA defines "interim storage" as storage "estimated to be anywhere from 2 to 5 years."[4] EPA does not define the term "imperative." DoD finds that multi-year storage of large quantities of PFAS-containing materials is not a viable option, from either a safety, environmental, logistical, or economic perspective.[5] Thus, in general, DoD assesses that, due to the volume of PFAS-containing materials at issue, DoD will need to implement actual destruction or disposal solutions for those materials.

DoD is currently conducting cleanup investigations and response actions at over 700 military installations and State Guard facilities. These investigations and response actions generate PFAS-containing materials (e.g., granular activated carbon, soils, investigation-derived wastes). If DoD had to plan for, locate, and secure storage of all PFAS-containing materials at

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[2] "Interim PFAS Destruction and Disposal Guidance (Notice of Availability for Public Comment)." 85 Federal Register 83554 (Dec. 22, 2020).

[3] "Interim Guidance on the Destruction and Disposal of Perfluoroalkyl and Polyfluoroalkyl Substances and Materials Containing Perfluoroalkyl and Polyfluoroalkyl Substances," pp. 5. Environmental Protection Agency, 18 Dec. 2020, https://www.epa.gov/pfas/interim-guidance-destroying-and-disposing-certain-pfas-and-pfas-containing-materials-are-not. *Referred to as "EPA Interim PFAS Disposal Guidance (Dec. 2020)" in later footnotes.*

[4] EPA Interim PFAS Disposal Guidance (Dec. 2020), page 5.

[5] EPA's proposed PFAS National Primary Drinking Water Regulation similarly states: "As part of this rulemaking, EPA considered that in drinking water treatment, large volumes of spent [granular activated carbon] and ion exchange resin must be removed which does not lend itself to on-site storage over time. The disposal options identified in the Interim Guidance (US EPA, 2020b) are landfill disposal and thermal treatment." 88 Federal Register at 18686 (Mar. 29, 2023).

applicable DoD/Guard facilities, these storage requirements would affect the pace of this necessary cleanup. In addition, the storage would generate its own risks of release to the environment.

DoD is also required to transition to a new firefighting agent for land-based applications and remove existing AFFF. The volume of AFFF that requires disposal is estimated to be over 2 million gallons. DoD does not have the warehouse capacity to properly and safely store this AFFF and associated rinsate at individual bases. DoD also is concerned with the risks of release to the environment from storage and believes that secondary containment would be needed to contain releases of PFAS. Storage areas at individual military installations or Guard facilities, where these PFAS-containing materials could potentially be stored if space was available, are not likely to have secondary containment. Building additional storage capacity, to include the necessary contracting actions, would negatively affect the pace of these required cleanup and AFFF replacement activities. While DoD believes it does not have the capacity to properly store all PFAS-containing materials at its facilities, and thus disposal or destruction of those materials is imperative, the DoD Components are directed to consider if onsite hazardous waste storage capacity exists for storage over ninety days at an individual military installation.

DoD next considered all the existing destruction and disposal options identified in the EPA guidance to identify options that are protective of human health and the environment. EPA identified several factors to consider in determining how to destroy or dispose of PFAS-containing materials:

- The relative uncertainty associated with the technologies' capabilities to control migration of PFAS,
- Whether it is imperative to destroy or dispose of these materials versus storing it and waiting for uncertainties to be reduced,
- The cost and availability of destruction and disposal options,
- The type of waste materials,
- The concentrations of PFAS in the waste, and
- Health risks from PFAS releases, especially for potentially vulnerable populations [6]

The first option DoD considered was deep well injection. EPA acknowledged deep well injection has the capability to control migration of PFAS to the environment, and the limited number of these wells currently receiving PFAS "may significantly limit the practicability of this disposal option."[7] Because of the limited availability of deep well injection locations, use for only liquid materials, and the volume of disposal required for DoD PFAS-containing materials, DoD believes this disposal option will rarely be an available option for DoD. DoD, however, has identified deep well injection as a disposal option that maximizes reduction of PFAS releases or emissions to the environment and human health exposures, and the DoD Components may consider whether deep well injection is an available and cost-effective option at an individual military installation.

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[6] EPA Interim PFAS Disposal Guidance (Dec. 2020), pages 5 and 83.

[7] EPA Interim PFAS Disposal Guidance (Dec. 2020), pages 5-6.

Consistent with the EPA guidance, DoD next considered permitted hazardous waste landfills. Hazardous waste landfills "have the most stringent environmental controls in place and higher potential capacity to manage the migration of PFAS into the environment."[8] Hazardous waste landfills are "more effective at minimizing PFAS migration into the environment than other landfill types."[9] Because "permitted hazardous waste landfills employ the most extensive set of environmental controls (e.g., double liner systems with leachate collection and leak detection) and practices (e.g., extensive record keeping) that are currently available for the containment of PFAS waste," DoD has identified these landfills as an available disposal option that maximizes reduction of PFAS releases or emissions to the environment and human health exposures.[10]

DoD next considered solid waste landfills. The EPA guidance identifies a variety of solid waste landfills: municipal solid waste, ash monofill, industrial, and construction and demolition landfills.[11] Because environmental controls can vary at landfills, EPA evaluated the viability of landfilling as a means of containing PFAS. Modern solid waste landfills "when constructed with appropriate controls (e.g., liner system and leachate and gas collection and management systems), can also control the migration of PFAS into the environment."[12] DoD has identified solid waste landfills with these controls in place (composite liner and gas and leachate collection and management) as an available disposal option that maximizes reduction of PFAS releases or emissions to the environment and human health exposures. Any solid waste landfill DoD uses for PFAS-containing materials must have a composite liner, gas and leachate collection and management systems, and an environmental permit.

The DoD Components, consistent with the Decision Tree in Attachment 2, will need to consider the type of PFAS-containing materials when considering the use of both hazardous waste and solid waste landfills. For example, liquids must be solidified to remove any free liquids before disposal in a landfill, which may increase the volume significantly (e.g., threefold).[13] The cost and availability of all destruction and disposal options are additional considerations that need evaluation.

DoD next considered thermal treatment technologies, recognizing that these options have higher levels of uncertainties regarding their capacity to control the migration of PFAS into the environment. Thermal treatment technologies include a wide-variety of technologies and controls, including hazardous waste combustors (e.g., incinerators, cement kilns, lightweight aggregate kilns), as well as other thermal treatment (e.g., carbon reactivation units, sewage sludge incinerators, municipal waste combustors, thermal oxidizers).[14] EPA, notwithstanding its acknowledgment of uncertainties with PFAS thermal treatment technologies, recognized that the subset of permitted hazardous waste combustors "may operate under conditions more conducive to destroying PFAS and controlling related [products of incomplete combustion] PICs relative to

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[8] EPA Interim PFAS Disposal Guidance (Dec. 2020), page 5.

[9] EPA Interim PFAS Disposal Guidance (Dec. 2020), page 6.

[10] EPA Interim PFAS Disposal Guidance (Dec. 2020), page 6.

[11] EPA Interim PFAS Disposal Guidance (Dec. 2020), page 56.

[12] EPA Interim PFAS Disposal Guidance (Dec. 2020), page 55.

[13] https://www.geoengineer.org/education/web-class-projects/cee-549-geoenvironmental-engineering-winter-2013/assignments/stabilization-solidification ("Volume of the treated wastes usually increases significantly")

[14] EPA Interim PFAS Disposal Guidance (Dec. 2020), page 6.

thermal treatment units that do not have both [Resource Conservation and Recovery Act] RCRA and [Clean Air Act] CAA permits."[15] EPA also recognized that permitted hazardous waste incinerators "are designed to optimize temperatures, residence times, turbulence, and other parameters" to "maximize organic destruction and minimize the formation of PICs."[16] These controls include pollution control devices which can remove hydrogen fluoride and other products of combustion.[17] After considering the latest studies and additional information[18] presented in the next section of this guidance on implementation of section 330 of the FY 2020 NDAA, DoD has identified hazardous waste incinerators as an available destruction option that maximizes reduction of PFAS releases or emissions to the environment and human health exposures.

Because DoD, and others, have widely utilized granular activated carbon (GAC) to remove PFAS from drinking water and groundwater, and "GAC reactivation is economically favored over replacement with virgin carbon,"[19] DoD also considered carbon reactivation units.[20] While carbon reactivation units "use high temperatures to thermally desorb contaminants from GAC, which allows for the carbon to be used again,"[21] they are not "incinerators" and instead are a form of recycling/preserving virgin materials. While there are about seventeen commercial carbon reactivation units across the country, currently only four "operate under RCRA permits and applicable air permits" which "provide additional regulatory oversight and include operating requirements and emission limitations to safely and effectively treat the hazardous contaminants."[22] Due to these additional safeguards, RCRA-permitted carbon reactivation units "may operate under conditions more conducive to destroying PFAS and controlling related PICs."[23] Therefore, DoD has identified RCRA permitted carbon reactivation units as an available destruction option to address PFAS-containing GAC that maximizes reduction of PFAS releases or emissions to the environment and human health exposures.

B. EPA Guidance on Environmental Justice

DoD also considered section 4 of the EPA guidance, which addresses environmental justice and impacts on vulnerable communities. The recent April 2023 Executive Order on "Revitalizing Our Nation's Commitment to Environmental Justice for All",[24] emphasizes that every person has a right to breathe clean air, drink clean water, and live in a healthy community. Under Executive Order 12898, "Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations", Federal agencies are directed to identify and address,

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[15] EPA Interim PFAS Disposal Guidance (Dec. 2020), page 35.

[16] EPA Interim PFAS Disposal Guidance (Dec. 2020), page 35.

[17] EPA Interim PFAS Disposal Guidance (Dec. 2020), pages 33-35.

[18] Several of those studies post-date EPA's December 2020 Guidance and its findings on relative uncertainty.

[19] EPA Interim PFAS Disposal Guidance (Dec. 2020), page 95.

[20] EPA's proposed PFAS National Primary Drinking Water Regulation similarly states: "At present, the most likely management option for spent materials containing PFAS is reactivation for GAC and incineration for spent IX resin." 88 Federal Register at 18686 (Mar. 29, 2023).

[21] EPA Interim PFAS Disposal Guidance (Dec. 2020), page 36.

[22] EPA Interim PFAS Disposal Guidance (Dec. 2020), page 36.

[23] EPA Interim PFAS Disposal Guidance (Dec. 2020), page 36.

[24] "Executive Order 14096 of April 21, 2023, Revitalizing Our Nation's Commitment to Environmental Justice for All," *Federal Register* 88, no. 80 (April 26, 2023): 25251-25261. https://www.govinfo.gov/content/pkg/FR-2023-04-26/pdf/2023-08955.pdf.

as appropriate, "disproportionately high and adverse human health or environmental effects of their actions on minority and low-income populations."[25] In Executive Order 14008, "Tackling the Climate Crisis at Home and Abroad," Federal agencies shall "develop programs, policies, and activities to address the disproportionately high and adverse human health, environmental, climate-related and other cumulative impacts on disadvantaged communities, as well as the accompanying economic challenges of such impacts."[26] DoD is also a signatory to a Memorandum of Understanding on Environmental Justice, and a member of the Environmental Justice Interagency Council under these Executive Orders. DoD considered these White House documents, as well as the EPA guidance, in determining what currently available disposal and destruction options should be included in this interim guidance.

As the EPA guidance notes, certain communities "may be highly exposed to environmental contaminants because they live or work near the sources of release or presence in the environment."[27] This includes "those living near and using PFAS-contaminated environments (e.g., drinking water, fishing, hunting, and recreation)."[28] DoD acknowledges that many of the communities surrounding our military installations are communities with environmental justice concerns. We have prioritized our cleanup program to address the highest risks first, regardless of the community demographics, and address exposures (e.g., drinking water) under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA, also known as Superfund). Environmental justice principles are incorporated into CERCLA through public participation in the cleanup process, as well as the additional public outreach and engagement that DoD conducts (e.g., Restoration Advisory Boards). It is this cleanup program that addresses high exposures to PFAS that generates a large volume of PFAS-containing materials for disposal. Impact on vulnerable communities is thus addressed primarily in our cleanup program, and we support the Superfund Community Involvement Toolkit referenced in the EPA guidance. DoD is working on improving its public outreach and community dialogue for our PFAS cleanups through expanded public outreach at both senior leadership and local levels, a more user-friendly DoD PFAS website, and updating our Restoration Advisory Board guidance. We also note that EPA's Office of Land and Emergency Management is working with DoD and State representatives to develop "approaches to characterizing communities adjacent to three federal facility [National Priority List] NPL sites, to identify those with [Environmental Justice] EJ concerns."[29] When completed, these projects will inform EPA's understanding of best practices and be publicly shared. DoD supports this approach.

We also considered the vulnerable communities that exist near landfills and hazardous waste incinerators. We found this to be more complex in helping to choose among existing

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[25] "Executive Order 12898 of February 11, 1994, Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations," *Code of Federal Regulations,* title 3 (1994): 1-101, https://www.archives.gov/files/federal-register/executive-orders/pdf/12898.pdf.

[26] "Executive Order 14008 of January 27, 2021, Tackling the Climate Crisis at Home and Abroad," *Federal Register* 86, no. 19 (February 1, 2021): 7619-7633, https://www.govinfo.gov/content/pkg/FR-2021-02-01/pdf/2021-02177.pdf.

[27] EPA Interim PFAS Disposal Guidance (Dec. 2020), page 87.

[28] EPA Interim PFAS Disposal Guidance (Dec. 2020), page 87.

[29] EPA Office of Land and Emergency Management, "EJ Action Plan. Building Up Environmental Justice in EPA's Land Protection and Cleanup Programs (Sept. 2022), page 25.

disposal and destruction options. For example, studies have identified that a disproportionate number of landfills and other hazardous waste facilities, such as incinerators, are located in communities with environmental justice concerns. DoD also used EPA's Environmental Justice Screening and Mapping Tool ("EJScreen")[30] to identify potentially impacted communities living near PFAS destruction or disposal sites identified in this guidance, as well as communities surrounding our military installations where PFAS cleanups are ongoing and AFFF will be replaced. DoD also considered the relative risk between its top priority of addressing elevated levels of PFAS in drinking water from DoD activities versus indirect potential PFAS exposures from destruction and disposal facilities.

In choosing among disposal options, however, one of the most significant factors for DoD was the additional oversight and controls provided at disposal and destruction facilities with environmental permits. We recognize the statutory authority and responsibility of the EPA and State environmental regulatory agencies to regulate the disposal of wastes that may threaten human health or the environment, and to issue environmental permits that are protective of human health and the environment. Section 4 of the EPA guidance thus focuses on considering vulnerable populations and community engagement in the regulatory siting or permitting processes for destruction and disposal facilities. DoD acknowledges that more work is needed to ensure that the impacts associated with the operation of destruction and disposal facilities are equitable. While DoD does not have a regulatory role, we encourage regulators and disposal facilities to consider PFAS in these regulatory processes. In addition, to facilitate engagement with communities near our military installations, as well as possibly adjacent to PFAS destruction and disposal facilities, we have developed a DoD PFAS Disposal Fact Sheet that will be posted on our DoD PFAS website (https://www.acq.osd.mil/eie/eer/ecc/pfas/index.html). This fact sheet summarizes this DoD PFAS disposal guidance, provides background information on PFAS and potential health effects based on EPA and the Agency for Toxic Substances and Disease Registry statements, and provides information on how DoD is incorporating environmental justice principles when addressing PFAS. DoD will also explore new partnership opportunities with EPA and other federal agencies to advance environmental justice issues in accordance with Executive Order 14096.

C. DoD Implementation

DoD is therefore identifying the following options, **in order of priority**, for the DoD Components to utilize for the destruction or disposal of PFAS-containing materials, including AFFF, that are not hazardous wastes:[31]

- **Carbon reactivation units with environmental permits (for used GAC only).** GAC is a common PFAS water treatment technique where PFAS attaches to the

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[30] See https://www.epa.gov/ejscreen.

[31] Hazardous waste is regulated pursuant to RCRA authority. See 42 U.S.C. § 6903. The regulatory definition of hazardous waste is found in 40 CFR § 261.3. PFAS is currently not a listed or characteristic hazardous waste, but a PFAS-containing material may meet the regulatory definition of hazardous waste if PFAS is mixed with a listed hazardous waste or if a PFAS-containing mixture exhibits a hazardous characteristic (e.g., ignitability). Materials that qualify as a RCRA hazardous waste must follow RCRA storage and disposal requirements and are outside of the scope of this guidance.

carbon until the carbon is full. Carbon reactivation units use high temperatures to thermally treat contaminants collected in GAC, which allows for the carbon to be used again. Carbon reactivation units permitted under RCRA and the CAA have additional regulatory oversight and include operating requirements and emission limitations to safely and effectively treat hazardous contaminants.

- **Hazardous waste landfills with environmental permits.** These landfills have stringent environmental controls in place to manage the migration of PFAS into the environment. Permitted hazardous waste landfills employ the most extensive set of environmental controls (e.g., double liner systems with leachate collection and leak detection) and practices (e.g., extensive record keeping) that are currently available for the containment of PFAS waste.
- **Solid waste landfills with environmental permits that have composite liners, and gas and leachate collection and treatment systems.** Modern municipal solid waste landfills, when constructed with appropriate controls (e.g., liner system, leachate and gas collection and management systems, permits), can also control the migration of PFAS into the environment.
- **Hazardous waste incinerators with environmental permits**. These high temperature incinerators have stringent regulatory controls on temperature and other operating parameters to achieve a 99.99 percent destruction efficiency for other (non-PFAS) organic chemicals, and evidence suggests that a similar destruction efficiency may apply to PFAS-containing materials (see below). Currently, thermal treatment is the only commercially available technology that has the potential capability to destroy PFAS, rather than contain it.

In addition to these four DoD-wide options, the DoD Components are directed to consider onsite hazardous waste storage on a site-specific basis, for storage over ninety days. The DoD Components may also consider underground injection control, on a site-specific basis. Third, the DoD Components, upon notification to OASD(EI&E), may also consider other existing and developing PFAS treatment or destruction technologies that are accepted/permitted by the appropriate State or Federal regulator, *instead of* utilizing hazardous waste incinerators, on a site-specific basis. For example, at one site with a large volume of PFAS-impacted soils, where landfills were not an option in that State, OASD(EI&E) was notified that a State permitted thermal desorption unit would be considered rather than hazardous waste incineration. The DoD Components, when selecting one of the options above for the destruction or disposal of PFAS-containing materials, must continue to make informed decisions consistent with this guidance and the Decision Tree.

2. DoD Implementation of Section 330 of the FY 2020 NDAA

Section 330 of the FY 2020 NDAA requires DoD to ensure that when PFAS-containing materials or AFFF are disposed:

> "(1) all incineration is conducted at a temperature range adequate to break down PFAS chemicals while also ensuring the maximum degree of reduction in emission of PFAS, including elimination of such emissions where achievable;
> (2) all incineration is conducted in accordance with Clean Air Act (42 USC 7401 et seq.), including controlling hydrogen fluoride;

> (3) any materials containing PFAS that are designated for disposal are stored in accordance with the requirement under part 264 of title 40, Code of Federal Regulations; and
> (4) all incineration is conducted at a facility that has been permitted to receive waste regulated under [the Resource Conservation and Recovery Act][32] (42 USC 6921 et seq.)."

This guidance addresses the second, third, and fourth criteria together, followed by the first criterion.

The second criterion in section 330 requires that all incineration of PFAS-containing materials is conducted in accordance with CAA requirements. The third criterion in section 330 requires that PFAS-containing materials stored at hazardous waste combustors prior to incineration be stored in accordance with RCRA requirements. The fourth criterion in section 330 requires that incineration is conducted at a RCRA-permitted hazardous waste facility. **Based upon the review of these three criteria, if a DoD Component chooses to incinerate PFAS-containing materials in its custody, the DoD Component must send those PFAS-containing materials, including AFFF, only to RCRA- and CAA-permitted Hazardous Waste Incinerators (HWIs)**. RCRA-permitted HWIs with CAA Title V permits operate under conditions that represent the maximum commercially available destruction efficiencies for PFAS, including the control of hydrogen fluoride and other PICs. Additionally, RCRA- and CAA-permitted HWIs have experience in the proper storage of regulated hazardous wastes and must comply with part 264 of title 40, Code of Federal Regulations, concerning storage of material at their facilities. Therefore, the DoD Components will implement the CAA and RCRA permit and storage criteria in section 330 by ensuring that the HWIs utilized for the incineration of PFAS-containing materials, including AFFF, have valid RCRA and CAA operating permits.

The first criterion in section 330 requires that if DoD sends PFAS-containing materials to incinerators, the incinerators utilize a temperature range adequate to break down PFAS while also minimizing emissions of PFAS. Because the second, third, and fourth criterion in section 330 require incineration at permitted HWIs and because these permitted facilities are required to maintain minimum temperature thresholds, DoD used those minimum thresholds in determining whether it can reasonably conclude that its candidate HWIs will achieve the requirements of the first criterion in section 330.

A. Relevant RCRA and CAA permitting requirements

The regulatory requirements for RCRA- and CAA-permitted HWIs are summarized as follows:

> RCRA-permitted HWIs must follow stringent regulatory requirements and are required by EPA to conduct testing to determine a Destruction and Removal Efficiency (DRE). The key factors in achieving a high DRE are time in the incinerator (residence time), high temperature, and turbulence (i.e., mixing). The purpose of DRE testing is to demonstrate that virtually all the molecules of a surrogate compound are destroyed in the incinerator.

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[32] The Solid Waste Disposal Act of 1965 is commonly referred to as the Resource Conservation and Recovery Act (RCRA), which significantly amended the Solid Waste Disposal Act, in 1976.

> For HWIs, EPA requires a minimum DRE of 99.99%. During DRE testing, a surrogate compound is fed into the incinerator that represents classes of compounds that are extremely difficult to destroy. EPA has developed a system of ranking these surrogate compounds, based on their difficulty to destroy. After a 99.99% DRE is achieved, EPA or the delegated State, issues a CAA Title V permit that includes requirements for operation. This includes a high temperature range and other parameters that are continuously monitored, and if not complied with, the incinerator will stop the flow of materials to the combustion unit automatically and immediately.

While there are several operating conditions specified in a HWI permit, the first criterion in section 330 focuses on a temperature range adequate to break down PFAS. DoD reviewed minimum temperatures specified in nine existing HWI permits to achieve their DRE and found their permits require a minimum temperature in the kiln that range from 1200°F to 1824°F. At these facilities, the kiln is followed by an afterburner/secondary combustion chamber to maximize organic destruction and their permits require a minimum temperature in the afterburner/secondary combustion chamber that ranges from 1488°F to 2026°F. Based on the studies and information described below, HWIs at their permitted temperature range will be adequate to break down detectable PFAS chemicals.

B. Existing Data on Destruction Capabilities of Incinerators

EPA’s guidance contains the following findings on the destruction capabilities of HWIs:

> HWIs are designed to optimize temperatures, residence times, turbulence, and other parameters to ensure compliance with organic DRE requirements. Most commercial HWIs use rotary kilns…that maintain high temperatures. Typically, solids retention time in the kiln is 0.5 to 1.5 hours, while gas residence time through the kiln is usually around two seconds. Kiln flame/solids temperatures range from 650°C to 1,650°C (1,200°F to 3,000°F). The rotary kiln is followed by an afterburner where additional high-heating-value gaseous and liquid wastes, and auxiliary fuels are added. The afterburner is typically operated at about 1,100°C to 1,370°C (2,000°F to 2,500°F) with a gas residence time from 1 to 3 seconds to maximize organic destruction and minimize the formation of PICs.[33]

Studies and information on PFAS destruction indicate that the temperature ranges used in these types of HWIs are effective in destroying the 50 PFAS that can currently be detected in air emissions through an EPA methodology:

- In 2021, EPA began conducting pilot-scale PFAS incineration studies using its “Rainbow” furnace, which allows EPA to conduct incineration experiments under controlled conditions.[34] This research identified fluorocarbon tracer gases (surrogates) that could potentially be used to monitor destruction efficiencies during incineration, and then began experiments. The first publication from these

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[33] EPA Interim PFAS Disposal Guidance (Dec. 2020), page 35.

[34] “Combustion of C_1 and C_2 PFAS: Kinetic Modeling and Experiments,” Krug et al., *Journal of the Air & Waste Management Association*. 2022, 72:3, 256-270. Published Feb. 11, 2022.

experiments suggests that PFAS can be destroyed when subjected to aggressive thermal environments above 1100°C. EPA is also conducting experiments to understand the incineration of PFAS present in AFFF.[35]

- In 2021, the New York State Department of Environmental Conservation (NYSDEC) announced that it had completed a study to determine if the thermal treatment of PFAS-containing materials at the Norlite facility in Cohoes, New York, resulted in soil and surface water contamination. The Norlite facility is a RCRA- and CAA-permitted hazardous waste combustor that had treated AFFF over a number of years. This NYSDEC study found no clearly discernible pattern of aerial deposition of PFAS that could be traced to Norlite's operations. Sampling identified low-level detections of PFAS compounds in all soil samples collected at upwind, downwind, and at background locations, consistent with emerging research on the prevalence of PFAS in urban, suburban, and rural environments. Concentrations of PFAS found in soils in the vicinity of the facility were below guidance values NYSDEC developed, indicating that the facility successfully destroyed the PFAS material and did not emit traceable amounts of PFAS during combustion.[36]
- In 2021, a commercial RCRA- and CAA permitted HWI conducted a PFAS-specific study. In this study, AFFF was added in high concentrations to a waste feed, and sampled at various times throughout the incineration process. A 99.9999% DRE was obtained for Perfluorooctanesulfonic Acid, Perfluorooctanoic Acid, Perfluorohexane Sulfonic Acid, and hexafluoropropylene oxide dimer acid (otherwise known as Gen-X) at a temperature of 1800 °F. The study determined that the 50 specific PFAS that can currently be measured were turned into hydrogen fluoride, which was trapped in the air pollution control system.[37] To measure PFAS air emissions, this study utilized EPA test method OTM-45, published in 2021, for stack gas sampling of PFAS air emissions during this testing program. This study has undergone EPA and peer review, and became publicly available in August 2022.[38]
- In 2022, a literature review covering 163 published works on thermal treatment of PFAS was published.[39] This paper suggests that "complete combustion of PFAS will likely be most successful in incinerators that employ a two-stage process. In these, the waste is first fed into the primary combustion chamber where PFAS desorb and partially degrade. The gaseous byproducts are sent to a secondary chamber (the afterburner) that operates in excess air (stoichiometric excess of oxygen) at high

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[35] Shields, E. "ER21-1288: Multi-Scale Evaluation of PFAS Thermal Destruction Requirements." Strategic Environmental Research and Development Program In-Progress Review Meeting, Aug. 17, 2022 (Virtual).

[36] *Norlite Environmental Sampling Report*, pp 25-26. New York State Department of Environmental Conservation, March 2021, https://www.dec.ny.gov/docs/materials_minerals_pdf/norlitesamplingfull0321.pdf.

[37] EPA's Interim PFAS Disposal Guidance (Dec. 2020), page 34, recognizes that hydrogen fluoride is a break-down product of PFAS destruction, and is captured in air pollution control devices. ("…PFAS destruction is defined as the complete severing of all carbon-fluorine bonds in a PFAS molecule. Severing all carbon-fluorine bonds results in conversion to carbon dioxide, hydrogen fluoride (HF), and other compounds. HF and some of the other products of combustion can be removed in pollution control devices.").

[38] http://cleanharbors.dev-cleanharbors.acsitefactory.com/services/industrial-field-services/field-services/PFAS-PFOA-PFOS-Remediation

[39] "Critical Review of Thermal Decomposition of Per- and Polyfluoroalkyl Substances: Mechanisms and Implications for Thermal Treatment Processes," Wang et al., *Environ. Sci. Technol*. 2022, 56, 5355-5370. Published April 21, 2022.

> temperature (>950 °C) and short residence times (1-3 seconds)."[40] DoD notes that HWIs employ this two-stage process. This paper also stated that the "general consensus across these lab-scale studies is that even the most stable PFAS (e.g., long-chain sulfonates) desorb at temperatures less than 1000°C, and they are destroyed in the gas phase at temperatures greater than 1000°C."[41]

DoD acknowledges that the studies mentioned above and the EPA guidance identified uncertainties regarding PFAS thermal treatment. According to the EPA guidance:

> Key uncertainties include the lack of PFAS-specific information on these facilities. EPA currently has no emission characterizations from these sources when they burn PFAS, and is working to develop measurement methodologies as well as gather information to conclude whether potential [PICs] are adequately controlled. EPA recognizes that PICs are formed (even for nonfluorinated compounds); however, based on the unique characteristics of fluorine combustion chemistry, it needs to be determined whether thermal treatment devices and their associated post-combustion control devices are controlling fluorinated PICs.[42]

EPA, notwithstanding its general finding that there are uncertainties with PFAS thermal treatment technologies, recognized that there is less uncertainty for the permitted facilities that DoD will use for incineration if other disposal options are not deemed viable. According to EPA, the subset of permitted HWIs "may operate under conditions more conducive to destroying PFAS and controlling related PICs relative to thermal treatment units that do not have both RCRA and CAA permits." [43] EPA also recognized that permitted HWIs "are designed to optimize temperatures, residence times, turbulence, and other parameters" to "maximize organic destruction and minimize the formation of PICs." [44] These controls include pollution control devices which can remove hydrogen fluoride and other products of combustion.[45]

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[40] *Id.* at page 5363.

[41] *Id.* at page 5363.

[42] EPA Interim PFAS Disposal Guidance (Dec. 2020), page 6.

[43] EPA Interim PFAS Disposal Guidance (Dec. 2020), page 35.

[44] EPA Interim PFAS Disposal Guidance (Dec. 2020), page 35.

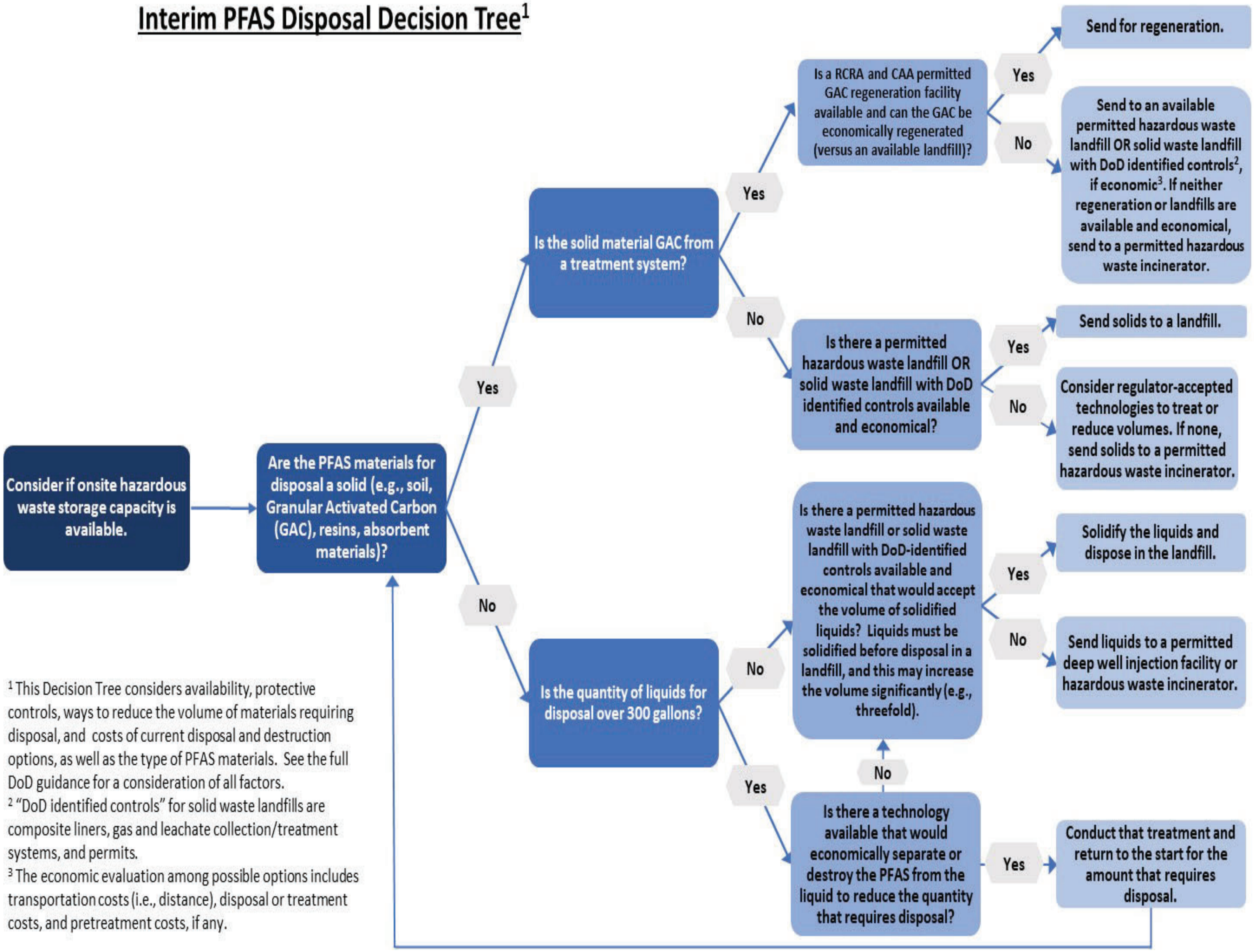
[45] EPA Interim PFAS Disposal Guidance (Dec. 2020), pages 33-35, 42-43.

3. DoD's Finding

In light of the 2021 PFAS air emission methodology and studies identified above, including at a full-scale RCRA- and CAA-permitted HWI, DoD finds that incineration at these facilities at their permitted temperature range will be adequate to break down detectable PFAS chemicals while also ensuring the maximum degree of reduction in emission of detectable PFAS. Based on the above studies and information that show HWI permits specify a temperature range and other operating parameters to achieve a 99.99% DRE, and HWIs are required to have air emission control devices, RCRA- and CAA permitted HWIs meet section 330's requirements for an adequate temperature range to break down PFAS that currently can be detected in air emissions and meet emission reduction requirements. Additional research is underway, and DoD will update this guidance annually to reflect changes as technologies mature, EPA updates its guidance, and additional data, including air emission detection methods, becomes available.

Attachment 2 –DoD PFAS Disposal Decision Tree

Interim PFAS Disposal Decision Tree[1]



[1] This Decision Tree considers availability, protective controls, ways to reduce the volume of materials requiring disposal, and costs of current disposal and destruction options, as well as the type of PFAS materials. See the full DoD guidance for a consideration of all factors.

[2] "DoD identified controls" for solid waste landfills are composite liners, gas and leachate collection/treatment systems, and permits.

[3] The economic evaluation among possible options includes transportation costs (i.e., distance), disposal or treatment costs, and pretreatment costs, if any.

Port Angeles Fire Department

Disposal Preference: Incineration. We firmly believe that storage on site of individual fire agencies and taking no action are the worst options. This creates small pockets of Hazardous Waste storage at fire stations across the state until an indeterminate future solution is developed. The increased regulatory requirements and permitting may not be possible for all agencies to ensure safe storage.

Guidance Needed: We echo the same concerns mentioned in the comment by the Tumwater Fire Department regarding the removal of AFFF stored in our apparatus. Departments will need guidance for the removal of all AFFF from onboard apparatus tank storage, cleaning run-off capture, and disposal of runoff.

We appreciate the efforts being put into this, and the opportunity for comment.

Friends of Rocky Top

Sean Smith   On behalf of Carole DeGrave and Friends of Rocky Top (FORT), attached are written comments on Ecology’s AFFF Collection and Disposal Draft EIS. Please let me know if you have any problem downloading the comment letter.   Sincerely,   Scott Cave S.C. Communications (360) 789-2772

This letter was submitted to Ecology February 5, 2024 at: AFFFDisposal@ecy.wa.gov:

To:
Sean Smith
Washington State Department of Ecology
P.O. Box 330316
Shoreline, WA 98133-9716

From:
Scott Cave, President
S.C. Communications
P.O. Box 258
Ritzville, WA 99169

Subject:
Comments on Aqueous Film-Forming Foam Collection and Disposal Program Draft Programamatic Environmental Impact Statement, PN 3-04-064

On behalf of *Carole DeGrave* and *Friends of Rocky Top* (FORT), we appreciate the opportunity to comment on the Aqueous Film-Forming Foam (AFFF) Collection and Disposal Program Draft Programamatic Environmental Impact Statement (DEIS) regarding the public health impacts associated with the collection, transport and disposal of AFFF stock at municipal fire stations.

FORT is a group of neighbors and concerned citizens seeking to protect the land, air, and water resources around the Rocky Top area from further environmental degradation from *East Mountain Investments, Inc. and DTG Enterprises, Inc. (*DTG*)* toxic landfill and associated facilities. FORT is a CascadiaNOW! fiscally sponsored project: https://www.cascadianow.org/friends-of-rocky-top. In September, 2022 Ecology declared an area of DTG's landfill Cell 1, a *Model Toxics Control Act* (*MTCA*) cleanup site, and soon confirmed subsurface fires; see Anderson Landfill, Facility Site ID: 79747294 https://apps.ecology.wa.gov/cleanupsearch/site/11537#site-documents.

Ownership note: DTG purchased the Anderson limited purpose landfill (landfill), petroleum contaminated soil (PCS) remediation site, and surface mine on Oct. 31, 2019 renaming it a *Sustainability Park*. On December 1, 2022, Macquarie Asset Management (MAM), the world's largest infrastructure manager, announced that one if its funds had acquired DTG. Notably, the *MTCA* site agreed order (AO) lists *East Mountain Investments, Inc. and DTG Enterprises, Inc.,* not MAM as Potentially Liable Persons (PLP) for the cleanup (more below).

Comment 1: While the state recognizes the potential threat posed at 'secondary sources' (landfills that received and disposed of AFFF) from AFFF/PFAS contamination of groundwater in this DEIS, it does not include them, and strictly considers AFFF fire service release sites only. Given the AFFF/PFAS threat to groundwater at known secondary sources, Ecology should separately evaluate the benefit of AFFF/PFAS monitoring at secondary sources that would establish baseline data and increase early detection at problem sites.

Between 2004 and 2006, contaminated soils containing *elevated concentration levels* of *AFFF/PFAS* were removed from the U.S. Army, Department of Defense, Yakima Training Center (YTC) near Selah and remediated and disposed at the Anderson PCS site and landfill on Rocky Top, Yakima County, respectively.

From the DEIS & Executive Summary (ES):

> *"PFAS within AFFF are water soluble and highly mobile, meaning they can easily contaminate groundwater and can be hard to filter out. There are no known natural processes that can break down these substances. Exposures could continue for hundreds of years or more."*
>
> ES-3

> *"If released into the environment, PFAS can contaminate soil, sediment, surface water, and groundwater. Many PFAS are highly mobile and, due to their unique structures, can strongly sorb to soils and sediments. If PFAS compounds reach groundwater or surface water, they can travel long distances due to their chemical stability."*
>
> DEIS, p. 1-3

> *"PFAS are often found in the environment in multiple areas on sites where AFFF was applied, stored, or released. These areas include emergency response locations, fuel spill areas, hazardous waste storage facilities, hanger-related AFFF storge tanks and pipelines, firefighting equipment test areas, stormwater and/or surface water drainage features, and outfalls. Landfills that received AFFF and wastewater treatment plants that receive stormwater and landfill biosolids may become secondary sources. AFFF is responsible for some of the larges PFAS releases to the environment. These are also complex, costly, and difficult to investigate and remediate."*
>
> *"When AFFF was historically used, the foam residual wasn't always collected or pretreated prior to discharge, and may have reached drinking water sources, such as groundwater and surface water. PFAS-containing Class B firefighting foam has been associated with drinking water contamination in Washington. In their risk-based efforts to identify and mitigate PFAS in drinking water, both the military and Washington Department of Health focused on firefighting foam release sites."*
>
> DEIS, p 1-5

Last year Ecology informed the Yakima Health District (YHD), the jurisdictional solid waste permitting agency, about the disposal of 743 cubic yards of YTC AFFF/PFAS contaminated soils on Rocky Top:

> *"Ecology staff in our solid waste management division has recently learned that soils removed from the Yakima Training Center's (YTC) former Fire Training Facility were brought to the former Anderson Landfill (now DTG) for petroleum contamination treatment and disposal in 2004. As you may be aware, YTC's Fire Training Facility was a shallow unlined pit that was periodically filled with old fuel and set on fire so that fire crews at the YTC could practice fighting fires with aqueous film forming foam (AFFF). Prior to 2004, soil and groundwater at the YTC site was determined to be contaminated with petroleum-related compounds and cleanup was initiated. One of the selected remedies was to excavate the contaminated soil and remove it from the site. Approximately 743 cubic yards of the excavated soils were taken to Anderson Landfill for treatment at the petroleum contaminated soils (PCS) treatment site and disposal in the landfill."*
>
> *"In 2004, at the time of excavation of the YTC Fire Training Facility, the toxic characteristics of the ingredients of AFFF were not understood by YTC, the Yakima Health District (YHD), or Ecology. AFFF contains per- and poly-flouroalkyl substances (PFAS) which are now understood to be toxic at very low concentrations and extremely persistent in the environment. At the time of disposal of the Fire Training Facility soils, analytical methods were not available to identify and quantify PFAS in soil, and regulators were not aware that these compounds were as persistent or as toxic as they are now understood to be."*
>
> *"The PCS removed from the YTC site, were transported to the Anderson Landfill for treatment at the PCS site and disposal in the landfill. This material likely contained elevated concentrations of PFAS. Because the existing landfill and the PCS treatment site are unlined, there is a risk of migration of PFAS into groundwater. Ecology recommends that the sampling and analysis plan for routine monitoring at*

> *the landfill be amended to include analysis for PFAS. Ecology also recommends soil grid sampling of the PCS pad area and installation of monitoring wells around the PCS treatment area and development of a sampling and analysis plan for the site which should include soil sampling to determine if PFAS is present. Ecology recommends this work gets completed within 1 year time."*
>
> James Rivard, Regional Manager, Solid Waste Management Program,
> Washington State Department of Ecology, Central Region Office, January 19, 2023

The AFFF/PFAS soil removal, transfer, remediation and disposal at Rocky Top facilities occurred nearly two decades ago, when the state's analytical methods were not capable to properly identify and quantify the PFAS concentration in the YTC AFFF/PFAS soils. State and federal regulators were also less informed about the persistent and toxic characteristics of PFAS. That dramatically changed in the last 8 years, with U.S. EPA's reconsideration of the harmful impacts from PFAS exposure. In March, 2023 the agency proposed national drinking water standards for six types of PFAS, and last week EPA's Administrator declared nine PFAS as hazardous:

> *"… signed a proposal to change the Resource Conservation and Recovery Act (RCRA) regulations by adding nine particular per- and polyfluoroalkyl compounds, their salts, and their structural isomers, to its list of hazardous constituents in Title 40 of the Code of Federal Regulations Part 261 Appendix VIII. These nine PFAS are:*
>
> 1. *Perfluorooctanoic acid.*
> 2. *Perfluorooctanesulfonic acid*
> 3. *Perfluorobutanesulfonic acid.*
> 4. *Hexafluoropropylene oxide-dimer acid.*
> 5. *Perfluorononanoic acid.*
> 6. *Perfluorohexanesulfonic acid.*
> 7. *Perfluorodecanoic acid.*
> 8. *Perfluorohexanoic acid.*
> 9. *Perfluorobutanoic acid.*
>
> *To be listed as a hazardous constituent under RCRA, scientific studies must show that the chemical has toxic, carcinogenic, mutagenic, or teratogenic effects on humans or other life forms. EPA evaluated toxicity and epidemiology data for these chemicals and determined that these nine PFAS compounds meet the criteria for listing as a RCRA hazardous constituent.*
>
> *With this proposal, EPA is working to protect communities by strengthening its ability to address PFAS contamination under the RCRA cleanup program, known as the RCRA Corrective Action Program. This change would facilitate additional corrective action to address releases of these specific PFAS at RCRA hazardous waste treatment, storage, and disposal facilities. It would not require the suite of cradle to grave management controls that are associated with a RCRA hazardous waste."*

In a press release February 1, 2024, the Biden Administration stated:

> *"EPA is proposing to modify the definition of hazardous waste as it applies to cleanups at permitted hazardous waste facilities. This modification would assure that EPA's regulations clearly reflect EPA's and authorized states' authority to require cleanup of the full range of substances that the Resource Conservation and Recovery Act (RCRA) intended, including emerging chemicals of concern, such as PFAS, that may present substantial hazards, at permitted facilities.*

> *"EPA is also proposing to amend its RCRA regulations to add multiple PFAS compounds as hazardous constituents. These PFAS would be added to the list of substances identified for consideration in facility assessments and, where necessary, further investigation and cleanup through the corrective action process at hazardous waste treatment, storage and disposal facilities."*
>
> *"These proposed rules would strengthen protections for communities and drinking water supplies located near the 1,740 permitted hazardous waste facilities across the nation."*

EPA's action is good news as it will increase our national response to PFAS contamination at these permitted hazardous waste facilities.

Comment: But what about the people and communities near unlined 'secondary sources' that are known to have received and disposed of AFFF/PFAS materials and contamination soils? As noted by in the above Ecology quote, the contaminated *AFFF/PFAS* soils approved for remediation and disposal at Rocky Top contained "*elevated concentrations*". Today, EPA considers even minimal exposure of AFFF/PFAS harmful to human health, and the *elevated concentration levels* in the soils remediated and disposed on Rocky Top would be considered hazardous today, requiring site controls for containment, handling and transfer, and disposal at a Subtitle C facility (out of state).

The two unlined facilities have not historically monitored for PFAS. The landfill (3 wells) was required to add PFAS to future quarterly monitoring. For years, Ecology and the YHD have requested DTG to drill additional monitoring wells to update site characterization, and establish a compliant groundwater monitoring system, which is the drinking water source for neighbors. DTG has informed regulators of its intention to drill wells in 2024.

Neighbor concerns about the lack of groundwater monitoring and determination of contamination flowpaths is exasperated by the threat posed by 'forever chemicals' in the liner of the landfill and PCS site. To appreciate our concern of the contamination threat on Rocky Top, consider the following:

1) **Model Toxic Control Act cleanup site**

DTG's 'Sustainability Park', is an unlined toxic waste site, known as the Anderson Contaminated Landfill Site ID:79747294 :https://apps.ecology.wa.gov/cleanupsearch/site/11537#site-documents.

Volatile organic compounds (VOCs) were detected in ambient air and in landfill gas at the facility in December 2021 and confirmed in July 2022. Benzene and naphthalene were detected in ambient air at concentrations 40-50 times higher than the USEPA's default concentrations for Municipal Solid Waste landfills (USEPA, AP-42, Section 2.4, October, 2008) exceeding outdoor air quality standards under the state *MTCA.* From Ecology's Anderson Landfill Cleanup Site page:

> ***Cleanup***
>
> *In 2023, Ecology and the two parties responsible for cleanup, East Mountain Investments, Inc. and DTG Enterprises, Inc. negotiated an agreed order for cleanup work at the site. An Agreed Order is a legal agreement between Ecology and the Potentially Liable Persons (PLPs) outlining the expectations, process, and schedule for site cleanup. The order requires delineation of hazardous compounds in gas originating in the waste and groundwater monitoring to identify if hazardous compounds have reached groundwater.*
>
> ***Fire***

> *In March 2023, contractors working for DTG identified temperatures greater than 500ºF at a depth of 10 feet below the landfill's surface. These high temperatures as well as gas readings collected from within the landfill indicate fire beneath the surface. Additional investigation in September 2023 and subsequent gas monitoring identified high temperatures and gas readings that indicate a fire that at extends from a depth of approximately 10 feet to at least 40 feet below the landfill's surface. The fire is in the same area that the agreed order intends to investigate.*
>
> *As of late December 2023, DTG completed application of a soil cap in the fire area. The intent of the soil cap is to reduce emission of combustion products from the landfill and to suppression oxygen within the waste to smother the fire. Ecology is working with the YHD, who has jurisdiction over the landfill's operating permit, to review the effectiveness of the soil cap in suppression of oxygen and extinguishment of the fire. The effectiveness of the soil cap in reducing emissions of combustion products from the landfill will be evaluated as part of the agreed order.*
>
> ***Next Steps***
>
> *The investigation required by the agreed order cannot be conducted safely until the fire is extinguished and temperatures within the landfill have returned to normal. Therefore, the work required by the agreed order has been postponed until the fire has been addressed. The next steps for this site include creation and implementation of a fire suppression plan.*

Point Comment: In September, 2022, Ecology determined a portion of the landfill a MTCA site and has signed an Agreed Order with DTG to investigate the area, identify workplans and implement remedies. However, Ecology paused the investigation pending completion of the emergency effort to remediate landfill fires. The MTCA investigation should include the AFFF/PFAS soil layer in Cell 1.

2) **Ongoing landfill fires create emergency situation, pause MTCA investigation**

Since DTG ownership, neighbors have registered complaints of horrible, eye-watering odors, including burning smells, starting in the summer of 2020. DTG and regulators would point to the landfill quarterly methane monitoring that never detected any levels of concern. But in November 2021, regulators investigated the odor complaints and agreed the facility was in violation and required landfill gas sampling. In December, 2021 independent sampling detected volatile organic compounds (VOCs) in ambient air and in landfill gas at the facility, and was confirmed in July 2022, and soon after the presence of landfill fires.

Review of DTG LPL quarterly methane monitoring with a hand wand flipped on for a few seconds at five locations around the landfill perimeter, have consistently revealed no noticeable methane emissions, implying the facility was, and is, compliant with state required and permitted air emissions, and by extension, does not pose a health threat to landfill workers or neighbors.

Point Comment: The toxic fumes and fire reflect poor management, potentially suspect disposal and a constrained, limited regulatory structure of oversight. More concerning is the potential for the landfill to generate leachate, increasing the risk of migration to downgradient, nearby drinking supply wells. The failure of adequate property setbacks and reduced environmental controls (no liner or leachate collection system), limited regulatory oversight and coordination, and ability and willingness to enforce permit and code violations, all contributed to the facility proximity to neighbors, loose compaction, steep slopes and subsurface fires that required purchase of adjacent property.

The state should recognize and evaluate the gaps in the current regulatory structure and landfill air emission monitoring system that failed to detect obvious toxic emissions and landfill fires.

Specifically, the state should consider increasing the monitoring requirements for groundwater and methane emissions, similar to those recently proposed for MSW landfills.

3) **Disposed AFFF/PFAS contaminated soils part of LPL alternative liner**

As this DEIS acknowledges, PFAS are 'forever chemicals' and poise a serious threat to human health and the environment even at low levels of exposure, prompting U.S. EPA and state regulatory agencies to exponentially reduced allowed maximum contamination levels (MCL) and categorize them as hazardous. Exposure to these highly fluorinated chemicals are of grave concern to Rocky Top neighbors, recreationalists, and nearby residents whose air quality has been compromised by DTG facilities and operations. Like Selah, DTG Rocky Top neighbors fear future groundwater contamination.

As reported, the DoD is responsible for the U.S. Army Yakima Training Center (YTC) near Selah, and the resulting AAAF and PFAS contamination of local groundwater. Arguably, it would bear responsibility for future PFAS contamination of groundwater at Rocky Top, the 'secondary source' that received, remediated, and disposal of 743 cubic yards of YTC AAAF contaminated soils with elevated concentration levels of PFAS.

> *The Yakima fire training facility was a shallow unlined pit, filled with old fuel and set on fire so fire crews could practice fighting fires with AFFF. Prior to 2004, soil and groundwater at the YTC site was determined to be contaminated with petroleum-related compounds and cleanup was initiated. One of the selected remedies was to excavate the contaminated soil and remove it from the site. Approximately 743 cubic yards of the excavated soils were taken to the Anderson Landfill for treatment at the petroleum contaminated soils (PCS) treatment site and disposal in the landfill.*
>
> James Rivard, Regional Manager, Solid Waste Management Program,
> Washington State Department of Ecology, Central Region Office, January 19, 2023

During the period regulatory agencies approved the YTC AFFF/PFAS contaminated soils for remediation and disposal, the facility was using native and remediated soils to construct an alternative liner (300 inches of compacted soil) that was proposed and approved for Anderson's 2007-08 Limited Purpose Landfill application. Determining the approximate location of the alternative liner is complicated by the absence of required as-built diagrams and schematics that would show the excavation for each phase (1, 2 & 4) in Cell 1.

The alternative compacted soil layer replaced the WAC 173-350-400 prescriptive composite liner consisting of a two-foot layer of compacted soil with a hydraulic conductivity no greater than 1 x 10-7 cm/sec overlying a high-density polyethylene (HDPE) geomembrane with a leachate collection and control system.

<u>Point Comment</u>: Since June, 2023, this facility is required to monitor for PFAS during quarterly groundwater monitoring events. Currently the facility has 3 monitoring wells, located in two, or three separate water bearing zones, according to water quality sampling and the limited site characterization and questionable interpretations provided and approved by, jurisdictional permit authorities. While PFAS has been added to the quarterly landfill monitoring, regulators did not support local neighbor's request for PFAS sampling of nearby drinking supply wells. We respectfully request the state to consider sampling at 'secondary sources', and for the MTCA investigation to include the PFAS soil layer in Cell 1.

4) DTG remains out of compliance with state groundwater monitoring requirements, per WAC 173-350-500

Unfortunately, regulators approved a two well monitoring system (MW-2 & MW-3) for the Anderson 2007-08 LPL permit, and the Anderson 2015 LPL 78-acre expansion. While a third well (MW-4) was drilled in July, 2022, DTG has refused to install the additional 9 monitoring wells requested by state and local regulators to 1) launch the MTCA investigation and 2) further characterize site conditions, including groundwater flow and flowpaths to develop a compliant groundwater monitoring system.

In 2021 neighbors complained the approved two-well groundwater monitoring system for the Rocky Top landfill and PCS site were inadequate and indefensible. Ecology agreed, and in early 2022 informed the YHD:

> *"Per WAC 173-350-500, the groundwater monitoring network must have enough wells to yield representative samples and sufficient data to interpret groundwater flow paths during each sampling event. It does not appear… that the existing monitoring network is satisfactory to meet these (state) regulatory requirements"*

James Rivard, Ecology, letter to Shawn Magee, Yakima Health District
DTG Yakima Limited Purpose Landfill New Cell Development – Hydrogeology Comments, February 11, 2022

DTG's limited landfill site characterization and groundwater monitoring system fails to meet the requirements of WAC 173-350-500:

(3) ***Groundwater monitoring - System design.***

(a) The groundwater monitoring system design and report must be submitted with the permit application and must meet the following criteria:

(i) A sufficient number of monitoring wells must be installed at appropriate locations and depths to yield representative groundwater samples from those hydrostratigraphic units which have been identified during site characterization as the earliest potential contaminant flowpaths;
(ii) Represent the quality of groundwater at the point of compliance, and include at a minimum:

(A) A groundwater flow path analysis which supports why the chosen hydrostratigraphic unit is capable of providing an early warning detection of any groundwater contamination;

(b) Upgradient monitoring wells (background wells) must meet the following performance criteria:

(i) Must be installed in groundwater that has not been affected by leakage from a solid waste handling unit; or

(ii) If hydrogeologic conditions do not allow for the determination of an upgradient monitoring well, then sampling at other monitoring wells

> *which provide representative background groundwater quality may be allowed.*
>
> *(c) Downgradient monitoring wells (compliance wells) must meet the following performance criteria:*
>
> *(i) Represent the quality of groundwater at the point of compliance;*
>
> *(ii) Be installed as close as practical to the point of compliance; and*
>
> *(iii) When physical obstacles preclude installation of groundwater monitoring wells at the point of compliance, the downgradient monitoring system may be installed at the closest practical distance hydraulically downgradient from the point of compliance that ensures detection of groundwater contamination in the chosen hydrostratigraphic unit*.

In addition, the PCS site was proposed and approved with three monitoring wells, but to date, there are no monitoring wells at this 30-year old site. In addition, regulators did not require the PCS site to apply for and obtain the required air emissions permit (see next point).

Point Comment: DTG has drilled a single additional monitoring well (July, 2022) the month before it was declared a MTCA site. The landfill's three well monitoring system remains non-compliant with state regulations and permit conditions, and is not effectively monitor downgradient flow of potential contamination, including of AFFF/PFAS. Regulators need to not allow facilities to negate their requirement to adequately characterize groundwater conditions necessary to generate data and information, including flow direction and likely flow paths, to establish a compliant groundwater monitoring system.

5) **No air emissions permits required/approved for Rocky Top landfill or PCS site**

In the 30 years the PCS site operated (1992-2022) the local agency responsible for air quality in Yakima County, the Yakima Regional Clean Air Agency (YRCAA), never required it to have an approved air emissions permit, as required. To date, the agency has not offered a public explanation for not requiring the operator to apply and secure an air operating permit.

In the 15 years the landfill has been permitted as a limited purpose landfill (2007 to present), the YRCAA never required it to obtain an air emissions Order of Approval in violation of the first and second conditions of the landfill's conditional use permit, CUP2015-00051:

> 1. *The applicant shall obtain all necessary local, state, and federal permits relevant to the operation of the Limited Purpose Landfill prior to the expansion and commencement of use….*
> 2. *The applicant must obtain necessary permits from the Yakima Regional Clean Air Agency.*

Point Comment: The LPL and PCS site have operated for their entirety without required air emission permits. DTG's neighbors witnessed and submitted complaints to regulators of the company's questionable operations, harsh odors and violations the years before it became a MTCA site, on fire. YRCAA's abdication of its responsibility to do its job and evaluate air emission from potentially harmful sources, is not just failure of duty, but a failure of the public trust.

When a local agency responsible to protect air quality fails to require permits and monitoring at facilities known to be capable of generating a toxic brew of volatile organic compounds, they put neighbors and the community at risk. The result in Yakima County is a privately owned and operated landfill that accepted unrestricted amounts of waste, including huge volumes of ground 'drywall backing paper' (gypsum based product) from Canada, and a mix of Construction & Demolition material, some ground, and residual waste from its Puget Sound collection facilities that helped it create a toxic dump on Rocky Top that threatens groundwater resources.

6) **Challenges with adequate and multi-jurisdictional oversight**

DTG receives revenue from tipping fees paid by customers dropping off loads of debris at its material recovery facilities (MRFs). The company is only permitted to accept construction and demolition waste (not household garbage or other municipal solid waste) at its western Washington MRFs, which includes materials such as wood, metal, carpet, and commingled construction and demolition debris. Once collected, these materials are required to be sorted and separated. MRFs exist to recover these materials so they can be sold to industries that will process and integrate them back into the economy, diverting them from landfills. Any leftover material ("residual waste") is required to be disposed of at a landfill in accordance with local regulations.

A patchwork of state, county, and city regulations governs the construction and demolition recycling industry, and these regulations vary in consistency and scope. Some counties, like Snohomish and King, require that any residual waste collected within their jurisdiction be disposed at the County-designated municipal solid waste landfill, referred to as "flow control," intended to ensure that residual waste disposal fee revenue stays within the local system. Because DTG moves collected material among its facilities across county lines, tracking materials and residuals for enforcement of local regulations can be challenging. Nonetheless, DTG has still been cited for violating relevant ordinances. In 2021, Snohomish County issued a Notice of Violation to DTG for having hauled a load of residual waste from its MRF in Woodinville and disposing of it at the Yakima landfill.

The state-level regulatory landscape is fragmented, with Ecology and the Utilities and Transportation Commission (UTC) each playing a role. Ecology requires annual reporting of recycling rates for each type of construction and demolition material but has no means for validating the information in these reports, while the UTC regulates the transportation of solid waste, requiring any firms hauling garbage in the state to obtain a specific permit. However, because DTG presents itself as a recycling company, it is not required to, and has not, obtained a permit for transporting solid waste. The UTC currently has only one investigator for suspected solid waste transportation violations, making it difficult to catch unpermitted companies in the act of illicitly hauling garbage.

This matters because limited public funds and resources dedicated to the regulation and enforcement of solid waste requirements, permit conditions and code enforcement, including for jurisdictional coordination to monitor waste flow across jurisdictions to prevent 'sham' recycling.

It appears the lack of adequate regulatory tools and coordination has incentivized bad actors to not comply, and ignore regulatory concerns. Historically, limited public health resources are dedicated to permitting, inspecting and investigating solid waste facilities for compliance, violations or enforcement. This situation or reduced regulatory capability and oversight in Yakima County is called out in a Yakima Herald editorial, on February 24, 2023:

Closer to home, ask the folks who live near Rocky Top if it might help to have closer oversight of DTG Recycle's landfill, which seems to get noisier and less neighborly as it expands operations. Or check with Naches-area folks who live anywhere near the Caton Landfill, which, if we're lucky, might not be on fire for the moment.

Oddly, many of these "smaller government" politicians argue passionately that we must give law enforcement agencies every dime we can spare for the sake of protecting our communities. Enforcing traffic rules and chasing down criminals is a top priority, but preventing businesses from fouling our environment and threatening our children's health? Somehow, that's different.

The two local landfills are by no means the only commercial sources of community complaints and potential health hazards. Other businesses cut corners, get away with it and in small ways degrade our lives, too. And as distinctly different as the DTG and Caton landfills are, they have one key thing in common:

Evidently, they don't need to worry much about oversight or consequences.

No less than three government agencies have some sort of say in permitting and monitoring local landfills — the Yakima County Planning Department, the Yakima Health District and the state Department of Ecology.

Yet none showed much sign of stepping forward until neighbors were up in arms because of dust, after-hours racket or flames.

Why? We suspect it's partly because none of those agencies wanted to get entangled in a messy fight that could end up in court — as the Caton Landfill case has after county officials concluded the landfill was operating beyond the scope of its permits. And we suspect none of them wanted to be the bad guy. Nobody wanted anyone to think "The Government" was interfering in a local business.

It's also because those agencies lack the manpower to do much in the way of effective code enforcement. They wait until complaints pile up before they do much actual regulating. Instead of being out in the field, scouting for potential problems, it's all they can do to keep up with reading and reviewing permit applications, site maps and so forth.

The end result of all this is that companies like DTG, Caton and others know they face few, if any, consequences if their operations break any rules. Who's going to notice, let alone try to stop them?

Point Comment: DTG's operations demonstrate how current waste acceptance and state and local solid waste and recycling rules create a multi-jurisdictional regulatory system that has allowed a so-called recycling company to flow huge volumes of largely unregulated material to Rocky Top, not for recovery but disposal, and how this disposal created harmful, dangerous air pollutants that triggered a MTCA site determination. Important to this DEIS, was the remediation and disposal of 743 cy of YTC PFAS soils at elevated concentrations at the Anderson PCS site and landfill, when PFAS was not fully understood or regulated as hazardous. Federal and state agencies need to reconsider the potential threat from known secondary sources of PFAS contamination, including the Macquarie/East Mountain Investments, Inc., DTG/Anderson contaminated site on Rocky Top.

Both the DTG LPL and the Caton LPL are privately owned and operated and have received significant volumes of waste from outside of Yakima County, primarily Westside counties and gypsum-based waste from Canada. Both LPLs represent significant unknown environmental and regulatory challenges, and highlight the difficulty for state and local regulators in coordinating oversight across multiple jurisdictions to ensure compliance and site management that arguably would have prevented the current crises at these two Yakima LPLs.

Secondary Source Final Comment: How do landfills and PCS sites become hazardous waste sites? Arguably, when regulators permit facilities with alternative, less protective environmental controls, limited study of groundwater, and approval of a two well monitoring system. Waste acceptance and handling at these facilities matter because they operate on a largely honor based system. Regulators need to evaluate and verify facility waste flow, acceptance, disposal, and recycling by examination of operating records and coordination with jurisdictional regulatory partners.

The state should acknowledge ‘secondary sources’ of AFFF/PFAS disposal that have or the state suspects could detect contamination, due to their risk to human health and the environment, including at Rocky Top from DTG’s facilities, and consider agency legislation to address known suspected or known secondary sources, including at DTG’s facilities on Rocky Top that accepted, remediated and disposed of 743 cy of PFAS contaminated soils. Forthcoming MCLs, ground and air monitoring requirements, potential waste acceptance limitations, material handling modifications for worker safety, and contamination remedies, present a mix of uncertainty and future potential challenges for landfills, including at ‘secondary sources’.

Comment 2: A recent “Whitepaper”, *Choosing the Right PFAS Tech for Landfill Leachate - A Review of Currently Available Technology for Landfill Leachate Management* by Aclarity, 2023 Technology Guide provides insight into multiple ‘Destruction Technology’ alternatives for PFAS that may have application for the agency’s DEIS review, as well as Ecology PFAS programs to remediate suspect and contaminated landfills. Aclarity’s mission is to destroy PFAS forever. The guide can be requested here: https://www.aclaritywater.com/landfill-pfas-treatment-technologies/?utm_source=wastedive&utm_medium=newsletter. Here’s a few quotes:

> *“Aclarity is eliminating man made “forever chemicals” that bioaccumulate in humans, animals and remain permanently in our environment. Aclarity’s proprietary technology and commercialized solution break the current PFAS cycle. By design, PFAS chemicals have strong molecular bond. Until now, the current way to “remediate” PFAS has been a dangerous cycle of removal and disposal, either by putting the PFAS back into landfills after removal or by burning the removed PFAS and releasing toxic aerosols into the air. Aclarity’s technology utilizes electricity to zap the carbon and fluorine bonds that make PFAS compounds so robust.” “As PFAS destruction technologies continue to advance, a pressing distinction is how effective they will be in handling both short- and long-chain PFAS. In addition, the safety and overall efficacy are of top concern for landfill operators. Workplace safety is a paramount concern for landfill operators, with sweeping ramifications should issues arise onsite. When evaluating new technologies, technological readiness factor is extremely important. Aclarity had an independent leading company validate at a Technology Readiness Level of 9 (max) while others in the emerging PFAS destruction field had TRL of 6 or lower.”*

Org-12-1

> *"At the moment, removal and disposal of PFAS could sound alluring, especially when combined with concentration methods that concentrate PFAS and lessen the need for options like incineration, deep well injection, or further disposal that have detrimental environmental effects. However, forward-thinking companies are assessing PFAS destruction technologies that eliminate the need for any PFAS disposal and destroy PFAS on-site, which can be very cost-feasible and serve as a desirable alternative for landfill sites as the increasing regulatory oversight and compliance designations from the EPA loom."*

I'm not an expert in PFAS chemistry, but it may be worthwhile for the state to consider PFAS 'destruction technologies' for onsite remediation at municipal fire stations, in addition to the proposed five alternatives. If applicable, given the long-term costs and liability for PFAS removal and disposal, this could be a viable option for some fire service agencies.

Comment 3: The U.S. Department of Defense (DoD) recently announced a prototype project to demonstrate remediation technologies for PFAS, calling it "*a major step forward in the effort to provide [it] with commercial PFAS treatment options for a variety of scenarios*."

Six companies - Clean Earth, Aquagga, Arcadis, 374Water, Battelle, and General Atomics - will participate in remediation of PFAS-impacted waste collected from two Department of Defense bases in Pennsylvania with the waste being treated at Clean Earth's offsite locations. Clean Earth is a division of Enviri Corporation, an environmental and waste management services firm. According to a waste trade publication:

> "*This collaboration represents a synergy of exciting technology, world-class expertise, and a practical strategy for scale-up and accelerated commercialization*," said Craig Divine, Ph.D., Arcadis, Senior Vice President and Project Principal Investigator. "*As we coordinate this pivotal project's implementation and performance analysis, Arcadis is proud to partner with Clean Earth and 374Water, bringing forth advanced and cost-effective solutions to tackle PFAS contamination*."

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> "*Clean Earth's ReSolve™ program has tested various methods to treat PFAS-contaminated soil and water*," said Beswick. "*With operations covering all 50 states, Clean Earth can support on-site PFAS remediation or treat it offsite at one of our facilities. Rather than a short-term fix, we are committed to implementing sustainable solutions that minimize the long-term risk for our customers*."

Clean Earth Joins in Department of Defense Study for PFAS Remediation,
WASTE ADVANTAGE, January 23, 2024

Comment: As stated, the DoD is responsible for the U.S. Army Yakima Training Center (YTC) near Selah, and the resulting AAAF and PFAS contamination of local groundwater. Arguably, it would also bear responsibility for future PFAS contamination of groundwater at Rocky Top, a ‘secondary source’ of contamination where the remediation and disposal of 743 cubic yards of YTC AAAF contaminated soils with elevated concentrations of PFAS. As the state engages with federal partners, including DoD regarding AFFF/PFAS contamination and storage at military installations and airports, it should include consideration of ‘secondary sources’.