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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

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 publication¹ 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
<u>Canister Analyses (µg/m³)</u>						
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

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>.

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 compounds². 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 RCRA³ and carried over into the Clean Air Act requirements⁴ 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 2020⁵ and 2022⁶ 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 method⁷ 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.

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 incinerators⁸, 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

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 Dayton⁹. 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

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. Only 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.

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