EPA
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Agency

Multi-Industry Per- and Polyfluoroalkyl Substances (PFAS) Study – 2021 Preliminary Report

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need to be replaced or disposed, generating a solid waste product. The following types of membranes are well-studied for PFAS removal:

- **Reverse Osmosis (RO).** RO is a form of membrane filtration in which pressure is applied to transport liquid through a membrane with a pore size of less than 1 nanometer. RO can be run as a continuous flow or batch process. EPA's DWTD reports that RO typically achieves at least 98 percent removal of PFAS regardless of chain length or functional group (EPA, 2021f). One full-scale treatment study has reported between 67 and 97 percent removal of total PFAS using RO (Glover et al., 2018).
- **Nanofiltration (NF).** NF is a membrane process that is lower in pressure than RO in which the membrane has pore sizes between 1 and 10 nanometers. Nanometer-sized membrane pores are used to remove compounds in a process similar to RO, but NF allows smaller PFAAs and salt ions to pass through which would otherwise be captured by the smaller pore sized used in an RO system. Lab-scale studies have shown nanofiltration removal of PFAS up to 90 percent (Boo et al., 2018).
- **Low Pressure Membrane Filters.** Ultrafiltration and microfiltration, two additional types of membrane filters with pore sizes larger than 10 nanometers, are less effective at capturing nonpolymer PFAS and are typically used for particulate removal. Sampling at full scale DWTPs using microfiltration or ultrafiltration has shown no or inconsistent removal (typically less than 50 percent) of PFCAs and PFSAs (EPA, 2021f), unless a powdered adsorbent is used within the system.

Wastestreams may need to go through a pretreatment step to reduce the risk of membrane damage or fouling (loss of production capacity) due to accumulation of material on the membrane surface.

10.4 Incineration/Thermal Treatment

Thermal treatment or incineration is using high temperatures to chemically break down PFAS. Incineration has been used to destroy other halogenated organic chemicals such as polychlorinated biphenyls (PCBs) and ozone-depleting substances, where sufficiently long exposures to sufficiently high temperatures break the carbon-halogen bond, after which the halogen can be scrubbed from the flue gas, typically as an alkali-halogen (EPA, 2019c). These treatments can be used for AFFF and solid wastes onto which PFAS has adsorbed, such as spent GAC or sludge, but may also be applied to PFAS-containing wastewater. However, PFAS are more difficult to break down than other halogenated organic chemicals due to fluorine's electronegativity and the chemical stability of fluorinated compounds.

Incinerators or combustors that are already in place for hazardous or municipal waste destruction may be used to destroy PFAS (Watanabe et al., 2016; EPA, 2020e). Incomplete destruction of PFAS during combustion can result in the formation of smaller PFAS or mixed halogenated organic byproducts, referred to as products of incomplete combustion (PICs) (EPA, 2019c, 2020f).

The effectiveness of incineration to destroy PFAS and the tendency for formation of PICs is not currently well understood. Few experiments have been conducted under oxidative and temperature conditions representative of field-scale incineration. Limited studies on the thermal destructibility of fluorotelomer-based polymers found no detectable levels of perfluorooctanoic acid after 2 second residence time at 1,000°C (Yamada et al., 2005; Taylor et al., 2014). Emission studies, particularly for PICs, have been incomplete due to lack of necessary measurement methods suitable for the comprehensive characterization of fluorinated and mixed halogenated organic compounds. EPA is actively researching the effective destruction temperatures and treatment times for PFAS, the potential to generate PICs, and the release and potential land deposition of PFAS-containing stack gases.

10.5 Advanced Oxidation and Reduction Processes

Advanced oxidation and reduction as methods for destruction of PFAS have been studied more in recent years. Through a series of oxidation and reduction reactions, PFAS molecules are defluorinated, decreasing the fluorinated carbon chain length until the PFAS molecules are degraded into base components such as CO_2, H_2O,