PFAS in Biosolids

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JULY 2025

Background

When domestic sewage is transported and conveyed to a wastewater treatment plant, it is treated to separate liquids from the solids, which produces a semi-solid, nutrient-rich product known as “sewage sludge”. The terms “biosolids” and “sewage sludge” are often used interchangeably by the public; however, the U.S. Environmental Protection Agency (EPA) and wastewater treatment facilities typically use the term “biosolids” to mean sewage sludge that has been treated to meet the requirements in the EPA’s regulation entitled, “Standards for the Use or Disposal of Sewage Sludge,” promulgated at 40 CFR Part 503, and intended to be applied to land as a soil conditioner or fertilizer.

Biosolids are primarily composed of water and organic (carbon-rich) materials. Biosolids contain macronutrients like nitrogen, phosphorus and potassium as well as micronutrients like copper, zinc and iron. Additionally, biosolids contain inert (no carbon) solids like sand, trace elements and, depending on the level of treatment, low concentrations of microorganisms. Biosolids that comply with state and federal regulations are considered safe for the environment and protective of human health and may be beneficially used for land application as a fertilizer and soil amendment, as well as for use in composted products.

Biosolids are widely used as a soil amendment in agriculture, forestry, and land reclamation due to their beneficial macro- and micronutrient content, soil-conditioning properties, and carbon sequestration potential (Elgarahy et al., 2024; Xue et al., 2025).

Biosolids are recycled on farms and forests throughout the United States and in most developed countries worldwide. As of 2023, the EPA estimates about 60% of the total biosolids produced annually in the United States are applied for beneficial uses, while the remainder is either incinerated or disposed of in landfills.

In Virginia, the Department of Environmental Quality (DEQ), reports 37,786 acres received biosolids applications in 2024, an increase from 36,145 acres in 2023. Despite this, the acreage where biosolids are recycled represents less than 1% of all agricultural land in Virginia.

What are PFAS in Biosolids?

Per- and polyfluoroalkyl substances (PFAS) are a large family of thousands of synthetic chemicals that have been used in various industries and consumer products since the 1940s. These chemicals are valued for their resistance to heat, water, and oil, making them common in products such as non-stick cookware, water-repellent fabrics, paints, carpets, and firefighting foams.

PFAS are ubiquitous, environmentally persistent, highly mobile, and bioaccumulative, which has earned them the nickname “forever chemicals.” PFOS (perfluorooctanesulfonate) and PFOA (perfluorooctanoic acid) are two specific types of chemicals within the larger PFAS family. Although both have been phased out of production in the United States, they remain of concern due to their widespread presence in the environment.

Sources of PFAS in Wastewater and Biosolids

Wastewater treatment plants do not produce PFAS but receive them from multiple sources, including:

- Discharges from industries that use PFAS in their processes
- Runoff from areas where PFAS-containing products have been applied
- Household wastewater containing PFAS from everyday consumer products such as personal care products, food packaging, carpets, and clothing
- Extensive discharge of landfill leachate into municipal sewage systems (Masoner et al., 2020).

Current biosolids treatment technologies cannot fully remove PFAS compounds; however, wastewater treatment plants play a critical role in treating sewage and protecting communities across the Commonwealth.

Environmental Presence and Potential Impacts

Even with advanced treatment, PFAS can persist at background levels in soil and rainwater (Brusseau et al., 2020; Coates and Harrington, 2024). PFAS present in biosolids may pose potential environmental concerns through:

- Uptake by plants
- Contamination of groundwater
- Accumulation in the food chain through animal intake.

Science-based research is needed to fully understand the potential risks associated with PFAS in land-applied biosolids.

Health Effects

Certain PFAS compounds have been linked to adverse health effects in humans, including:

- Liver toxicity
- High cholesterol
- Impaired lung function
- Lowered immune response
- Developmental effects in infants
- Increased risk of cancer (Teymourian et al., 2021; Panieri et al., 2022).

Regulatory Status

Currently, aside from the EPA’s drinking water standard of 4 ng/L, there are no federal standards specifically regulating PFAS levels in biosolids in the United States. The EPA is studying the risks associated with PFAS in biosolids and has provided information on its ongoing risk assessment.

Some states have begun developing their own regulations or guidelines for PFAS in biosolids (Hughes, 2023). These may include:

- Monitoring requirements
- Threshold levels for land application
- Restrictions on land application in certain contexts.

The EPA recommends that states monitor biosolids for PFAS, identify industrial sources of PFAS discharges, and implement pretreatment programs to reduce PFAS at the source.

Management and Mitigation Strategies

To address growing concerns about PFAS in biosolids, the EPA recommends that states take proactive steps including monitoring biosolids for PFAS, identifying industrial sources of contamination, and implementing pretreatment programs to reduce PFAS at the source. In response, several states have begun developing their own regulations or guidance, including threshold levels, monitoring requirements, and restrictions on land application (Hughes, 2023).

Effective strategies to manage and mitigate PFAS in biosolids include:

- Source reduction: Reducing or eliminating the use of PFAS in industrial processes and consumer products is the most effective way to minimize their presence in wastewater and carryover to biosolids.
- Pretreatment technologies: Implementing technologies to effectively remove PFAS from industrial wastewater before it enters the municipal sewer system.
- Monitoring and testing: Regularly test biosolids to assess PFAS levels and guide safe management practices.
- Land application best practices: Control application rates, select appropriate sites, and monitor soil and water quality to reduce migration risks.
- Advanced treatment technologies: Invest in research and development of technologies to remove PFAS from wastewater and biosolids (Thoma et al., 2022; Kumar et al., 2023).

Virginia Practices

In Virginia, the DEQ oversees all land application of biosolids under a robust regulatory framework designed to protect public health and the environment. Key elements of Virginia's program include:

- **Permitting Process**: Wastewater treatment facilities and land appliers must obtain a permit from DEQ before biosolids can be applied. Each permit requires a thorough site evaluation, including proximity to water supplies, slopes, soil characteristics, vegetation, and distance to streams or wells, and includes public notification and comment periods.
- **Nutrient Management Plans**: Every site permitted for biosolids application must follow a site-specific nutrient management plan. These plans are designed to match nutrient application with crop needs, reducing the risk of nutrient runoff or groundwater contamination.
- **Buffer Requirements**: Biosolids cannot be applied near certain sensitive areas, including homes, wells, water bodies, and environmentally sensitive zones. Buffer distances vary based on the season, slope, and method of incorporation.

- **Approved Crop Use**: Biosolids in Virginia are most commonly applied to hay, pasture, forests, and grain crops like corn and wheat. Restrictions apply to food crops and livestock grazing to prevent bacterial contamination.
- **Public Engagement and Oversight**: DEQ notifies local governments and nearby residents of proposed application sites. Public meetings and comment periods are held for initial permits. After permit issuance, DEQ requires a 100-day waiting period before biosolids may be applied to newly permitted sites.
- **Inspection and Enforcement**: DEQ employs biosolids specialists across its seven regional offices who conduct site inspections, often unannounced, before, during, and after application. These specialists document conditions and ensure compliance with permit requirements.
- **Local Monitoring**: Virginia law allows local governments to appoint trained local monitors who may inspect biosolids application sites, stop activities if violations are found, and serve as a point of contact for the public. DEQ can reimburse localities for these monitoring efforts.

This regulatory framework, established under the authority transferred from the Virginia Department of Health to DEQ in 2008, ensures consistent and science-based oversight across all biosolids land application activities in the Commonwealth.

Research

Virginia Tech and the Virginia Biosolids Council are currently monitoring several PFAS studies, including:

- Occurrence of PFAS Compounds in US Wastewater Treatment Plants (WRF 5031)
- Investigation of Alternative Management Strategies to Prevent PFAS from Entering Drinking Water Supplies and Wastewater (WRF 5082)
- Investigation of Treatment Alternatives for Short-Chain PFASs (WRF 4913)
- Studying the Fate of PFAS through Sewage Sludge Incinerators (WRF 5111)
- Evaluating PFAS Occurrence and Fate in Rural Water Supplies and Agricultural Operations to Inform Management Strategies (EPA)
- Decreasing polyfluoroalkyl substances (PFASs) in municipal wastewater effluent and minimizing release from land-applied biosolids (EPA)
- Unregulated Organic Chemicals in Biosolids: Prioritization, Fate and Risk Evaluation for Land Application (EPA)

Overall Considerations

In summary, PFAS are persistent chemicals that are ubiquitous in the environment and ultimately find their way into biosolids due to their widespread use. Wastewater treatment plants do not produce or use PFAS during treatment but receive them from various household, industrial, and commercial sources.

Scientific understanding of the risks associated with PFAS in land-applied biosolids continues to evolve, and regulatory oversight at both the state and federal levels is developing in response. Effective management of PFAS in biosolids requires a multi-faceted approach, including source reduction, industrial pretreatment, regular monitoring, and the use of best practices and treatment technologies to reduce PFAS concentrations.

References

Brusseau, M. L., Anderson, R. H., & Guo, B. (2020). PFAS concentrations in soils: Background levels versus contaminated sites. *Science of the Total environment*, *740*, 140017.

Coates, K. A., & Harrington, P. D. B. (2024). Contamination Levels of Per-and Polyfluoroalkyl Substances (PFAS) in Recent North American Precipitation Events. A Review. *Water Research*, 122390.

Elgarahy, A. M., Eloffy, M. G., Priya, A. K., Yogeshwaran, V., Yang, Z., Elwakeel, K. Z., & Lopez-Maldonado, E. A. (2024). Biosolids management and utilizations: A review. *Journal of Cleaner Production*, 141974.

Hughes, S. G. (2023). PFAS in biosolids: A review of state efforts & opportunities for action. *The Environmental Council of the States, ecos. Org*, 29.

Kumar, R., Dada, T. K., Whelan, A., Cannon, P., Sheehan, M., Reeves, L., & Antunes, E. (2023). Microbial and thermal treatment techniques for degradation of PFAS in biosolids: A focus on degradation mechanisms and pathways. *Journal of hazardous materials*, *452*, 131212.

Masoner, J. R., Kolpin, D. W., Cozzarelli, I. M., Smalling, K. L., Bolyard, S. C., Field, J. A., ... & Bradley, P. M. (2020). Landfill leachate contributes per-/poly-fluoroalkyl substances (PFAS) and pharmaceuticals to municipal wastewater. *Environmental Science: Water Research & Technology*, *6*(5), 1300-1311.

Panieri, E., Baralic, K., Djukic-Cosic, D., Buha Djordjevic, A., & Saso, L. (2022). PFAS molecules: a major concern for the human health and the environment. *Toxics*, *10*(2), 44.

Thoma, E. D., Wright, R. S., George, I., Krause, M., Presezzi, D., Villa, V., ... & Zemek, P. G. (2022). Pyrolysis processing of PFAS-impacted biosolids, a pilot study. *Journal of the Air & Waste Management Association*, *72*(4), 309-318.

Teymourian, T., Teymoorian, T., Kowsari, E., & Ramakrishna, S. (2021). A review of emerging PFAS contaminants: sources, fate, health risks, and a comprehensive assortment of recent sorbents for PFAS treatment by evaluating their mechanism. *Research on Chemical Intermediates*, 1-36.

Xue, J., Verstraete, W., Ni, B. J., Giesy, J. P., Kaur, G., Jiang, D., ... & Uchida, Y. (2025). Rethink biosolids: Risks and opportunities in the circular economy. *Chemical Engineering Journal*, *510*, 161749.