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NEW DIRECTIONS IN LEACHATE MANAGEMENT:

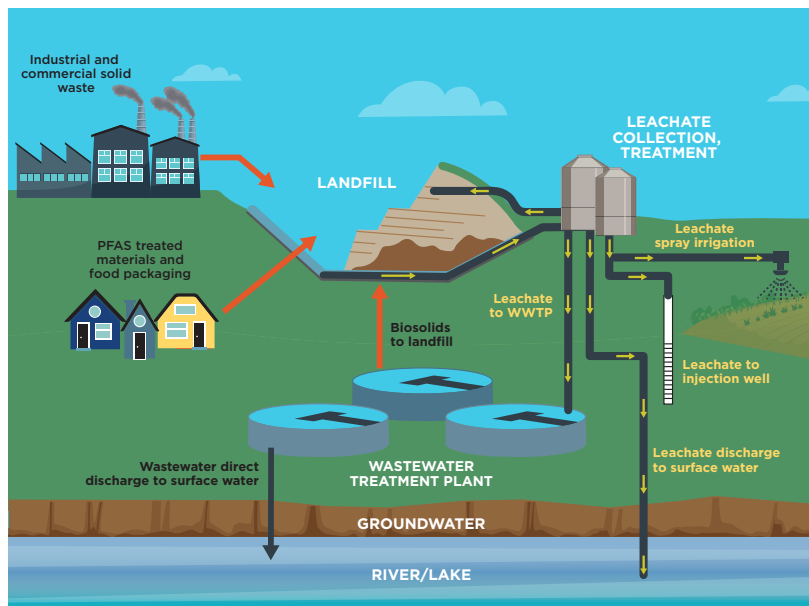
Learn How PFAS
Regulations and Treatments
Are Transforming the Industry

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Landfills have a unique role in the environmental life cycle of per- and polyfluoroalkyl substances (PFAS). They receive consumer and industrial waste materials and municipal biosolids that most likely contain PFAS and then generate leachate, which often contains those PFAS. Currently, this leachate is often disposed of through reinjection, spray irrigation, deep well injection, indirect discharge to publicly owned treatment works (POTWs), and direct discharge to surface waters. The degree of treatment provided, if any, varies by site and disposal method. Leachate generated at hazardous waste landfills is also often incinerated.

This unique role in the PFAS life cycle is about to get more complicated for landfill owners and operators because the United States Environmental Protection Agency (EPA) has signaled that it is getting involved to reduce PFAS released to the environment, and this includes PFAS in landfill leachate.



EPA Is Getting Involved

Plan 15 indicates that EPA will develop PFAS guidelines and limitations for direct dischargers and pretreatment standards for indirect discharges.



In 2021, EPA began a detailed study of PFAS in landfill leachate using publicly available information. EPA found that over 95% of leachate discharges from over 200 landfills studied contained PFAS, with average concentrations as high as 14,000 parts per trillion or ppt (EPA 2023). While EPA has not published its detailed findings, the results are consistent with other state studies and a nationwide survey (Lang et al. 2017).

Based on its findings, EPA determined that effluent limitation guidelines (ELGs) and pretreatment standards for PFAS from landfill leachate discharges are warranted. The ELGs and pretreatment standards establish technology-based controls for wastewater discharges to surface waters (i.e., direct discharges) and to POTWs (i.e., indirect discharges) from 59 industry categories, including landfills. EPA announced this determination in ELG Program Plan 15, which was released in January of 2023.

What do the current landfill ELGs require?

The ELGs, finalized in 2000, apply to Resource Conservation and Recovery Act (RCRA) Subtitle C (hazardous) and Subtitle D (nonhazardous) landfills, which are new sources and directly discharge to surface waters. For Subtitle C landfills, ELGs are based on equalization, chemical precipitation, biological treatment, and multimedia filtration. For Subtitle D landfills, limits are based on equalization, biological treatment, and multimedia filtration. The ELGs include conventional pollutants and a limited number of priority and nonconventional pollutants, but not PFAS. **This is about to change.**



Change Is Starting at the State Level

EPA has not yet published specific information about proposed changes to the landfill ELGs and has not formally announced a schedule for rulemaking. In the meantime, in December of 2022, EPA issued guidance on how states and municipalities can use National Pollutant Discharge Elimination System (NPDES) permits and pretreatment programs to reduce PFAS discharges to the environment (EPA 2022). For direct dischargers, EPA recommended that states

- require quarterly effluent monitoring;
- require PFAS pollution prevention and source reduction evaluations and source reduction plans; and
- implement effluent limitations using best professional judgement, state water quality standards, and/or narrative criteria.

For POTWs with pretreatment programs, EPA recommends that POTWs

- review and update their industrial user inventory, including all industry categories suspected of PFAS discharges (including landfills);
- update industrial user permits to require PFAS monitoring;
- develop local limits for PFAS where authority exists; and
- encourage pollution prevention, product substitution, and good housekeeping by industrial users to reduce PFAS discharged to the POTW.

Several states are also beginning investigations specifically related to PFAS in leachate and groundwater near active and closed landfills.

Leachate Is a Complex Matrix

Leachate, which is most of the wastewater that landfills discharge, is complex. The composition of landfill leachate is variable and depends on multiple factors, including waste received, age of the landfill, operating practices, amount of infiltration, depth of fill, and compaction (EPA 2000). Most commonly, leachate has some combination of elevated bulk organic matter (e.g., biochemical oxygen demand, chemical oxygen demand, total organic carbon), metals, ammonia, total suspended solids, and total dissolved solids (e.g., calcium, magnesium, sodium, alkalinity, chloride, sulfate). Various synthetic organic compounds can also be present depending on the waste received.

Typically, the majority of PFAS present in leachate are fluorotelomer precursors (e.g., 5:3 fluorotelomer carboxylic acid [5:3 FTCA]) and perfluoroalkyl acids (e.g., perfluoroalkyl carboxylic acids [PFCAs]) (Hamid, 2018; Maldonado et al. 2022). However, the composition of PFAS in leachate varies with landfill age, waste types received, changes in the PFAS product profiles, and seasonal and climate variations (Benskin 2012, Lang et al. 2017).

Promising Tools Are Available to Remove PFAS from Complex Matrices Like Leachate

The well-established technologies that are available to remove PFAS from drinking water—granular activated carbon, ion exchange, and reverse osmosis—can also be effective in removing PFAS from landfill leachate. In addition to the commonly available technologies, foam fractionation can also effectively remove long-chain PFAS from landfill leachate. PFAS reduction rates for these common technologies range from over 50% to over 90% for simpler matrices. However, the composition of leachate is considerably more complex than drinking water; therefore, when these common treatments are used for landfill leachate, there are additional considerations. For instance, ion exchange and activated carbon require pretreatment to remove fouling and constituents that interfere with removing PFAS, and reverse osmosis and foam fractionation produce waste streams that require additional treatment and/or disposal.

Biological treatment (e.g., membrane bioreactor, sequencing batch reactor) is often used as a pretreatment step for PFAS in landfill leachate to reduce the load of other contaminants, reduce the complexity of the matrix, and transform perfluoroalkyl acid (PFAA) precursors to nonbiodegradable or terminal PFAS (e.g., perfluorooctanoic acid [PFOA]) prior to treatment by PFAS removal technologies (Lu et al. 2023).

Pretreatment, post-treatment (polishing), and residual management drive the design and cost of treatment technologies for PFAS in landfill leachates.



Geosyntec pilot tested, designed, permitted, and commissioned an advanced pretreatment system for an active municipal solid waste landfill in the southeastern United States that included a membrane bioreactor. In a second phase, nanofiltration was added to remove color from the leachate for further treatment at the POTW.

Technology Trends and Innovation

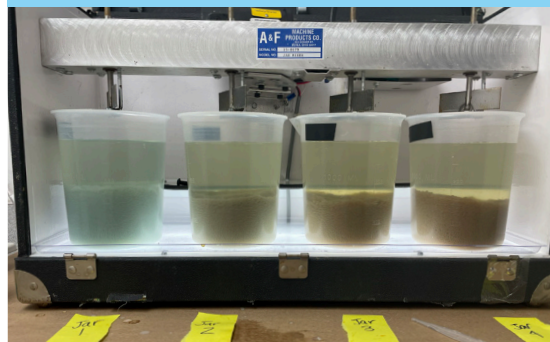
There are promising innovative technologies—both physical and destructive—being studied for managing and/or treating PFAS. Some innovative physical technologies include thermal evaporation for volume reduction and engineered adsorbents that capture PFAS in their structure. Examples include crosslinked beta-cyclodextrin (β -CD) polymer adsorbents (Yang et al. 2020), coal-based magnetic activated carbon (Zhang et al. 2018), and modified fly ash (Patel et al. 2022). These innovative adsorbents have shown to remove more than 50% of target PFAS in leachates. However, some of these technologies have only been tested at a bench scale and further testing at larger scales is needed.

Destructive technologies that transform PFAS through oxidation and/or reduction processes, including electrochemical oxidation, photocatalysis, plasma treatment, and supercritical water oxidation, have shown to be effective in reducing PFAS concentrations in landfill leachates. The main working principles of some destructive technologies are described below:

- **Electrochemical Oxidation:** Uses an overpotential or electric current generated by electrodes to oxidize PFAS into simpler constituents. The oxidation of PFAS occurs at the anode surface of electrodes. However, indirect oxidation of PFAS also occurs in the bulk liquid through oxidizing agents formed at the electrode (Schaefer et al. 2017).
- **Photocatalysis:** Degrades PFAS under the influence of natural (e.g., solar radiation) or assisted (e.g., ultraviolet light) radiation with or without the assistance of photochemical catalysts that include chemicals or anodes (Wang et al. 2017).
- **Plasma treatment:** Uses gas (e.g., argon) pumped through submerged diffusers to produce bubbles and form a layer of foam that concentrates PFAS on the liquid surface and exposes them to reactive oxidative and reductive species on the plasma that degrades them (Singh et al. 2019, Singh et al. 2021).
- **Supercritical Water Oxidation:** Uses high temperature and pressure above the critical point of water in conjunction with oxidizing materials and added oxygen or hydrogen peroxide to create an aggressive oxidative environment that degrades PFAS (Wei et al. 2021).
- **Incineration:** Uses high temperatures in the presence of oxygen to degrade PFAS (Solo-Gabriele et al. 2020). Although PFAS can be degraded at high temperatures, the effectiveness of incineration is highly dependent on the waste characteristics and incinerator operating conditions and has not yet been investigated in detail.



Geosyntec collaborates with technology providers and our SiREM laboratory to test innovative solutions for treatment of complex matrices such as leachate.





Landfill Owners and Operators Should Plan

The changes EPA has signaled in Plan 15 relate to the federal requirements that apply to your facility either through technology-based effluent limits or pretreatment standards for new sources (PSNS) and pretreatment standards for existing sources (PSES). In addition, both EPA and several states (e.g., Colorado, Michigan, Minnesota, Wisconsin) have or are developing in-stream water quality criteria or standards for certain PFAS. These changes could impact your water-quality-based effluent limits or local limits. Local limits are based on several factors, including the POTW's maximum allowable headworks loading.

Even though timelines for these regulatory changes remain dynamic and undefined in many cases, landfill owners and operators can plan for these changes by staying informed about both federal and local regulatory trends through outreach pieces, industry associations, and legal counsel.

First, understand your discharge permit responsibilities and stay informed of regulatory changes at the state and federal level:

- If you discharge leachate to a surface water: The effluent limits in NPDES permits come from federal requirements (technology-based effluent limits) and from water-quality standards that protect the uses of receiving water (water-quality-based effluent limits). Your next permit may require PFAS monitoring or PFAS treatment.
- If you discharge to a local POTW: Your industrial pretreatment/waste discharge permit contains limitations based on the federal requirements—PSNS and PSES. Your permit also contains local limits specific to the POTW effluent and biosolids and possibly additional monitoring and controls set by the POTW to protect their employees, collection system, and infrastructure. POTWs in several states are beginning to monitor for PFAS to understand the sources of PFAS to their treatment systems.

Next, understand the factors that influence the discharge volume and characteristics at your facility:

- Understand how the types of wastes you receive contribute to the characteristics of your leachate.
- Learn about leachate management and treatment options and the variables that influence feasibility and cost.

Last, consult with the experts who keep up with the latest in PFAS and regulatory changes.

Ask Those Who Know

Geosyntec's team of engineers, scientists, and technicians has expertise in landfill planning, permitting, design, and construction and can assist with all aspects of leachate projects starting with the overall regulatory strategy and continuing to initial feasibility studies to design, permitting, and final construction-related activities. Our leachate services team works with you to execute the project in a manner that suits the needs and preferences of your site.

Contact a Geosyntec specialist to help you find the best compliance solution for your business.

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