PFAS and Thermomechanical Treatment Facilities

What are PFAS?

Per- and polyfluoroalkyl substances (PFAS) are a group of synthetic chemicals first introduced in the 1940s that are widely used in a variety of everyday products. While there are thousands of different PFAS chemicals, they all share a structure with fluorine atoms on a carbon chain (see Figure 1).[1] These carbon-fluorine bonds, amongst the strongest in organic chemistry, make PFAS compounds very persistent in the environment, leading many to refer to them as "forever chemicals."[2]

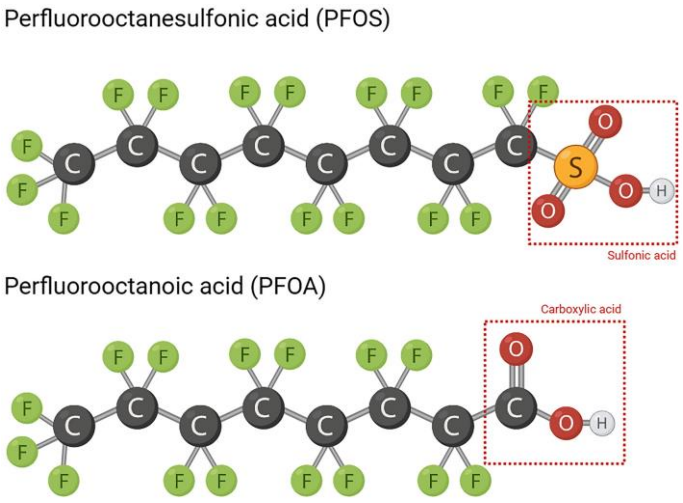

***Figure 1**. Chemical representation of PFOS and PFOA – two of the most common PFAS molecules.* [1]

Where are PFAS found?

Its durability and resistance to heat, water, and oil make PFAS particularly useful in a variety of applications. PFAS have been widely used in stain-resistant carpets, waterproof textiles, food packaging, and cookware due to their heat and water-resistant properties.[1] PFAS can be found in products designed for grease, water and stain resistance, as a non-stick coating for cookware, as a dispersant in agricultural fertilizers and pesticides, and to improve performance of firefighting products (Table 1).[2-5]

PFAS and human health

PFAS compounds, particularly PFOA and PFOS, have been linked to a range of adverse health effects including increased risks of kidney and testicular cancers, liver damage, thyroid disease, high cholesterol, obesity, fertility issues, as well as immune system effects.[6-9] These compounds can disrupt cellular mechanisms, including the immune and endocrine systems, and have been associated with cancer, cardiovascular disease, and reduced birthweight.[7,9]

How are humans exposed to PFAS?

Human exposure to PFAS occurs primarily through ingestion, particularly via food and drinking water. PFAS can be introduced into our food chain through the application of biosolids, fertilizers and pesticides on agricultural land.[10] In addition, dietary exposure has been linked to the leaching of PFAS into food from its packaging, even during relatively short periods of contact.[2,10] PFAS contamination in drinking water has been traced to nearby industrial activity, including manufacturing plants, airports, military bases and fire training areas, landfills, wastewater treatment plants, and sites where biosolids are applied to agricultural land.[11] When PFAS compounds enter groundwater and flow into other bodies of water, concentrations can bioaccumulate in aquatic species, which can end up in seafood.[12] Fabrics treated with stain and water resistant coatings can be an additional source of PFAS in the environment, including in our homes, where we can be exposed through accidental ingestion of dust.

Product Category	Common Consumer Products Containing PFAS
Food packaging	Fast-food wrappers, microwave popcorn bags, take-out paperboard containers
Textiles	Stain-resistant clothing, carpets, upholstery, waterproof jackets
Cookware	Non-stick cookware
Firefighting foam	Aqueous film-forming foam (AFFF) used for fire suppression
Electronics	Smudge-resistant coatings, insulation, electronic waste

***Table 1.** Consumer products with PFAS applications*[2-5]

Scientific work on the contribution of air emissions of PFAS to human exposure is still evolving. A comprehensive review of exposure pathway studies found direct inhalation to be a relatively minor source of human exposure, well below exposure through food and drinking water.[13] Atmospheric deposition may also be a source of human exposure through ingestion of food, dust or water. Dispersion modeling completed to-date has found PFAS emitted from point sources to be dispersed over long distances, resulting in lower relative local deposition compared to other pollutants. One recent study predicted that 95% of total PFAS emissions from a fluoropolymer

manufacturing facility traveled over 150 km from the site.[14]

PFAS in the waste stream

Once materials containing PFAS enter the municipal solid waste (MSW) stream, the fate of PFAS depends on how the waste is managed. PFAS in waste is either destroyed, stored, or released into the air, water, or residual waste depending on how that material is managed.

Landfills are the predominate means of waste management in the United States. Much of the PFAS that enters landfills is stored, but the retention times and mechanisms for storage are not well understood. PFAS emitted from landfills is predominately through landfill leachate and landfill gas (LFG). Recent estimates have found that landfills contribute approximately 18% of the total PFAS loading to publicly owned treatment works (POTWs).[4] Annually, of all PFAS released into the environment, an estimated 11% of PFAS is released through landfill leachate.[2] In addition to leachate releases, PFAS is emitted through landfill gas, a portion of which is combusted in flares and internal combustion engines. The temperatures and retention times in typical landfill flares and engines are less than those understood to result in complete PFAS combustion, leading to residual PFAS or products of incomplete destruction (PIDs), which can be volatile PFAS compounds themselves.[2] LFG emissions may account for up to 75% of total PFAS releases from landfills when fugitive emissions are considered.[15,16]

Fate of PFAS in TTFs

The destruction of PFAS compounds in combustion processes is primarily driven by both temperature and retention time. Research indicates that the mineralization (i.e., full thermal degradation into simpler molecules) of PFAS compounds requires temperatures exceeding 1,000°C (1,832°F), with lower temperatures potentially resulting in volatile PIDs.[17] In experimental lab and pilot tests, PFAS destruction exceeded 99% with minimal presence of PIDs when temperatures reached 1,000-1,100°C (1,832-2,012°F).[18-21]

Reworld's TTFs operate well above these thresholds. While TTFs are designed to operate at minimum combustion temperatures of 980°C (1,800°F) for at least one second, actual operating conditions frequently exceed 1,093°C (2,000°F), with retention times of over two seconds.[22] In addition, moisture, present in MSW processed by TTFs, has been found to aid in complete mineralization of PFOA and reduce PID concentrations.[17]

Testing completed of stack gases at TTFs demonstrates non-detectable or very low concentrations of PFAS compounds. Testing of five Reworld TTFs as part of a voluntary program with the Pennsylvania Department of Environmental Protection (PADEP) was completed using USEPA's Other Test Method 45 (OTM-45), which targets various PFAS compounds from stationary air sources. The tests found targeted PFAS compounds were either non-detect or very low when compared to available guidelines for PFAS compounds in ambient air (Figure 2). Peer reviewed research demonstrates that PFAS concentrations are also low or non-detectable in the ash remaining after the combustion process, suggesting that high-temperature treatment through TTFs is effective at destroying PFAS compounds found in MSW.[23,24]

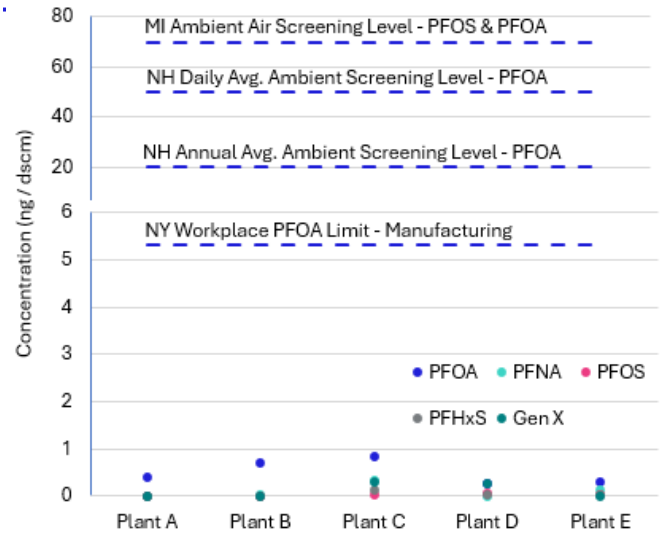

***Figure 2**. MWC Flue Gas Concentrations (OTM-45) and State Ambient Air Standards*

For more information, please e-mail us:
sustainability@reworldwaste.com

Reworld™

References

[1] Arnesdotter, E. et al. (2025). Per- and polyfluoroalkyl substances (PFAS) – immunotoxicity at the primary sites of exposure. *Critical Reviews in Toxicology*, **55**: 484-504. https://doi.org/10.1080/10408444.2025.2501420.

[2] Tolaymat, T. et al. (2023). A critical review of perfluoroalkyl and polyfluoroalkyl substances (PFAS) landfill disposal in the United States. *Science of the Total Environment*, **905**: 167185. https://doi.org/10.1016/j.scitotenv.2023.167185.

[3] Björklund, J. et al. (2024). Distribution of per- and polyfluoroalkyl substances (PFASs) in a waste-to-energy plant: Tracking PFASs in internal residual streams. *Environmental Science & Technology*, **58**: 8457-8463. https://doi.org/10.1021/acs.est.3c10221.

[4] Masoner, J. et al. (2020). Landfill leachate contributions of per- and polyfluoroalkyl substances (PFAS) to municipal wastewater. *Environmental Science: Water Research & Technology*, **6**: 1300-1311. https://doi.org/10.1039/d0ew00045k.

[5] Zemba, S. (2017). PFAS and Landfills. *Solid Waste Association of North America, Northern New England Chapter*. Sanborn Head & Associates. https://nneswana.org/wp-content/uploads/sites/51/2019/02/Zemba-PFSAs_and_Landfills.pdf.

[6] U.S. EPA. (2023). *Our Current Understanding of the Human Health and Environmental Risks of PFAS*. https://www.epa.gov/pfas/our-current-understanding-human-health-and-environmental-risks-pfas.

[7] National Cancer Institute. (2022). *PFAS Exposure and Risk of Cancer*. https://dceg.cancer.gov/research/what-we-study/pfas.

[8] European Environment Agency. (2024). *What are PFAS and how are they dangerous for my health?* https://www.eea.europa.eu/en/about/contact-us/faqs/what-are-pfas-and-how-are-they-dangerous-for-my-health.

[9] Agency for Toxic Substances and Disease Registry (ATSDR). (2024). *Health Effects: PFAS Information for Clinicians - 2024*. https://www.atsdr.cdc.gov/pfas/hcp/clinical-overview/health-effects.html.

[10] Sunderland, E. et al. (2019). A review of the pathways of human exposure to poly- and perfluoroalkyl substances (PFASs) and present understanding of health effects. *Journal of Exposure Science & Environmental Epidemiology*, **29**: 131–147. https://doi.org/10.1038/s41370-018-0094-1.

[11] Salvatore, D. et al. (2022). Presumptive contamination: A new approach to PFAS contamination based on likely sources. *Environmental Science & Technology Letters*, **9**: 983–990. https://doi.org/10.1021/acs.estlett.2c00502.

[12] Ehsan, M. et al. (2024). PFAS contamination in soil and sediment: Contribution of sources and environmental impacts on soil biota. *Case Studies in Chemical and Environmental Engineering*, **9**: 100643. https://doi.org/10.1016/j.cscee.2024.100643.

[13] De Silva, A. et al. (2021). PFAS exposure pathways for humans and wildlife: A synthesis of current knowledge and key gaps in understanding. *Environmental Toxicology and Chemistry*, **40**: 631-657. https://doi.org/10.1002/etc.4935.

[14] D'Ambro, E. et al. (2021). Characterizing the air emissions, transport, and deposition of per- and polyfluoroalkyl substances from a fluoropolymer manufacturing facility. *Environmental Science & Technology*, **55**: 862-870. https://doi.org/10.1021/acs.est.0c06580.

[15] Lin, A. et al. (2024). Landfill gas: A major pathway for neutral per- and polyfluoroalkyl substance (PFAS) release. *Environmental Science & Technology Letters*, **11**: 730-737. https://doi.org/10.1021/acs.estlett.4c00364.

[16] Zemba, S. et al. (2024). PFAS releases from landfills: Consideration of air emissions in mass balances. *The Magazine for Environmental Managers*, 13-17. https://online.1stflip.com/dsup/3qtq/.

[17] Weber, N. et al. (2025). Thermal mineralization of perfluorooctanoic acid (PFOA): The synergistic role of oxygen and water vapor inhibiting products of incomplete destruction (PID) formation. *Chemical Engineering Science*, **301**: 120659. https://doi.org/10.1016/j.ces.2024.120659.

[18] Shields, E. et al. (2023). Pilot-scale thermal destruction of per- and polyfluoroalkyl substances in a legacy aqueous film forming foam. *American Chemical Society Environmental Science & Technology Engineering*, **3**: 1308-1317. https://doi.org/10.1021/acsestengg.3c00098.

[19] Krug, J. et al. (2022). Combustion of C1 and C2 PFAS: Kinetic modeling and experiments. *Journal of the Air & Waste Management Association,* **72**: 256-270. https://doi.org/10.1080/10962247.2021.2021317.

[20] Weber, N. et al. (2023). Thermal Mineralization of Perfluorooctanesulfonic Acid (PFOS) to HF, CO2, and SO2. *Industrial & Engineering Chemistry Research*, **62**: 881-892. https://doi.org/10.1021/acs.iecr.2c03197.

[21] Weber, N. et al. (2024). Influence of reactor composition on the thermal decomposition of perfluorooctanesulfonic acid (PFOS). *Journal of Hazardous Materials,* **461**: 132665. DOI: https://doi.org/10.1016/j.jhazmat.2023.132665.

[22] Giraud, R. et al. (2021). Combustion operating conditions for municipal Waste-to-Energy facilities in the U.S. *Waste Management*, **132**: 124-132. https://doi.org/10.1016/j.wasman.2021.07.015.

[23] Liu, Y. et al. (2022). Municipal solid waste incineration (MSWI) ash co-disposal: Influence on per- and polyfluoroalkyl substances (PFAS) concentration in landfill leachate. *Waste Management*, **144**: 49-56. https://doi.org/10.1016/j.wasman.2022.03.009.

[24] Björklund, J. et al. (2023). Emission of per- and polyfluoroalkyl substances from a waste-to-energy plant – occurrence in ashes, treated process water, and first observation in flue gas. *Environmental Science & Technology,* **57**: 10089-10095. https://doi.org/10.1021/acs.est.2c08960.