How PFAS Biosolids Problems Evolved

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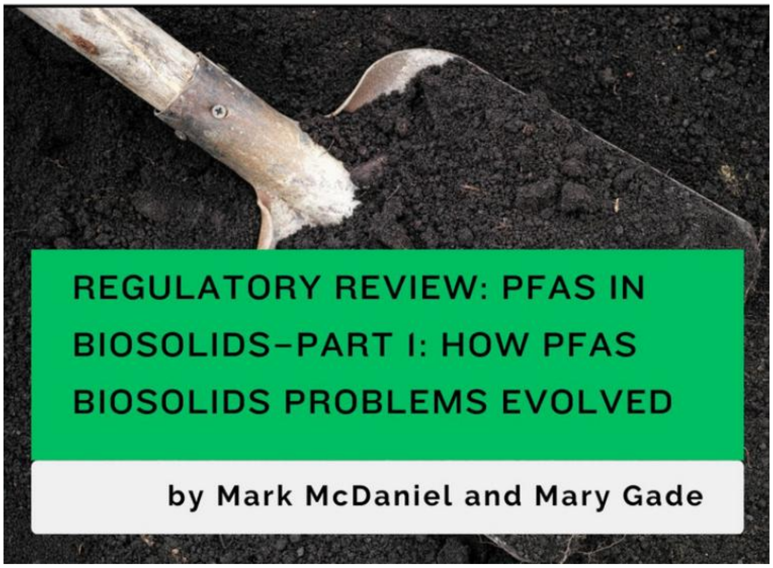

REGULATORY REVIEW: PFAS IN BIOSOLIDS–PART I: HOW PFAS BIOSOLIDS PROBLEMS EVOLVED

by Mark McDaniel and Mary Gade

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Regulating PFAS in Biosolids: Challenges and Opportunities

Per- and polyfluoroalkyl substances (PFAS), commonly called "forever chemicals" have gained significant attention due to their persistence in the environment and potential health risks.

Key Findings

PFAS are found in nearly all biosolids due to their prevalence in industrial discharges, consumer products, and landfill leachate entering wastewater treatment plants (WWTPs). Current wastewater treatment technologies are ineffective at removing PFAS, resulting in their accumulation in biosolids used for agricultural applications, landfilling, or incineration. While federal regulations for PFAS in biosolids are limited, a patchwork of state laws—ranging from outright bans on biosolid application to mandatory PFAS testing—has emerged. The U.S. Environmental Protection Agency (EPA) has designated certain PFAS as hazardous substances under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) and is pursuing additional regulations under the Clean Water Act (CWA).

Regulatory Landscape

Federal oversight is evolving, with the EPA taking steps to establish PFAS risk assessments and pollutant limits for biosolids. However, states like Maine, Connecticut, and Michigan have implemented stricter controls, emphasizing the need for a unified approach. Legal actions are also increasing, with citizen suits targeting municipalities, industries, and landowners linked to biosolid-related PFAS contamination.

Management Strategies

Biosolid management options include land application, landfilling, and incineration, each with associated risks and challenges. Emerging technologies focusing on PFAS stabilization and transformation show promise but face scalability and cost barriers. Upstream controls, such as pretreatment of industrial discharges and monitoring requirements, are critical to reducing PFAS loads entering WWTPs.

This first article in a three-part series addresses the growing regulations surrounding PFAS as they relate to biosolids, also known as sewage sludge.

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PFAS are very useful, making stain-resistant fabrics, firefighting foams, food packaging, medical devices and as a surfactant in industrial processes. PFAS have been in use since the 1940s but only recently gained scrutiny as the potential toxicity of certain PFAS at low levels has come to light.

PFAS are a man-made family of chemicals that have a chain of carbon atoms bonded to fluorine atoms with an end or side carbon attached to a different functional group, for example here is the structure of perfluorooctanoic acid (PFOA).

The EPA recently added two PFAS chemicals—perfluorooctanic acid (PFOA) and perfluorooctanesulfonic acid (PFOS)—as hazardous substances under CERCLA. It introduced drinking water regulations with stringent limits for six different PFAS compounds. Additionally, PFAS are regulated by at least 23 states, and the EPA has added 205 PFAS to the Toxics Release Inventory under the Emergency Planning and Community Right-to-Know Act. While PFAS in biosolids have not received the same level of attention as PFAS in drinking water, they do impact drinking water, groundwater, surface water, crops, reclaimed land, and agricultural products.

Background and Use of PFAS

The term "PFAS" encompasses a family of over 15,000 compounds that have been in use for over 70 years.[1] While PFAS are often discussed collectively, each PFAS compound is unique.[2] Both scientists and regulators have thus generally sought to address and regulate PFAS using compound-specific data where feasible,[3] as compound-specific toxicity values vary widely among PFAS species and isomers. The two most studied, understood, and regulated PFAS are PFOA and PFOS,[4] early 8-carbon chain (C-8) PFAS that manufacturers had voluntarily moved away from by 2015 in favor of shorter chain C-6 chemicals like GenX (hexafluoropropylene oxide dimer acid) and ADONA (ammonium 4,8-dioxa-3H-perfluorononanoate) While these replacements were thought likely to have lower toxicity, current studies are casting doubt on their toxicity and treatability. Further, they also tend to be “precursors” (larger, newer, unknown and even undetectable PFAS) that break down into more toxic and persistent building block chemicals like PFOS and PFOA. These “building blocks” are very stable PFAS called “terminal PFAS” or “terminal degradation products.” Terminal PFAS will not degrade to other PFAS under normal environmental conditions.

Use of Biosolids

Biosolids are a nutrient-rich product derived from the wastewater (sewer) treatment process, where solids are separated and treated. These biosolids can be beneficially used in agriculture and land reclamation, offering advantages like nutrient addition, improved soil structure, and reduced reliance on synthetic fertilizers. They may also be disposed of through incineration, underground injection, landfilling, or other technologies.

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Biosolids are classified into "Class A" and "Class B" based on treatment levels. Class A is free of pathogens, whereas Class B contains manageable levels of pathogens, necessitating certain restrictions. Both classes must meet federal and state regulations under 40 C.F.R. Part 503, with additional state-specific requirements possibly in place. These requirements are discussed in detail in the second article of this three-part series.

PFAS Transformation in Biosolids Treatment

The treatments used to convert raw sewage sludge into Class A biosolids for land application involve transformative processes, such as anaerobic digestion, composting, heat drying, or other pathogen reduction methods. These treatments are transformative enough to significantly break down PFAS precursors into intermediate or even terminal PFAS compounds like PFOS and PFOA. This results in an increase of total detectable PFAS after biosolids Class A treatment.

Understanding the Sources of PFAS in Wastewater and Biosolids

PFAS can be found in virtually every municipal WWTP influent, effluent, and sewage sludge (biosolids) in the United States. In fact, many WWTPs have been sued over PFAS in their effluent, which is returned to surface water and, consequently, into drinking water. While PFAS may be transformed by the wastewater process, the source of PFAS is not the WWTP. PFAS is already in the wastewater (sanitary, industrial, and stormwater sewer streams) influent to the plants. How does PFAS end up in sewage and stormwater? Here are the main culprits:

- Industrial discharges. One of the primary sources of PFAS in wastewater is industrial discharge. Industries such as chemical manufacturing, textiles, electronics, electroplating, and firefighting foam production or use have historically used PFAS in their processes. Wastewater from these industries often contains high concentrations of PFAS, which can subsequently enter municipal wastewater treatment plants. Unfortunately, most conventional treatment processes are not equipped to remove PFAS, leading to their accumulation in treated effluents.
- Municipal wastewater. PFAS are also present in municipal wastewater due to their prevalence in everyday consumer products. Items such as nonstick cookware, water-repellent clothing, stain-resistant fabrics, and food packaging often contain PFAS. When these products are washed or disposed of, PFAS can enter the wastewater system. Personal care products like shampoos and cosmetics can also contribute to PFAS in wastewater.
- Landfill leachate. Landfills serve as another significant source of PFAS in wastewater. As PFAS-containing products break down in landfills, the resulting leachate (liquid that has percolated through waste) can carry PFAS into nearby water systems or be directed to wastewater treatment facilities. This leachate often contains a complex mix of contaminants, including PFAS, which poses a challenge for wastewater treatment.
- Aqueous film-forming foams (AFFFs). Firefighting activities, especially those involving AFFFs, are a well-known source of PFAS contamination. These foams have been widely used to combat flammable liquid fires and are known to contain high levels of PFAS.

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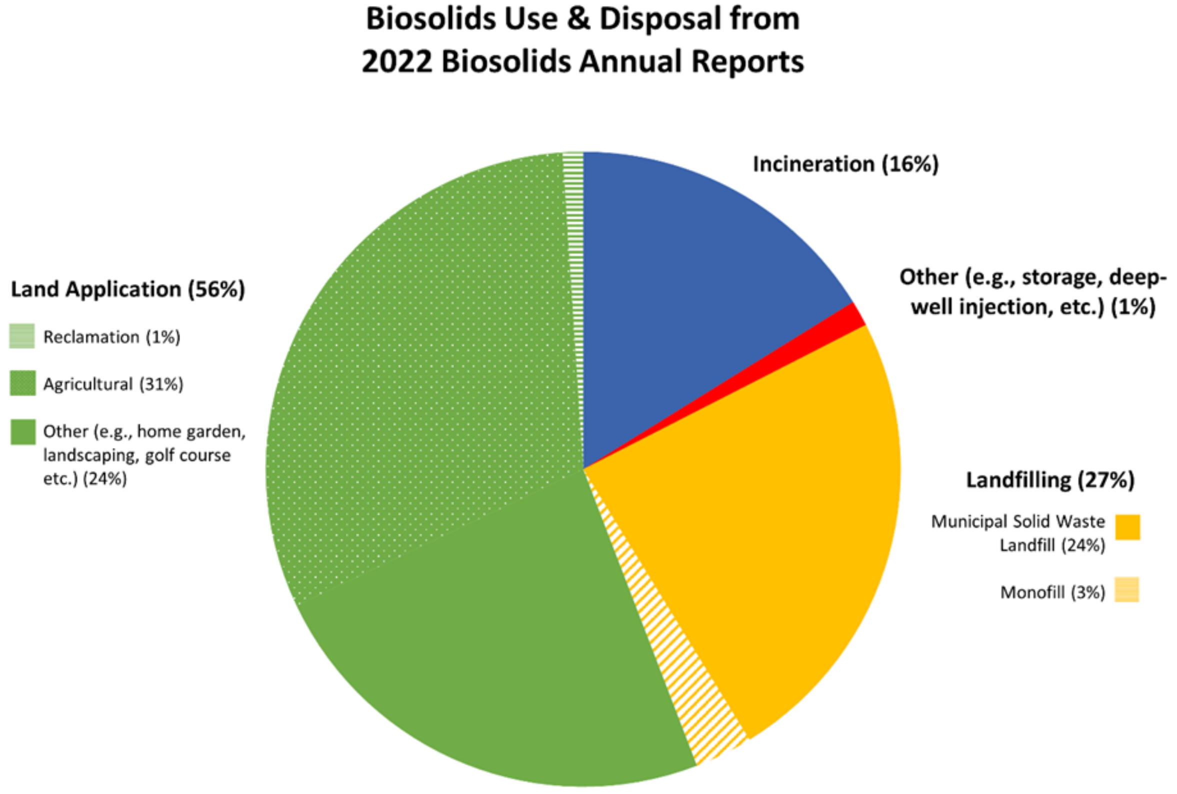
Runoff from firefighting activities or spills can lead to significant PFAS contamination in wastewater.

End Use and Impact

Biosolids are applied to approximately one-fifth of agricultural land in the United States.[5] This equals about 109,000 square miles, which is about the size of Arizona. Their use in agriculture is critical to managing the volume of sewage sludge created in the United States annually and increasing crop yields. In 2020, 20,750 facilities (wastewater treatment plants) generated biosolids, creating over 15 million tons of sludge. If land application or incineration of biosolids were paused or banned, storage of used biosolids would create an issue, especially in the northeastern U.S.

Figure 1 – US 2022 Biosolids Use and Disposal



The chart above shows the distribution of how biosolids were used or disposed of in 2022.As shown in the chart, biosolids management generally falls into three categories, land application, landfilling, and incineration. The general processes followed in each of these categories, and associate challenges associated with these processes are described below.

Land Application

- Process. Biosolids are applied based on the nutrient needs of crops. Individual states and the EPA regulate application rates to prevent overloading soils with nutrients or contaminants.

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- Challenges. PFAS can leach into groundwater, be carried away in surface water via runoff, or be taken up by crops, posing risks to human health and the environment.

Landfilling

- Process. Both 40 C.F.R. Part 503 and Part 258 regulate biosolids disposal in landfills, with specific requirements for monofills and co-disposal landfills.
- Challenges. Landfills have limited capacity, and managing PFAS leachate is complex. Leachate treatment at WWTPs may reintroduce PFAS into the environment. This is also a challenge in terms of sheer volume.

Incineration

- Process. Incineration involves burning biosolids to reduce their volume and destroy organic contaminants. Incinerators must meet stringent emissions standards under the Clean Air Act to control the release of pollutants.
- Challenges. Incineration may not completely destroy PFAS, leading to potential by-products. The costs to transport or landfill and incinerate biosolids would be much greater than land application.

Alternate Disposal Methods

While alternative disposal methods currently make up less than .01 percent of biosolids end uses, they may become more important if land application or incineration are halted, paused, or even banned:

- cement kiln or industrial furnace;
- deep well injection;
- gasification; and
- pyrolysis.

Emerging Treatment Technologies for PFAS in Biosolids

Emerging technologies for treating PFAS in biosolids focus on two primary approaches: stabilization and transformation. These methods address the persistent and resistant nature of PFAS, which poses environmental and health risks due to its ability to bioaccumulate and resist conventional treatment processes.

- PFAS stabilization technologies aim to immobilize PFAS in biosolids, reducing their potential to leach into groundwater or be taken up by plants. Stabilization methods generally focus on binding PFAS compounds to soil or other solid materials, thereby limiting their mobility. One such approach involves using adsorbents such as activated carbon, biochar, or mineral-based amendments. These materials can adsorb or absorb PFAS, especially long-chain varieties, by trapping them within their structure. Stabilization techniques provide a relatively low-cost solution for reducing PFAS mobility, but they don't break down the compounds, meaning that PFAS is still present in

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a stabilized form. Thus, while stabilization can mitigate the spread of PFAS into the environment, it doesn't completely remove the contaminant risk.

- PFAS transformation technologies go a step further by attempting to break down PFAS compounds into less harmful substances, ideally transforming them into inert by-products. Because PFAS are highly resistant to degradation, transformation technologies often involve aggressive chemical or thermal processes. For instance, thermal treatment technologies, such as incineration at high temperatures or pyrolysis, aim to destroy PFAS by subjecting biosolids to extreme heat. Chemical oxidation processes, such as electrochemical or advanced oxidation, have also shown potential for degrading PFAS, particularly in liquid waste streams. However, transforming PFAS within solid biosolids remains a technical challenge due to the complexity and cost of implementing these technologies on a large scale.

While these emerging technologies provide promising approaches to address PFAS in biosolids, there are still limitations in terms of scalability, cost, and the need for further research to confirm long-term efficacy and environmental safety.

In our next two articles, we will review the federal and state regulatory and liability frameworks emerging for PFAS in biosolids.

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[1] Centers for Disease Control and Prevention, "Per- and Polyfluoroalkyl Substances (PFAS),".

[2] *See* Agency for Toxic Substances and Disease Registry, "Toxicological Profile for Perfluoroalkyls," at 24 (May 2021) (noting "there is evidence of qualitative and mechanistic differences" between various PFAS species) (ATSDR Profile for PFAS); Jessica S. Bowman, "Fluorotechnology Is Critical to Modern Life: The FluoroCouncil Counterpoint to the Madrid Statement," 123 *Env't Health Persp.* A112 (2015) ("PFASs are designed for specific end uses, and therefore all PFAS chemistry is not the same.").

[3] *See, e.g.*, Nicole M. Brennan et al., "Trends in the Regulation of Per- and Polyfluoroalkyl Substances (PFAS): A Scoping Review," 18 *Int'l J. Env't Res. Pub. Health* 1, 19 (2021) ("the current regulatory structure at the U.S. national-level requires chemical-specific data").

[4] *E.g.*, ATSDR Profile for PFAS, *supra* note 3, at 5–6 (noting that "most of the studies have focused on PFOA and/or PFOS; fewer studies have evaluated . . . the remaining 10 perfluoroalkyls [PFBA, PFHxA, PFHpA, PFNA, PFDA, PFUnA, PFDoDA, PFBS, PFHxS, FOSA] included in this toxicological profile").

[5] U.S. Environmental Protection Agency, Biosolids Annual Program Report (2021).

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