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Key PFAS Research Needs & Knowledge Gaps

Per- and polyfluoroalkyl substances (PFAS) are a group of man-made, synthetic organofluorine chemical compounds that have multiple fluorine atoms attached to an alkyl chain. PFAS have been in use since the mid 1900's and are commonly used due to their chemically and thermally stable nature that allows products to be stain-resistant, water-repellent, and/or nonstick such as clothing, carpet, cookware and packaging. Through research of these compounds, PFAS were nicknamed "forever chemicals," due to their structure which breaks down very slowly over time and their propensity for bioaccumulation across many species, including humans.

There is a high degree of concern, sometimes hysteria, over PFAS for many reasons including that they are in the blood of most of us and have been discovered in otherwise pristine environments. Other probable adverse health effects in association with PFAS bioaccumulation in humans have been reported to include increased cholesterol levels, low infant birth weights, immune system effects, cancer, and thyroid hormone disruption. Unfortunately, most of these findings have been from studies where there have been high levels of exposure and very little research exists for health implications for people exposed to low levels or "environmental concentrations" of PFAS, which constitute most of society.

PFAS has been an ongoing issue that is affecting and has the potential to increasingly impact solid waste management. Because PFAS are incorporated into hundreds of industrial and consumer products that are used within our society, they are commonly found in waste materials managed at solid waste management facilities, including landfills, waste-to-energy facilities and compost operations. Despite their negative impacts and widespread presence throughout multiple industries, there are significant gaps associated with how much PFAS flows through society although it is widely assumed that a significant portion ultimately finds its way into the solid waste management system. As a result, the current and potential role of the solid waste management industry has important implications. Although the US EPA has recommended landfills and WTE/incineration as 2 of 3 ways to dispose of PFAS, there are more unknowns than knowns related to the impact of PFAS on solid waste management and broader society, especially in regards to:

1. How much PFAS ends up at solid waste management facilities,
2. How much is sequestered there,
3. How much is released over time, and
4. Potential environmental or health impacts from these activities.

EREF is well positioned to address a number of unknowns as they relate to the solid waste industry. While not an exhaustive list of research needs, the categories and listed needs within them identify gaps and needed knowledge that if gained will improve the understanding of solid waste management's role in PFAS management and the potential risks associated with such activities. Such activities are critically important to inform a rapidly evolving landscape around the ongoing use of PFAS and with policies related to PFAS.

The categories and research needs listed are in no particular order.

Mass Flow and Endpoints

A better understanding of how much PFAS wind up at solid waste management facilities and what the relative contributions are of PFAS from specific waste components is important as this impacts waste acceptance practices, helps quantify management and treatment costs, aids in informing sequestration potential in landfills and informs assessments of risk.

1) PFAS production (ideally mass for primary PFAS species) and how much PFAS produced ultimately goes to materials that are managed as solid waste
2) Concentration in products/materials likely to be disposed of or by specific waste component (aka. sources of PFAS), such as:
   - By waste component (e.g. packaging, food waste)
   - Consumer products (e.g. textiles, cookware, packaging)
   - Water and wastewater treatment sludges
   - Dredged soils/sediment
   - Various industrial wastes
   - C&D materials (e.g. carpet, wallboard)
3) PFAS mass/ton of:
   - MSW to landfills and/or WTE facilities
   - C&D waste
   - Recyclables to MRFs
   - Feedstock to compost facilities
   - Feedstock to anaerobic digestion facilities

Fate & Environmental/Health Implications

Ultimately, the primary basis for why PFAS is an issue in the first place has to do with human health implications and related topics of how humans can be exposed to PFAS. Given landfills are a recommended disposal option for PFAS by the EPA and that most PFAS-containing materials can wind up in solid waste management facilities, understanding the extent to which solid waste management can reduce potential exposure (by removing it from direct contact with society) as well as release PFAS into the environment are critical questions that have a variety of implications related to policy, risk and management.

4) Extent of sequestration in landfills
5) Mechanisms and differential sequestration and transport of PFAS species into landfill leachate and gas
6) PFAS transformation and fate (e.g. formation of daughter products that may be gaseous, soluble or particulate) in:
    - Collected landfill gas that is flared or used for energy (e.g. heat, energy)
    - Fugitive emissions through landfill cover systems
    - Recycling and secondary processing operations (e.g. paper, plastic)
    - WTE/incineration facilities in bottom ash and flue gas residuals
7) Concentrations of PFAS in:
    - Landfills *(data exists but is not well aggregated)*
        - leachate
        - gas
    - Incoming feed to WTE, compost, AD operations
    - Ambient air in/downwind of waste management facilities (e.g. landfills, MRFs, compost facilities, WTE)
    - PFAS deposition in soil and vegetation downwind of waste management facilities
    - Waste management facility stormwater runoff
    - Groundwater near or impacted by facilities
8) Compiling existing data related to PFAS in the environment (e.g. surface water-rivers, groundwater, ambient air, glaciers or ice/snow pack, oceans)
9) Comparison of PFAS in and loading to the environment from solid waste relative to other industries and infrastructure (e.g. military bases, airports, manufacturing, water/wastewater, urban stormwater runoff, etc.)
10) Identification of primary human exposure routes and relative potential exposure of PFAS to the human body from difference sources relative to those from solid waste management (e.g. PFAS in ambient air at landfill vs daily overall inhalation exposure)

<u>Treatment & Removal</u>

It has been noted that research funding specific treatment approaches may not be the best use of EREF research dollars. However, the following areas may help inform the broader conversation regarding PFAS treatment. Some of the biggest issues relate to understanding which treatment strategies are effective at PFAS removal, how to manage residuals generated from PFAS treatment, and what the cost implications are.

11) Comparison of available treatment technologies for landfill leachate and other waste-related liquids
12) What are the cost implications for PFAS management
13) Volume and concentrations in residuals generated from PFAS treatment
14) Efficacy of solidification/stabilization strategies
15) Impact of landfill operations on PFAS management, such as:
    a. Effectiveness of landfill flares on PFAS destruction and extent of destruction based on temperature and other operating parameters
    b. Extent of leachate generation based on rainfall and geographic location

Detection & Policy Analysis

The ability to detect and quantify different PFAS compounds is important given that this will provide a more complete assessment of the quantity of PFAS that are entering the solid waste management system. With current methods, fewer than 200 PFAS species can be specifically measured, making the mass of PFAS entering landfills and other waste management facilities uncertain. Policies can have significant implications on where PFAS-laden materials may go. Certain materials designated as a hazardous substance and of a certain quantity would go to a Subtitle C instead of a Subtitle D landfill, which is important in terms of management strategy and cost. Policies or recommendations to stop using PFAS in consumer packaging as recommended by the FDA in the Spring 2024 could substantially reduce PFAS concentrations in discarded MSW. These are 2 of multiple examples where policy analysis could help identify what potential outcomes would be which then aids in decision making.

16) How many species of PFAS can currently be detected relative to how many are manufactured
17) What are the potential costs for PFAS testing and analysis for solid waste management
18) Implications for the classification of PFAS as a hazardous substance/waste
19) What is defined as an 'essential use' of PFAS and what does this mean relative to PFAS mass loading to solid waste management facilities
20) Are current policies affecting PFAS loading to solid waste management and what happens if PFAS is banned from use in certain application (e.g. packaging), which is already occurring in some states.