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PFAS-CONTAMINATED SEWAGE SLUDGE

A REVIEW OF DISPOSAL OPTIONS, COSTS AND BENEFITS

EXECUTIVE SUMMARY

This policy brief addresses the issue of per- and polyfluoroalkyl substances (PFAS) contamination in sewage sludge, which is used as fertilizer in agricultural fields (as a biosolid). The management of PFAS-contaminated sludge and biosolids in Vermont currently relies on landfilling and agricultural land application, with some interim regulations in place. However, PFAS, often referred to as "forever chemicals," have been detected in wastewater, biosolids, soil, and water where biosolids are applied to land, leading to urgent questions about how to manage these substances and what levels of PFAS are safe. When developing permanent PFAS and sewage sludge regulations and long-term solutions, the state faces challenges in balancing cost-effectiveness with the need to protect human and environmental health. This report presents an initial cost assessment of three disposal options: land application, landfilling, and incineration. To further understand effective management strategies, a comprehensive cost/benefit analysis of various disposal options is recommended. As research on this issue continues, the State could evaluate emerging treatment methods and consider legislation to address PFAS contamination at the source.

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BACKGROUND & CONTEXT

There are thousands of different PFAS, which are synthetic chemicals with carbon-fluorine bonds[1], that are used in consumer products and industrial processes and technologies[2]. Some well-known sources of PFAS are non-stick cookware, firefighting foam, clothing, and cleaning liquids. Due to the widespread presence of PFAS, they are documented to accumulate in the body over time, and 'nearly everyone' in the US has been exposed to them[2], though concentrations of many PFAS chemicals have declined in human blood over the last several decades[3]. Exposure to different PFAS poses differential risks, and chronic, high levels of exposure is associated with the potential for reproductive harm, developmental delay, increased risk of cancer, and impact on the immune system[1]. There is a limited understanding of the level of risk associated with exposure to PFAS in soil or crops and how to assess human exposure to PFAS[4]. The risk of exposure to PFAS from land application sewage sludge is difficult to quantify. The issue of PFAS-contaminated sewage sludge has received more attention in the Northeast recently since a Maine law banned the land application of sewage sludge to mitigate PFAS contamination in 2022.

The primary options for disposal of PFAS sludge nationwide are land application, landfilling, and incineration[5]. Sewage sludge, when processed into biosolids, is spread on agricultural fields as a fertilizer across the U.S., including in Vermont[6], as an affordable option for farmers to replenish soil nutrients[7]. However, because PFAS have been discovered in the soil, water, crops, and animals from the places where sewage sludge is applied to land[8], and does not break down in natural environments, there is increasing focus on assessing potential alternative disposal pathways, as well as quantifying the potential risks of these chemicals. Since 2015, Vermont has looked at alternative management strategies for sewage sludge; in 2017 the Vermont Department of Environmental Conservation (VT DEC) imposed one of the strictest groundwater concentration standards in the world- 20 ng/L (ppt) for the sum of five PFAS- after PFAS were detected in all samples from wastewater treatment facilities in 2016. In 2023 VT DEC released the PFAS Roadmap. Then in 2024, the VT DEC issued the Interim Strategy for Mitigating PFAS Risks Associated with Residuals Management, which includes additional guidance to mitigate risks associated with PFAS-contaminated biosolids[9]. In the current legislative Bill H.292 was introduced to the House Committee on Environment, which proposed ban land application and sale of sewage sludge that contains PFAS, but the bill did not make it to cross-over[10].

DISPOSAL OPTIONS

Below we present a summary of the costs and benefits of three disposal options for PFAS-contaminated biosolids. Each state utilizes multiple sewage sludge disposal methods, including

[1] National Institute of Environmental Health Sciences. (2023)
[2] Glüge, et. al. (2020)
[3] Centers for Disease Control and Prevention. (2024)
[4] De Silva, et. al. (2021)
[5] U.S. Environmental Protection Agency. (2016)
[6] U.S. Environmental Protection Agency. (2019)
[7] Pritchard, et. al. (2010)
[8] U.S. Environmental Protection Agency. (2025)
[9] Vermont Residuals Management Working Group. (2024).
[10] Vermont General Assembly. (2025).

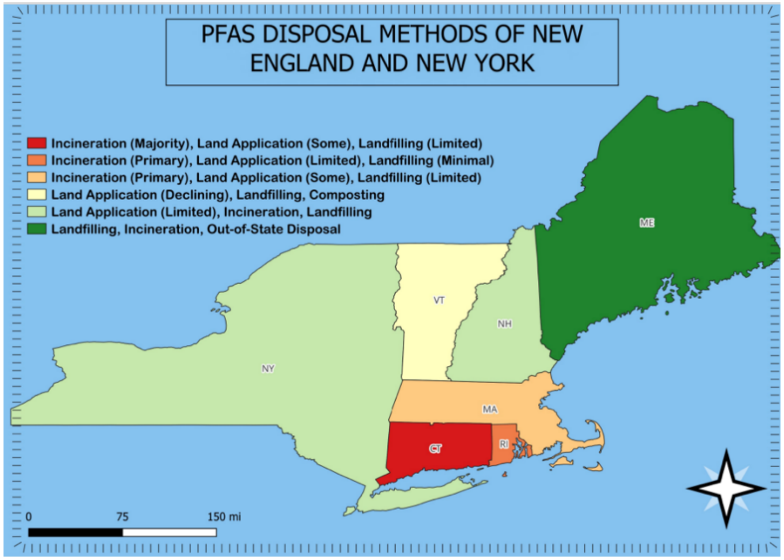

Figure 1. *Map of PFAS Disposal Methods in New England and New York. Data retrieved from each state's Department of Environmental Services or Conservation.*

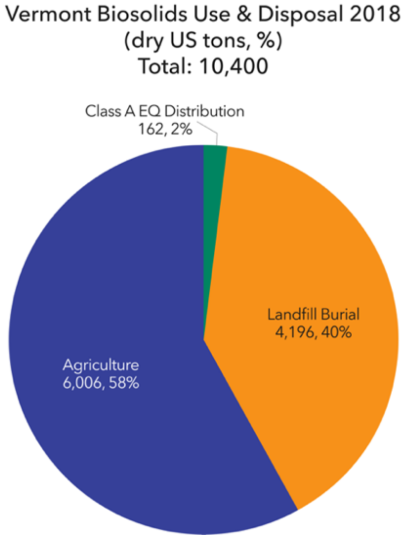

Figure 2. *Vermont Biosolids Use & Disposal, 2018[1]*

Vermont, which follows a multi-pronged approach [See Figure 1]. Biosolid waste in Vermont is currently disposed of by land application and landfilling both in and out of state [See Table 1]. Biosolids applied to land in Vermont are primarily applied to agricultural land [See Figure 2]. Vermont has one commercial landfill, which accepts municipal biosolids. Vermont regulates two classes of biosolids under the Vermont Solid Waste Rules: Class B and Exceptional Quality (EQ)[9]. Class B land application sites require a site-specific permit due to the greater level of pathogenic content relative to EQ biosolids.

Table 1. Vermont Sewage Management, 2022[9].

Management Option	Amount (dry tons) and Percent of Total		
	In-State	Out-of-State	Total
Class B Biosolids Land Application	194 (2%)	0	194 (2%)
EQ Biosolids Distribution	3,796 (31%)	4,965 (40%)	8,761 (71%)
Landfill Disposal	2,699 (22%)	609 (5%)	3,307 (27%)
Incineration	0	0	0
Total	**6,689 (55%)**	**5,573 (45%)**	**12,262 (100%)**

Disposal Option 1: Land Application

Summary of Risks: Land application has historically been a simple, cost-efficient disposal option for biosolids, that provides benefits to the soil. Biosolids can be applied to agricultural land (cropland and pasture), and nonagricultural land for reclamation or restoration, or on commercial sites like golf courses. The EPA Draft Sewage Sludge Risk Assessment for PFOA and PFOS[8] found that in some cases, land application exceeded the agency's human health risk thresholds where sewage sludge PFAS concentrations exceeded 1 part per billion (ppb), equivalent to 1 microgram per kilogram (ug/kg). However, the risk to human health is highly variable based on site-specific factors, like the amount of sludge applied and the geological conditions[8]. Human health risks are expected to be lower in areas with protected groundwater, that are distant from surface waters and drinking water sources, and when applied to certain crops, such as grain, fuel, or fiber crops[8]. The highest risk pathways for human health effects from land application include consuming milk, beef, or eggs from animals raised on contaminated pasture, contaminated drinking water, and consuming fish from lakes impacted by contaminated runoff[8].

Regulatory Approaches: No federal criteria have been established for PFAS in biosolids regulation. States are reacting to the risks of PFAS and determining guidelines for land application in real time, and at least seven states have begun to regulate PFAS in some way. In 2022, Maine banned land application and sale of biosolids from wastewater[11]. In 2024, Connecticut banned the sale and use of biosolids containing PFAS as a soil amendment[12]. Colorado, Maryland, Michigan, Minnesota, New York, and Wyoming have developed a tiered approach to regulate land application depending on PFAS concentration[12] (see Table 2). For comparison, we have added the PFOA/PFOS concentrations from the VT Interim Strategy for Mitigating PFAS Risks[9]. In addition to states currently regulating aspects of PFAS land application, Texas has introduced legislation to limit PFAS levels in biosolids for agricultural purposes, and Oklahoma and Mississippi have introduced legislation to ban land application of sludge from wastewater, like Maine[13].

Table 2. State strategies to regulate land application of biosolids based on the PFAS concentration.

State	PFAS Indicator	Tier 4 (µg/kg)	Tier 3 (µg/kg)	Tier 2 (µg/kg)	Tier 1 (µg/kg)
CO[12]	PFOS	≥ 50	N/A	≤50	N/A
MD[12]	PFOS/PFOA	≥ 100	50-99	20-49	≤20
MI[12]	PFOS/PFOA	≥ 100	20-99	N/A	≤20
MN[12]	PFOS/PFOA	≥ 125	50-24	20-49	≤20
NY[12]	PFOS/PFOA	≥ 50	N/A	21-49	≤20
WI[12]	PFOS/PFOA	≥ 150	50-149	21-49	≤20
VT[9]	**PFOS** **PFOA**	**N/A**	**N/A**	**>3.41** **>1.61**	**<3.40** **<1.60**

Land application of Tier 4 biosolids is prohibited in all states. Waste in Tiers 2 and 3 is applied to land at reduced rates, and the cumulative application rate or soil concentration is tracked. Tier 1 waste can be applied with no additional restrictions beyond the typical state biosolid regulations. Land application rates and thresholds can be set based on land use type and potential risk to human and environmental health.

Costs and Benefits: Land application of biosolids is a relatively low-cost option that can improve soil health, increase carbon sequestration, reduce demand for chemical fertilizers, and emit less greenhouse gases than other disposal options[5]. Limiting or prohibiting land application typically increases sludge management costs[12], by forcing the use of higher-cost methods, and end users may have to switch to chemical fertilizers, which carry their own health and environmental risks[13]. Many Vermont municipalities have invested in biosolids processing—those investments may be stranded if biosolids recycling is banned or so restricted as to be infeasible in Vermont. Vermont, and other states, are regulating land application using a tiered approach based on PFAS concentration in biosolids, which allows biosolids to be applied to

[11] MOST Policy Initiative. (2025).
[12] Marten Law. (2025).
[13] McCallum, K. (2024)

land while attempting to mitigate risks to human and environmental health. Ongoing regulation of land application requires monitoring and testing which incurs administrative and laboratory costs. Investment in upstream mitigation and treatment approaches can increase the viability of land application by reducing PFAS concentrations in biosolids.

Disposal Option 2: Landfill

Summary of Risks: Disposing of biosolids in municipal solid waste landfills or dedicated monofils is another common practice. When contained properly (i.e., with composite-lined sites), human and environmental health risk from landfill disposal can be low and do not exceed the EPA's risk thresholds for PFOA or PFOS in down-gradient groundwater. The EPA finds that there may be human health risks associated with drinking contaminated groundwater sourced near a surface disposal site when sewage sludge containing 1 ug/kg of PFOA or sewage sludge containing 4 to 5 ug/kg of PFOS is disposed in an unlined or clay-lined surface disposal unit[8].

Costs and Benefits: States like New Jersey and Massachusetts primarily rely on landfilling for biosolids disposal. A 2020–2021 study found that in some areas, increased landfilling and decreased land application resulted in biosolids management costs increasing by 37–72%[14]. Figure 3 shows the cost of switching from land application to landfill disposal for facilities in four states, which resulted in at least a 100% increase in costs across all five facilities[15]. For example, Concord, NH began exporting biosolids to Canada when land application was halted, increasing management costs from $29.10 per wet ton (wt) to $132.65 per wt. PFAS regulations have also played a role in increasing the cost of managing landfill leachate in Concord[15]. Casella is pilot-testing new methods to remove PFAS from landfill leachate in Vermont's landfill[15]. Landfilling sewage sludge does not eliminate the risk of environmental contamination, primarily because of the risk that leachate can seep into surrounding water sources.

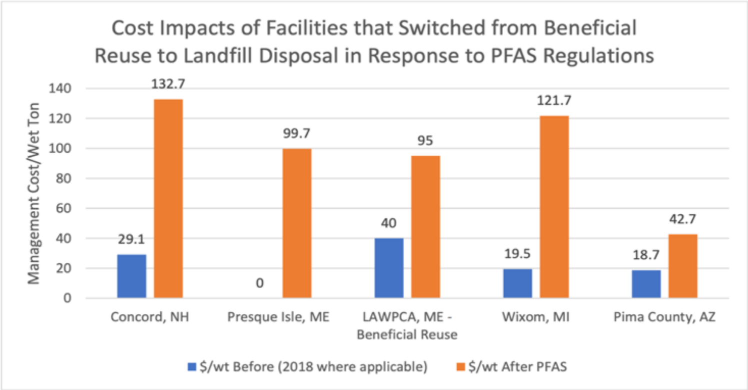

Figure 3. *Costs of switching from land application to landfill disposal of biosolids[15].*

Landfilling could be a temporary solution while sources of PFAS contamination in biosolids are identified and mitigated. For example, Wixom, MI, is diverting biosolid waste from land application to landfills due to high levels of PFAS from an industrial source; the PFAS source was mitigated using filtration, and after decreasing PFAS concentrations, the city hopes to continue producing Class B biosolids for land application[15].

Vermont, and many other states, continue to dispose of PFAS-contaminated sludge in landfills. In 2022, Vermont disposed of 27% of our biosolid waste in landfills, 22% in-state and 5% out-of-state[9]. Landfilling biosolid waste is limited by landfill capacity, and landfills produce leachate that contains PFAS, which must be treated at a wastewater treatment plant. Regionally, there are significant limitations on landfill capacity[16], with only one active landfill in Vermont that is

[14] CDM Smith. (2020)
[15] Cotton, E. (2024)
[16] Northeast Waste Management Officials' Association. (2021)

estimated to be full in 20 years. The volume of biosolids sent to landfills can be decreased by utilizing solid waste drying and dewatering methods, which have upfront infrastructure costs but can save landfill space over time[15].

Disposal Option 3: Incineration

Summary of Risks: There is evidence that incineration can destroy PFAS in biosolids, however there is a wide variation in results depending on the specific process and conditions of treatment[17]. In technical terms, thermal treatment of biosolid waste has three main types: incineration (burning with lots of oxygen), gasification (heating with limited oxygen), and pyrolysis (heating without oxygen)[18]. We use incineration to refer to any of the three options for ease of understanding. Studies involving thermal treatment ≥ 500 ℃ show that there is substantial removal and transformation of target PFAS from biosolids[18]. The resulting biochar typically contain extremely low or no detectable PFAS content, however more research is needed to determine the PFAS concentration in the resulting gases[18]. However, incineration of materials containing PFAS has the potential to release hazardous air pollutants capable of polluting air and water. The EPA Draft Risk Assessment notes that human health risks are possible, though not quantified, from the incineration of PFOA and PFOS-containing sewage sludge[8]. The primary exposure risk from incineration is from inhalation of air particulates, however PFAS in the air can be deposited into soil and water as well[8]. The EPA notes that deposition from air particulates into soil would lead to lower exposures than the land application of equivalently contaminated sewage sludge[8].

Incinerators for sewage sludge waste must abide by the Clean Air Act (CAA), which imposes strict limits on emissions from these facilities. However, PFAS isn't currently listed as a hazardous air pollutant, leaving monitoring requirements for PFAS non-existent or ineffective. While PFAS air emissions are not yet regulated at the federal level, three states (Michigan, New Hampshire, and New York) have enacted or proposed restrictions on PFAS in air emissions, a trend that other states are looking to follow.

Table 3. State restrictions on PFAS air emissions[19].

PFAS Indicator	Michigan	New Hampshire	New York (Proposed)
PFOA	0.07 µg/m3	N/A	0.0053 µg/m3
PFOS	0.07 µg/m3	N/A	N/A
APFO	N/A	24- hour limit: 0.05 µg/m3 Annual limit: 0.042 µg/m3	N/A

Costs and Benefits: Vermont does not currently export sludge for incineration[9]. Nationwide, only 14% of biosolids were disposed of via incineration[20]. Water resource recovery facilities (WRRFs) located throughout Southern New England primarily rely on incineration, and the limited regional capacity for incineration is compounded by the closure of several Northeast sludge incinerators [21] [22]. Connecticut incinerated 88% of its sewage sludge in 2018, New Hampshire incinerated 18%, New York incinerated 15%, Rhode Island incinerated 94%,

[17] Hakeem, et. al. (2024)
[18] Bridgwater, A. V. (1980).
[19] Bryan Cave Leighton Paisner. (2025).
[20] U.S. Environmental Protection Agency. (2016)
[21] New England Interstate Water Pollution Control Commission. (2022)
[22] Northeast Biosolids and Residuals Association. (2020)

Massachusetts incinerated 43%, and Maine incinerated 0%[22]. Compared to landfilling, incineration is typically more expensive[23], however costs vary widely based on location.

FURTHER RESEARCH

Currently, not enough is known about the long-term effects of PFAS from sewage sludge on human and environmental health. A comprehensive risk assessment of the impact of disposing of contaminated sludge through land application, landfilling, or incineration is needed. Future studies could produce a quantitative cost/benefit analysis of both pre-treatment and disposal options in Vermont and include short and long-term options as well as the risks of transporting biosolid waste out of the state or country. Since biosolids are an important agricultural input in Vermont, it is important to include the effects on farmers and agriculture in the analysis. Collecting data to support the practical application of potential management strategies could result in evidence-based decision-making. Furthermore, the state could closely follow new and innovative treatment and mitigation options and explore pilot testing opportunities that would benefit Vermont. Innovative PFAS sludge management possibilities include deep underground injection[24], mechanochemical chemical degradation to separate sludge from contaminates[25], supercritical water oxidization[26], and gasification which has been tested at a facility in Washington[27]. The above recommendation for cost/benefit analysis could include pilot testing or implementation of some of these innovative options.

CONCLUSION

PFAS contaminated sludge and wastewater solutions are continually evolving. To combat contamination risks, Vermont could consider banning PFAS use in consumer products, as proposed in VT H. 283, an act relating to the phaseout of consumer products containing added perfluoroalkyl and polyfluoroalkyl substances. The lowest cost option for disposal of biosolid waste is land application, though landfilling could become more cost effective with investments to lower the volume of biosolids produced. Without additional landfills or incineration facilities in the state, Vermont will likely have to pay additional transport and processing costs to dispose of waste not applied to land. In the future, advances in incineration and other emerging treatment methods could make these options viable in Vermont, which would require significant investment in new infrastructure. To understand the true costs and benefits, the state could invest in a quantitative analysis process to determine the way forward and assess the risks of different exposure levels and pathways.

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[23] Gerber, K. (2022)
[24] McCurdy, R. (2011)
[25] Gobindlal, et. al. (2023)
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FIGURE 1 (MAP) REFERENCES

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