Cost Analysis of the Impacts on Municipal Utilities and Biosolids Management to Address PFAS Contamination

NACWA

nebra
North East Biosolids & Residuals Association

Water Environment Federation®
the water quality people®

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CDM Smith

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Executive Summary

CDM Smith collaborated with the North East Biosolids & Residuals Association (NEBRA) in association with the Water Environment Federation (WEF) and the National Association of Clean Water Agencies (NACWA) to conduct a cost analysis of the impacts of PFAS policies and regulations on municipal utilities and biosolids management entities. The end goal was to produce informative materials to share with federal, state, and local legislators, regulators, government officials, and the broader public to inform PFAS policy decisions and identify unintended consequences. This is important to ensure that PFAS "receivers" -- like water resource recovery facilities (WRRFs) and thus their rate payers -- are not unduly penalized for receiving and processing PFAS that they did not produce, while appropriately protecting public health. This investigation was broken down into five (5) sections:

- Section 1 – Background
- Section 2 – Data on Actual Costs of Wastewater and Biosolids Management Programs from PFAS
- Section 3 – Case Studies
- Section 4 – Summary of Indicator Cost and Technology Information
- Section 5 – Relevant Studies and Articles

Task 1 consisted of close coordination with NEBRA, WEF, and NACWA staff to identify facilities across the country who have been impacted by PFAS, which utilized results from an online survey issued by NEBRA to identify potential facilities. Facilities identified were contacted to participate in an in-depth survey to help quantify the impacts. The CDM Smith team contacted parties such as WRRFs, residuals haulers, biosolids land appliers, and facilities dedicated to end use (incineration, compost, landfill, farms, etc.) and requested detailed information regarding cost and operational impacts from the growing variety of state and federal PFAS policies and regulations.

The team spoke with staff at 29 solids management facilities or operations. Participants were selected based on their anticipated - and in some cases, already experienced - impacts from PFAS and related policy and regulation. The responses to these surveys were compiled and the response pool evaluated for trends related to PFAS costs, concerns and impacts.

Results of the survey showed similar trends across participants of all management methods and facility types. Many of the contributors to this study were receivers, such as WRRFs, and it became clear that many of these outlets have already seen significant cost impact from having to deal with PFAS. Managing these costs can be a source of contention in many of these situations, with WRRFs concerned about being able to accommodate PFAS treatment and mitigation given existing budget constraints.

Section 2 presents a comprehensive analysis of the results, which are summarized below:

- Average biosolids management cost increased by approximately 37% in response to PFAS concerns
- Facilities which show minimal to no impacts to their management costs generally
  - Manage their biosolids utilizing methods other than beneficial reuse
  - Operate in states that do not yet have quantifiable PFAS regulations
- Beneficial reuse programs appear to experience the most significant cost impacts due to PFAS
- Facilities which reverted to landfill disposal after abatement of beneficial reuse programs have been burdened with biosolids management costs at least double their previous
- Some of the most common concerns regarding the impacts of PFAS regulations expressed by participants were:
  - lack of capacity for biosolids disposal,
  - public perception,
  - political vs. science-based decisions, and
  - liability and cost burden.

Based on the results of the expanded utility survey evaluation in Section 2, the CDM Smith team in collaboration with NEBRA, NACWA and WEF selected nine (9) case study participants. These participants provided additional information for a more thorough evaluation of their current biosolids management practices and the impact on their facility from PFAS thus far. The case study participants included in this report are listed below and a comprehensive summary of each facility is presented in Section 3.

- Concord WRRF, NH
- Essex Junction WRRF, VT
- Lewiston Auburn Water Pollution Control Authority, ME
- Orange County Sanitation District, CA
- Pima County Wastewater Reclamation, AZ
- Upper Blackstone Clean Water, MA
- Wixom Department of Public Works, MI
- Resource Management Incorporated (RMI), New England
- Farm in Central Maine

An additional concern amongst participants included limitations of available technology, as there is no proven or established technology to treat PFAS in wastewater or remove PFAS from biosolids. Commonly used treatment methods for removing PFAS in drinking water have been implemented, studied and examined since PFAS became emerging contaminants of concern in the early 2000s. The same cannot be said of treatment methods for wastewater or biosolid matrices containing PFAS, for which many of the treatment technologies are still emerging and being further investigated. Water treatment technologies such as anion exchange (AIX), granular activated carbon (GAC), and reverse osmosis (RO) are difficult to scale and relate to wastewater treatment standards due to the high total organic carbon (TOC) content in wastewater effluent when compared to typical ground water or surface water influent to a drinking water treatment plant. As a result, implementation of any of these technologies may require some level of additional treatment; coagulation, sand filters, membrane filters, etc., otherwise the PFAS treating technologies may become prohibitively large. These technologies are further evaluated in Section 4.

In conclusion, the purpose of the report is to reveal the economic impact regulations have had and will have on communities, the private sector, and farms that rely on biosolids for their livelihood. The report is intended to be used as a resource for legislators, regulators, and the general public, to promote an informed discussion of these issues and guide and the development of science-based regulations that will protect public health.

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Section 1

Background

1.1 Biosolids

Wastewater Treatment Facilities perform two primary functions. They treat water to a level that allows its re-introduction to surface and/or groundwater, and they treat the solids produced in this process to a level where they can either be recycled or disposed of properly. Both are done in a manner to ensure public safety and environmental protection.

Traditionally, the suspended and dissolved solids in the wastewater treatment process have been called "wastewater solids" . Wastewater treatment operations require careful management of wastewater solids, not only after removal from the treatment process, but also during the treatment process: wastewater solids are a critical biologically active mix of water, organic matter (derived from human wastes, food wastes, etc.), inorganic solids (including trace elements), dead and alive micro-organisms (including pathogens), and trace contaminants (e.g. chemicals). Routinely, some wastewater solids are recycled within the treatment facility process to optimize operations. However, as wastewater solids build up, batches of wastewater solids are removed ("wasted") regularly from the effluent treatment operations. The "raw" wastewater solids are typically 2-3% solids and 97-98% water and must be further treated in order to be utilized in a beneficial manner. It is typically a slightly thick, gray-brown liquid. Most often, wastewater solids are treated in either an aerobic (oxygen-rich) or anaerobic (oxygen-starved) digester to stabilize the material and reduces pathogens (disease-causing organisms). A variety of additional treatment options exist for wastewater solids in order for it to meet federal and state requirements for beneficial use. At the point it satisfies these requirements, the wastewater solids are called "biosolids."

Benefits

Throughout the U. S. and Canada, biosolids (treated and tested wastewater solids), septage, paper mill residuals, composts, and other organic residuals are commonly recycled to soils. This recycling accomplishes many beneficial things:

- enhances soil health
- recycles nutrients (the big three – nitrogen, phosphorus and potassium -- as well as numerous micronutrients such as zinc, iron, manganese and copper)
- sequesters carbon (mitigating climate change)
- reduces fertilizer & pesticide use
- strengthens farm economies (thousands of farmers choose to use biosolids, because they work)
- restores vitality to degraded lands

- puts to productive use residuals that every community has to manage.
  (Wastewater treatment is a vital public health service, and it creates residual solids that have to be managed!)

Sustainability & healthy soils require recycling organic residuals.

Biosolids are the nutrient-rich organic byproducts resulting from wastewater treatment. Biosolids have been treated and tested and meet strict federal and state standards for use as fertilizers and soil amendments. Biosolids provide plant nutrients and organic matter to soils. They can also be used to produce renewable energy through digestion and production of methane ("biogas") or by drying and thermal processing.

There are two classes of biosolids defined by regulations: Class B and Class A.

Class B biosolids still contain some pathogens (but less than untreated animal manures, for example) and must, therefore, be managed at sites with little public contact, in accordance with regulations. Site permits for use of Class B biosolids are required in New England, New York, and eastern Canadian provinces.

Most Class B biosolids are used on farms, in highly-managed forestry/silviculture, and/or for land reclamation work on sites with little public contact. These uses of Class B biosolids are safe, because further reductions in pathogens are achieved by natural forces in the environment - sunshine, competition with other bacteria, and weather conditions - that kill off remaining pathogens.

Class A biosolids are virtually free of pathogens, and some - such as cured composts and heat-dried biosolids pellet fertilizers – can be used anywhere. Class A products also include manure-like products that have been highly treated but may still be odorous and best used and managed like Class B biosolids.

End Use Options

A national survey of biosolids use and disposal (NEBRA et al., 2007) found that, in 2004, about 55% of the wastewater solids produced in the U. S. are treated and recycled to soils as biosolids. About 30% are landfilled and 15% are incinerated. Of the total beneficially used on soils, three-quarters is applied to agricultural land, 22% is distributed to consumers as Class A products, and 3% is used in land reclamation projects.

In many parts of the country, land application has long been, and remains, the simplest, most cost-efficient end use or disposal option for biosolids. However, in many areas, including in the densely populated states on the coasts, there has been a steady reduction in land application of biosolids, especially Class B. For example, in Maine in 1997, Class B land application accounted for 52% of the wastewater solids produced in the state; in 2008, it accounted for 10%. During the same period, Class A biosolids production (including composts) increased from about 30% to 60%, and landfilling increased from almost zero to 30%. Several factors have caused this reduction, including increases in state and local regulations, cost-competitive landfill disposal, concern about liability exposure (landfill disposal carries less), and public scrutiny of land application.

Meanwhile, in the past five years, sustainability and energy efficiency have become larger topics in the wastewater treatment profession. This has led to an increased focus on wastewater solids as a source of energy. As emphasized at the December, 2010 National Biosolids Partnership meeting on "Charting the Future of Biosolids Management," biosolids are increasingly recognized as a resource, and the goal is to maximize the use of all of the following potential beneficial attributes of biosolids, to the extent possible in the local situation:

- Nutrients (nitrogen, phosphorus, and micronutrients such as iron, magnesium, etc.)
- Organic matter (important for building healthy soils)
- Energy (a renewable source; 5,000 - 10,000 Btu / dry pound, similar to low-grade coal)
- Water (most valuable in dryland agriculture)
- Binding sites (reducing bioavailability of trace contaminants such as lead, mercury, and trace synthetic chemicals).

With the increased interest in sustainability have come advancements in research and technology. Tried and true biosolids treatment processes - such as lime stabilization, anaerobic digestion, composting, incineration, thickening, and dewatering - are being refined and enhanced to make them more energy efficient and cost effective. Newer treatment technologies are taking hold, including dewatering screw presses, a variety of smaller efficient heat drying systems, and systems for conditioning solids to improve anaerobic digestion. Technologies in the development stage include wastewater solids gasification and systems that harvest nutrients to create fertilizer products.

It is an exciting time for biosolids management! This document provides a summary of many of the current trends in technologies, end uses, and disposal options. See also the report from the "Charting the Future of Biosolids Management" forum held December 2nd and 3rd, 2010, in Alexandria, VA.

PFAS

In recent years, Per- and Polyfluoroalkyl substance (PFAS) have become a topic of public concern, particularly when they are discovered in community drinking water supplies. PFAS have been manufactured and used in various industries around the world since the 1940s. Their prevalence in the environment have raised concerns about the possibility of adverse health impacts which has led to many ongoing toxicological studies.

In 2016 after completing a comprehensive toxicology study, the EPA published Drinking Water Health Advisories for perfluorooctanoic acid (PFOA) and perfluorooctane sulfonate (PFOS) setting the level for the two compounds combined at 70 parts per trillion (ppt). Then in February 2019 EPA issued its PFAS Action plan. The plan included a goal to move forward with a regulatory determination for PFOA and PFOS limits in drinking water. In the meanwhile, many states have moved forward with their own limits and regulations, many well below the EPAs 70 ppt health advisory. Many of these limits have had major impacts on biosolids beneficial use programs with reductions in land application of the material. This has led to a reversal of all the sustainable and environmentally friendly efforts created by the beneficial use programs. So, the purpose of this report was to investigate the economic impact these regulations have had and will have on communities, the private sector, and farms that rely on biosolids for their livelihood. The hope is that it can be used to inform the public, politicians and regulatory bodies in developing regulations based on science that will protect public health while being science based and benefiting the environment as a whole. Regulators need to provide communities with the tools they need to limit the release of these substances at their sources, and to educate the public on the impact many of these consumer products have on the environment.

Source Control

The National Association of Clean Water Agencies (NACWA) and the Water Environment Federation (WEF) published the following statement in a letter dated May 21, 2019. The letter summarizes their position and recommendations to the Senate Environment and Public Works Committee Hearing Entitled "Examining Legislation to Address the Risks Associated with Per- and Polyfluoroalkyl Substances (PFAS)":

> *"The PFAS family constitutes a suite of more than 3,000 known chemical varieties that have been in production and in the environment since the 1940s. Recently, these chemicals have been detected in elevated concentrations in groundwater in certain parts of the country, especially near airports and military bases where aqueous film forming foams (AFFF) were used as well as near industrial manufacturing sites.*
>
> *These synthetic chemical substances are engineered and utilized specifically for their strong carbon-fluorine bonds which are enormously effective at resisting heat, water, and oil. As such, PFAS chemicals are commonly found in everyday consumer products including fast food containers, nonstick cookware, stain resistant coatings, water resistant clothing and personal care products. Due to their chemical structure and their commercial value and use, PFAS are ubiquitous in the environment. They are also persistent, bioaccumulate, and do not readily degrade.*
>
> *NACWA and WEF submitted comments to the U.S. Environmental Protection Agency (EPA) in 2018 urging the Agency to develop a federal response that appropriately reflects the risks posed by PFAS, close the unresolved scientific gaps—including fate, transport, and toxicity of PFAS using a science based approach—and evaluate the appropriate regulatory response to target the sources of PFAS and responsible disposal techniques."*

Resources utilized:

NACWA & WEF, PFAS ISSUE BACKGROUND AND ADVOCACY ASKS (2019), available at https://www.waterweek.us/wp-content/uploads/2019/04/pfas-3-onepager-1-FINAL-web.pdf

Section 2

Data on Actual Costs to Wastewater and Biosolids Management Programs from PFAS

2.1 Introduction

Task 1 consisted of close coordination with NEBRA, WEF, and NACWA staff to identify facilities across the country who have been impacted by PFAS and utilized the results from an online survey issued by NEBRA to develop and implement an in-depth survey of the affected facilities. The CDM Smith team contacted impacted parties such as WRRFs, residuals haulers, biosolids land appliers, and facilities dedicated to end use (incineration, compost, landfill, farms, etc.) and requested detailed information regarding cost and operational impacts from the growing variety of state and federal PFAS policies and regulations.

This section summarizes the work completed under Task 1 and presents an analysis of existing costs and cost trends to help understand operational impacts of PFAS policies and/or regulations on municipalities and utilities.

2.2 NEBRA Survey

2.2.1 Background

NEBRA provided CDM Smith with the results of a survey issued to various contacts connected to the association. This electronic survey consisted of 7 questions which included yes or no, open-ended, and multiple-choice questions. While response rates differed depending on the question, NEBRA was able to collect responses from 54 respondents. CDM Smith evaluated the results and used them to aid in the development of the expanded survey.

The seven questions included in the electronic survey were as follows:

1. In the past 2 years, have your operations managing wastewater and/or wastewater solids (sludge, biosolids, other residuals) changed in any way because of concerns about PFAS?

2. Indicate the former cost of managing solids/biosolids (e.g. in 2017 or 2018), using whatever measure you use (e.g. cost paid per wet ton to a contractor or tip fee at a landfill or total per-ton cost for managing solids).

3. What is the cost now, in 2019 or going into 2020, of managing solids/biosolids, using the same measure you used above?

4. Which of the following are you most concerned about, related to PFAS and biosolids/residuals/wastewater management?

5. Please let us know what you're experiencing! Add comments regarding PFAS & wastewater/residuals/biosolids management.

6. What is your role(s) in biosolids/residuals/wastewater management?

7. Where are you located?

2.2.2 Results

Based on the participant's responses, CDM Smith was able to evaluate the online survey results and extrapolate qualitative results. These results are summarized below in a bulleted list. However, it should be noted that the response rates differed depending on the question as participants could skip questions. It is also important to emphasize that these respondents are a self-selected sample of WRRFs – they volunteered to complete the online survey – and their responses are not representative of all WRRFs. Those responding are likely doing so because of increased knowledge and impacts related to PFAS. We are aware that the number of WRRFs impacted by PFAS remains relatively small, but it appears to be growing.

- In the past 2 years approximately half of the respondents have changed their operation for managing wastewater and/or biosolids due to PFAS concerns.
- Those who have not yet been operationally impacted left comments that they anticipate being impacted or have halted any proposed management changes as a result of uncertainty related to PFAS and related policies.
- Reoccurring trends across the impacted facilities included: increased management cost, limitations on septage and leachate acceptance, limitations on land application, moving towards landfill disposal, and increased concerns about public perception related to recycling biosolids.

2.3 Expanded Utility Survey

2.3.1 Background

CDM Smith in collaboration with NEBRA, WEF and NACWA compiled a list of potentially impacted facilities that were potential participants for an expanded survey. The team spoke with staff at 29 solids management facilities or operations; the responses were compiled and are presented both qualitatively and quantitatively below. Participants were selected based on their anticipated - and in some cases, already experienced - impacts from PFAS and related policy and regulation. The list of questions developed which helped to guide the discussions with each facility are below:

1. How are biosolids currently managed at your facility?

2. Has your facility/organization's management of wastewater and/or wastewater solids been affected by PFAS concerns or regulations? Has your end use site changed? Are you considering a change in response?

3. What were your biosolids end use costs before PFAS policies/regulations? (in 2017, 2018 and 2019 specifically)

4. What are your solids/biosolids management costs now "leaving the gate?"

5. Have you seen any impacts on your revenue (acceptance of leachate, septage, outside sludge, sale of compost, etc.) as a result of PFAS policies/regulations?
6. What are your greatest concerns related to PFAS and biosolids/residuals/wastewater management?
7. What challenges, if any, do you foresee facing as PFAS policies or regulations as enacted?
8. Have you participated in any discussions or activities with regulators regarding PFAS policies/regulations? If yes, please estimate staff time and costs.
9. Are you concerned with the longevity or diversity of your current outlets and/or beneficial use programs?
10. Have you already made capital investments attributed to PFAS concerns?
11. Type of Facility/Location/Size.

For purposes of this study and the outreach with each entity the metric used when discussing end use cost was dollar per wet ton ($/wt). This was the unit most commonly used amongst all those interviewed and is inclusive of the entire product being handled (wastewater solids or biosolids and the interstitial water). This is most relevant when the cost is inclusive of travel or hauling costs, where a significant percent of the overall cost may be associated with travel to the end use site. It is also a consistent metric that allows all of these entities to be compared to one another

The responses to these questions were compiled and the response pool evaluated for trends related to PFAS costs, concerns and impacts. The observations are presented in the following sections. A full record of the participant interviews and an overall facility summary are appended to this report in Appendix A.

2.3.2 Results

Results from the survey showed similar trends across participants regardless of management methods and facility types. Many of the contributors to this study were receivers, such as WRRFs, and it became clear that many of these outlets have already seen significant cost impact from having to deal with PFAS. Managing these costs can be a source of strife in many of these situations, with WRRFs concerned about where in their budget they will have room for PFAS treatment. Some may suggest that WRRFs are, by design, receivers of wastes that are generated by their customers. Further complicating this argument, however, is whether it is reasonable for WRRFs to receive and treat something "new," like PFAS, or whether that will be too difficult and costly and that other ways – such as source control and/or pretreatment – are the rational and most cost-effective approaches. These are questions that facilities continue to face as policies and regulations are enforced.

2.3.2.1 Cost Implications of PFAS in Biosolids

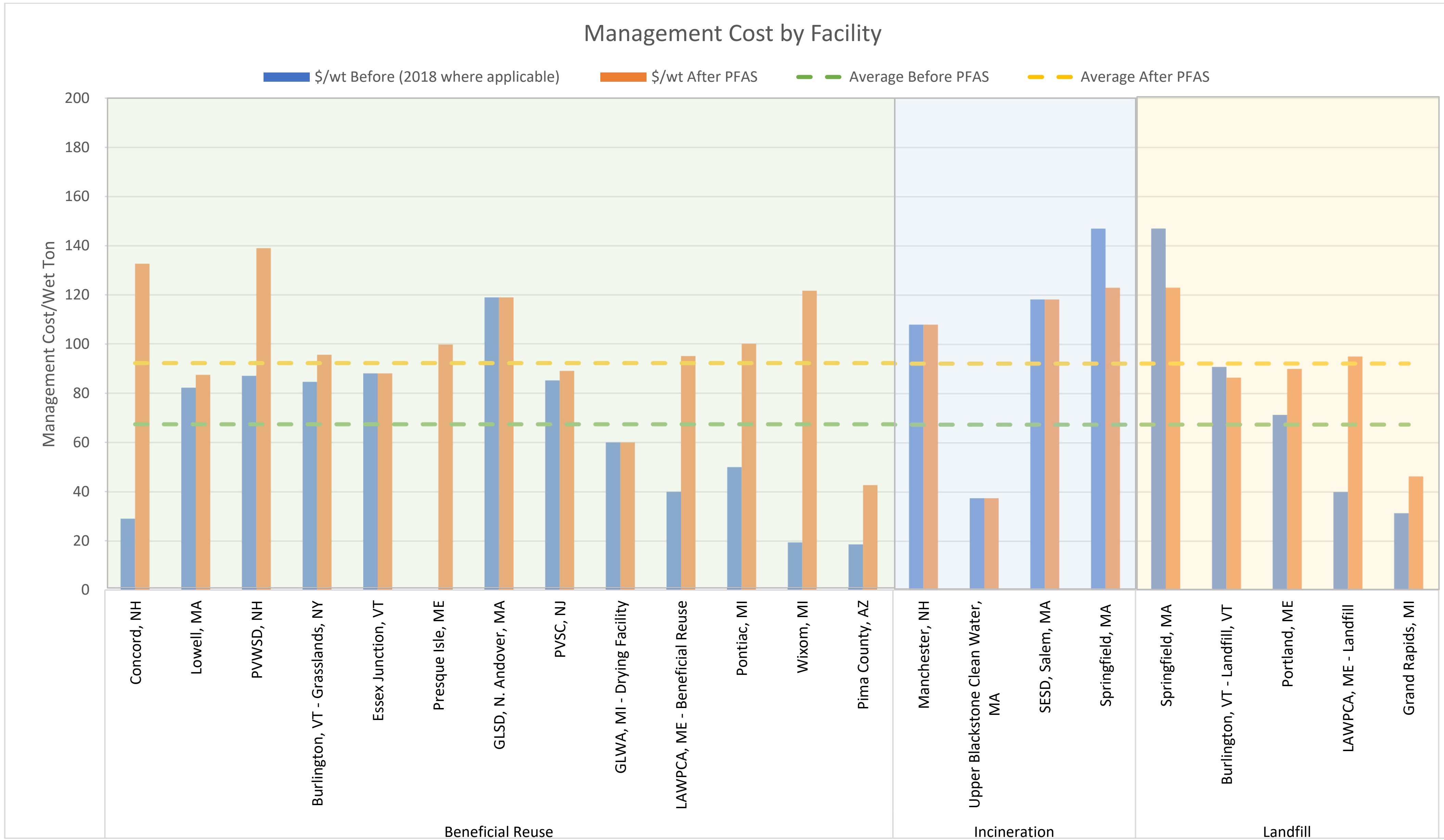
While many of the questions and subsequent responses were more qualitative than quantitative, most of the facilities were able to provide some quantitative management costs pre- and post-PFAS concerns. The cost information allowed for evaluation of the impacts of PFAS regulations on the biosolids management market so far and serves as a forecast tool for anticipated future costs if regulations proceed as proposed. The management costs provided by survey respondents were converted, for consistency, into terms of cost per wet ton of solids or biosolids leaving the WRRF property (**Figure 2-1**). The facilities are broken into groupings based on their management method.

Based on the data provided, the average management cost across the facilities surveyed increased by approximately 37% in response to PFAS regulations. These regulations varied in nature from those directly impacting biosolids management options, to others regulating ground water and inadvertently impacting biosolids land application programs. Some facilities have seen an increase much greater than 37%. In the solids management marketplace over the past couple of decades, there have been no such dramatic cost increases. The closest comparison, was in New England in 2016 when the sewage sludge incinerator (SSI) air pollution control regulations came into effect and incinerators were forced to shut down temporarily for upgrades which created a lack of sludge capacity in the region and drove up biosolids end use costs.

One example, a facility in Wixom, MI, is among the most heavily impacted- showing an increase in management cost per wet ton (wt) six times what the facility paid prior to the PFAS worries. This jump in cost was from $20/wt in 2018 to $120/wt after PFAS regulations. This facility is on the upper end of the spectrum. But several other facilities in states on the forefront of PFAS policy and regulation, such as Michigan, have experienced management cost increases on the order of two times or more.

Alternatively, some other facilities interviewed for this report show minimal to no impacts to their management costs. These are generally facilities that manage their biosolids utilizing methods other than beneficial reuse and/or operate in states that do not yet have quantifiable PFAS regulations. In the case of Springfield, MA the data displays a decrease in management cost. The Springfield Water and Sewer Commission currently manages biosolids through a contract operator who is responsible for finding an end use location for the product, generally a landfill or incineration facility. The Springfield facility was approaching the end of contract negotiations at the time of this study. Springfield's new contract had restructured the 20-year old biosolids section in response to market and regulatory changes. The previous contract and management cost included the contractor's risk and responsibility which prevented the Commission from fully understanding the cost per ton due to associated service fees built in. Subsequently, this new proposed contract allows for competitive bidding while the Commission continues to assess the market and plan for the future, eliminating the originally built-in risk fees and allowing the Commission more long-term flexibility. As a result, the proposed corresponding management cost is anticipated to decrease. Springfield is an example of facilities that were in the process of updating their solids management contracts when the PFAS scare hit, and they moved forward as best they could amidst the uncertainty of what PFAS means with relation to risks involved in management wastewater solids.

Overall, the impact to each facility varies depending on the type of management method and geographic location of the facility, among other contributing factors. However, Figure 2-1 presents clear evidence of significant cost impacts for biosolids management related to the promulgation of PFAS policies and regulations.



[1] Facilities with more than one biosolids processing method are listed under both management designations

Figure 2-1. Comparison of biosolids handling costs before and after PFAS concerns by end-use method.

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Figure 2-2 presents the same data from Figure 2-1 with an emphasis on state-by-state impacts. In grouping the facilities by state, it becomes clear that some states' PFAS responses have caused significant impacts on solids management costs while others have not.

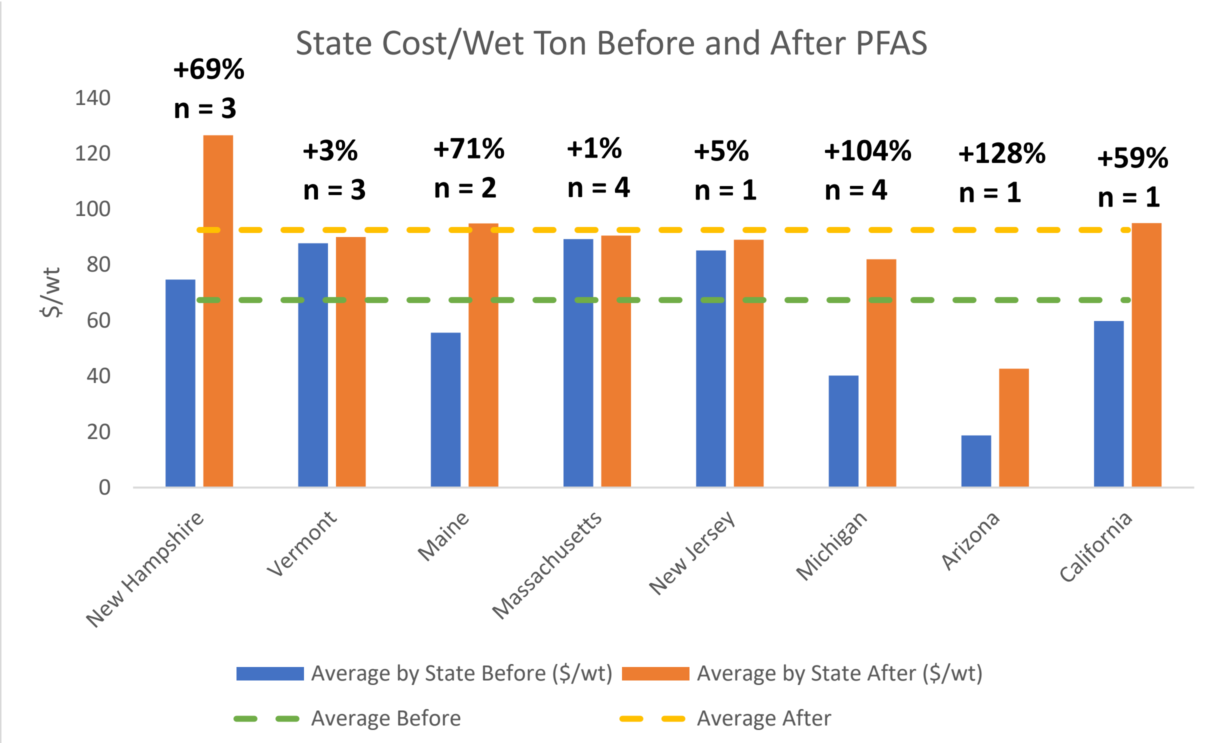

Figure 2-2. Comparison of average biosolids handling cost before and after PFAS concerns by state.

Though sample sizes were small, Figure 2-2 provides a qualitative sense of the varying degrees of impact in different states that agrees with stakeholders' perception of the impacts of PFAS actions. Notable conclusions from Figure 2-2 include Michigan and Arizona coming in as the most impacted states, both with an average of more than two times the management cost after PFAS impacts. Other significantly impacted states include New Hampshire and Maine who've experienced a 69% and 71% increase in management cost, respectively.

On the federal level, regulations have not been promulgated for PFAS in biosolids. The state-specific regulations and guidelines that have been proposed or enacted involve various concentration limits of different PFAS compounds in drinking water, groundwater, and, in a few cases, surface water. Only Maine has imposed a limit on three PFAS compounds in biosolids, and no state has imposed wastewater effluent standards. Nonetheless, the very low regulatory standards for waters that several states have adopted, including most of those included in Figure 2-2, are causing wastewater and biosolids management programs significant cost impacts. In the absence of national regulatory standards, individual states are taking action, and the future of PFAS standards is unclear – and varied. WRRFs and biosolids management programs are being forced to take into consideration current and/or anticipated state PFAS regulations which is why some states have already experienced a significant cost impact while others have not. The unintended consequences of proactively addressing PFAS with water quality standard include these increases in wastewater solids management costs, as observed in Figure 2-2. As states continue to set regulatory limits for PFAS, the wastewater and biosolids management markets will continue to assess the risks and liabilities around their programs. Regulating PFAS at stringent levels will significantly disrupt markets if WRRFs and other receivers of PFAS aren't provided additional management, compliance, or treatment options and funding for transitioning to managing materials for PFAS.

Figure 2-3 aids in understanding the extent of rate increases in those facilities which had to abandon their beneficial reuse program and secure another outlet, which in all cases ended up resulting in landfill disposal.

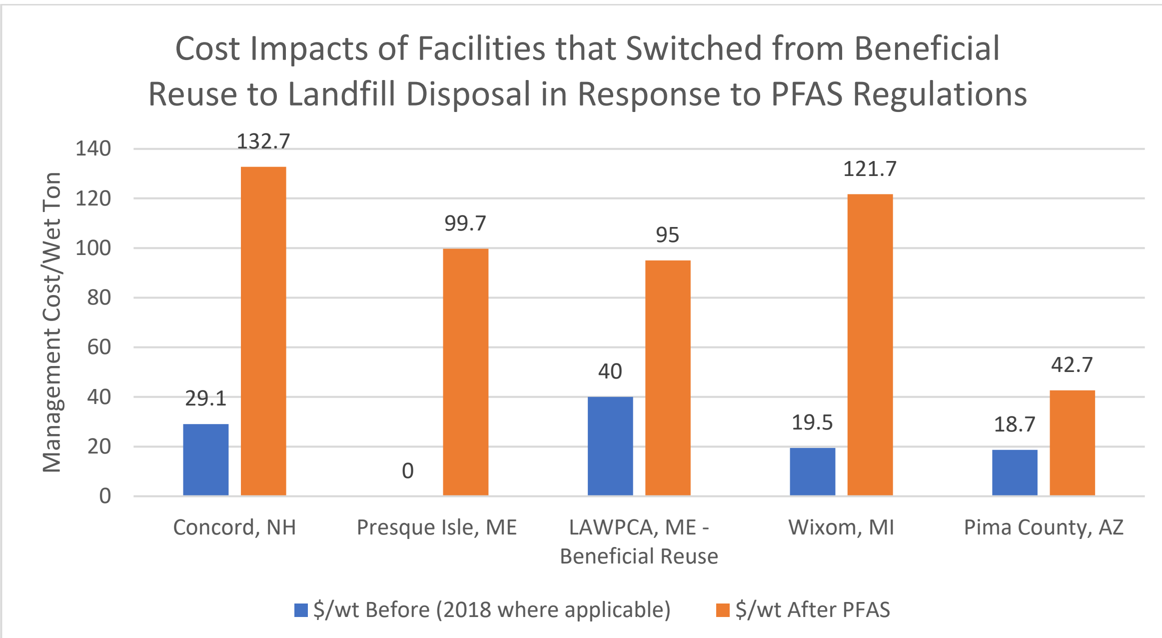

Figure 2-3. Comparison of biosolids disposal costs before and after PFAS concerns for facilities that switched from beneficial reuse to landfill disposal methods.

Figure 2-3 presents the cost impacts on facilities which have changed their end use from beneficial reuse to landfill disposal. Beneficial reuse programs appear to suffer the most significant cost impacts due to PFAS, as observed in Figure 2-1 and further confirmed by Figure 2-3. These facilities which have reverted to landfill disposal after choosing to abandon beneficial reuse programs have been burdened with management costs at least double what they used to pay. For example, beginning July 1st, 2020, Concord, NH – a city of almost 44,000 people – began paying 3.5 times as much per wet ton – meaning a total of $600,000 more per year – for managing their biosolids.

Residual haulers and management companies such as Denali Water Solutions, Casella and Resource Management Incorporated (RMI) provided perspective to the project team that allowed for a full understanding of PFAS regulatory impacts to the market as a whole. While most of their responses were not quantifiable in a material way due to the variety of facilities, generators and customers that they service, notable trends amongst these companies were evident. For example, residual haulers and management companies that operate beneficial reuse programs experienced significant revenue impacts, while those who operate or dispose of the material at outlets such as landfills have borne less impact from PFAS concerns.

Casella, which operates a number of compost and landfill facilities has experienced demand from customers to limit the total amount of PFAS in the final product being distributed, resulting in the sale of more blended products. Additionally, Casella has utilized their growing network to redistribute the material across multiple outlets and farther locations where there is more willingness to accept the product. Unfortunately, this has led to increased costs in handling and transporting the materials and increased fees to customers.

Denali, who appears to have been the least impacted by PFAS regulations thus far out of the residual haulers surveyed, shared experiences and concerns for the future of the market. The company operates several facilities nationally and participates in land application, alkaline stabilization, composting - and more recently - a gasification and pyrolysis partnership to further diversify their biosolids management options. Representatives from Denali noted that most of the facilities they operate had yet to be impacted by PFAS concerns, aside from one or two. Of these facilities, one is located at a service center in Michigan containing a landfill, ponds, and a compost operation. Denali operates the compost operation and experienced their first encounter with PFAS concerns when the City decided to clean out the ponds onsite and opted to test the dredge material and other material, such as compost, for PFAS. The results came back with detectable levels of PFAS in both materials. In response, the City decided to notify residents via a sign at the gate to the compost facility, stating the presence of PFAS.

RMI, a New England-based company that manages 70,000 wet tons per year of biosolids and other residuals through land application, has borne substantial cost impacts due to PFAS concerns. The company, which manages a variety of different generators' biosolids in the region, has had to raise their rates by at least double and in some cases by three to four times the pre-PFAS rates.

The impacts on a company like RMI or others with similar business models who might be restricted from recycling biosolids because of PFAS concerns are potentially enormous. Beneficial use has been slowly expanding throughout North America, because it is generally seen as the most environmentally sound option for management of wastewater solids, providing numerous proven benefits that are critical to the circular economy and sustainability. The emergence of PFAS as a worry and regulatory reactions have the potential to significantly reduce beneficial uses. The loss of that option and of the companies that have successfully offered it for decades would be detrimental to the solids management market, local economies, and progress toward sustainability.

> "If biosolids were banned from land application, we would need an additional 500,000 cubic yards of landfill air space every year to manage [Wisconsin's] sludge…"
>
> Coalition of Solid Waste & Wastewater Organizations, PFAS Webinar, July 29, 2020, https://www.wcswma.org/

2.3.2.2 Qualitative Survey Results and Associated Trends

The potential consequences of regulating PFAS in biosolids before fully understanding the impacts to the market don't stop with the cost implications presented above. Additional concerns, as outlined by surveyed participants are:

- Lack of available capacity for the sheer volume of biosolids and uncertainty about the longevity of current solids management outlets. There are only three options: beneficial use (e.g. land application, composting, etc.), landfill disposal, and incineration. All have their risks and benefits.
- The environmental impact of abating beneficial reuse programs and turning to disposal or incineration methods.
- Public perception and politics driving policy and regulations.
- The inability to manage PFAS in biosolids at the source due to lack of public education and engagement.
- Not making science or knowledge-based decisions.
- The lack of a universal EPA-approved testing method for PFAS in wastewater and solids. (The only available EPA-approved method as of August 2020 is for drinking water specifically.)
- Very low regulatory limits for PFAS in water being adopted by some states not being achievable.
- Drinking water PFAS standards universally applied to all regulated entities.
- Limitations of available technology commonly used for PFAS removal in drinking water and the incompatibility with wastewater matrices. For example, there is no proven technology to treat PFAS in wastewater (See Section 4 for additional detail).
- Liability and making those who receive PFAS responsible for removing it.

The word clouds in **Figures 2-4 and 2-5** display the most common key words stated by participants when answering the survey questions regarding their greatest concerns related to PFAS and biosolids management (Figure 2-4) and the challenges they foresee facing as PFAS policies/regulations are enacted (Figure 2-5). The word clouds display key words that were mentioned two or more times throughout all survey responses. Synonyms were combined under the representation of one word upon verifying they were used in similar context (e.g. "limits" and "levels"). The larger the word, the more frequently it was used. The words used to make each word cloud and their frequency of use are displayed in Tables 2-1 and 2-2.

Figure 2-4. Word cloud displaying the most common (mentioned more than once) responses to the survey question, "What are your greatest concerns related to PFAS and biosolids/residuals/wastewater management?" The frequency table used to make this figure can be found in Appendix B (Table B-1).

Figure 2-5. Word cloud displaying the most common (mentioned more than once) responses to the survey question, "What challenges, if any, do you foresee facing as PFAS policies or regulations are enacted?" The frequency table used to make this figure can be found in Appendix B (Table B-2).

In **Figure 2-4**, the words, “regulations,” “cost,” “impact,” “science,” and “liability” were some of the most used terms when participants discussed their concerns. This is reflective of common participant statements regarding the need for science-based regulations and the fears of liability and financial impacts. Similarly, **Figure 2-5** shows high frequency in the use of the words “regulations” and “cost,” suggesting that the most common challenge facilities foresee facing are the financial impacts of PFAS regulations.

2.3.3 Next Steps

Based on the results of the expanded utility survey evaluation in Section 2, the CDM Smith team in collaboration with NEBRA, NACWA and WEF selected nine (9) case study participants. These participants provided additional information for a more thorough evaluation of their current biosolids management practices and the impact on their facility from PFAS thus far. These case studies provide a comprehensive understanding of each facility and are presented in Section 3.

Section 3

Case Studies

3.1 Water Resource Recovery Facilities, Concord, New Hampshire

Brief Background

- Concord, NH has two facilities, the main WRRF (Hall Street) was built in 1979 and provides treatment for Concord and portions of Bow. The second wastewater treatment facility located in Penacook was originally built in 1973 and services the Penacook area of Concord and a portion of Boscawen. The biosolids produced from both facilities are processed at the Hall Street facility and, as of July 1, 2020, the City is under contract with a facility in Canada which uses the material to make compost.

PFAS Management Impacts

- Concord participated in a land application program that began in 1980 and up until April 2020 was still active. Initially, this was a Class B program, but an advanced alkaline treatment system has been producing Class A bulk biosolids in Concord for about 20 years.

- Approximately two years ago, the New Hampshire Department of Environmental Services (NHDES) concluded that Concord was a contributor to PFAS contamination at surface drinking water well in close proximity to a biosolids land application site. The level of PFAS in the well was right near the screening standard at the time, and there remains some uncertainty about the source(s) of the PFAS. Biosolids from other sources, including the NHDES-operated facility in Franklin, had also been applied at this site.

- The experience with NHDES resulted in Concord installing a point of entry treatment and monitoring system for the well, until PFAS levels reached half of the then Health Advisory (HA) of 70 ppt issued by the EPA.

- After compliance with NHDES' request, the City made a risk- and liability- reduction-decision to abate their land application program and began hauling their biosolids to Canada for management.

- More recently, the City renegotiated their contract for managing landfill leachate, resulting in increased costs to the landfill and while PFAS played a role in these rate increases, they were not the major driver.

- The City of Concord is most concerned about future PFAS impacts such as:

  - Surface water standards.

  - The long-term reliability of their current outlet, specifically because their management method is out of the country.

- Not having a back-up plan for the worst-case scenario.

Cost Impacts

- Concord, NH experienced a significant cost impact after making the risk- and liability-related decision to shift their end use site.
- Prior to PFAS concerns, the City was paying $29.10 per ton for a private management company to handle its biosolids.
- After PFAS concerns came to light, a $35.00 PFAS management fee was added to the cost per ton.
- When the City changed end use sites and began hauling to Canada the resulting cost was $132.65 per ton. Equivalent to a $600,000 per year increase due to PFAS.
- Additionally, there is a clause in the contract that if PFAS regulations come to fruition in Canada, the contractor can increase the management cost.
- The staff time associated with participation in PFAS activities is worth hundreds of hours. The superintendent has invested a minimum of four hours per week for the last couple years.
- A sampling collection study resulting from PFAS concerns costs the City approximately $10,000 per year.

Background

- Facility website: https://www.concordnh.gov/1353/Wastewater-Treatment.
- Both facilities have provided wastewater management services to customers for over 40 years.
- Hall Street Facility:
  - Designed for a capacity of 10.1 mgd and a peak flow capacity of 25 mgd.
  - Currently, the plant treats an average of 4 mgd.
  - Various off-site waste streams are accepted at the facility including approximately 5 million gallons of landfill leachate per year and 2 million gallons of domestic septage from nearby communities.
  - Annually, the facility generates approximately 7,500 wet tons of lime stabilized biosolids. This was reduced to 5,000 wet tons when the decision to transport to Canada was taken as the stabilization process with lime was no longer needed.
  - The facility occupies 28 acres of land and the City owns another 75 acres outside the bounds of the facility which they use as wooded area or farmland.
  - Treatment Process

- *Preliminary Treatment: bar screens for removal of coarse material and an aerated grit tank for inorganic material removal*
- *Primary Clarification: primary clarifiers are used to settle out solids which are collected and pumped to the sludge holding tank for processing*
- *Sludge Processing: solids are transferred to the processing tanks, heated and mixed to create stabilized biosolids which can be recycled for beneficial reuse*
- *Secondary Treatment: wastewater from primary clarification is mixed with RAS and pumped to one of two biotowers. The biofilm on the plastic media consists of bacterial organisms that feed on organic material in the wastewater. Afterwards, the flow is sent to aeration basins to encourage bacteria growth and removal of remaining organic materials.*
- *Secondary Clarification: flow is sent to two of the three secondary clarifiers where the wastewater is settled and separated from the bacteria*
- *Disinfection: the treated wastewater flows from secondary clarification to the chlorination building for disinfection using sodium hypochlorite*

- Penacook Facility:
  - Originally built to treat a significant industrial discharge from the now-closed Allied Leather Tannery, the facility has seen a significant decrease in flow since 1987 when the tannery closed
  - Designed for a treatment capacity of 1.2 million gallons, the facility treats an average of 300,000 gallons per day
  - Former primary clarifier and aeration tank are utilized for storage during high flow occurrences in the early spring
  - Treatment Process
    - *Preliminary Treatment: mechanical bar screen for removal of coarse material.*
    - *Sequencing Batch Reactor: two sequencing batch reactors (SBRs), one of which always accepts flow. The SBRs utilize naturally occurring bacteria to breakdown organics in the wastewater. Bacteria and inorganic material all settled to the bottom.*
    - *Flow Equalization: flow from the top of the SBRs is sent to one of two flow equalization tanks to allow for constant effluent flow production.*
    - *Disinfection: the treated wastewater flows from the equalization tanks and sodium hypochlorite is dosed and sent to the contact tanks.*

3.2 Water Resource Recovery Facility Essex Junction, Vermont

Brief Background

- The Village of Essex Junction Water Resource Recovery Facility is a 3.3 MGD advanced treatment facility that serves the Village of Essex Junction and the towns of Williston and Essex, VT. This facility has long been promoting sustainability with anaerobic digestion producing renewable, green energy followed by land application of liquid biosolids.

- Sludge at this facility is anaerobically digested to create Class B biosolids, as defined under EPA Part 503. The resulting biosolids are managed in two ways. Liquid biosolids are land applied and the remaining solids dewatered and transported off-site to a contractor for further processing to a Class A biosolid.

- For Essex Junction, the land application of solids is a more sustainable and cost-effective means of management than dewatering them and shipping them to a third party. Land application provides the facility with a local management option, a win-win situation which benefits the local community. Local MS4 stormwater criteria and property nutrient management plans are also an important consideration. The land application site owner's economics are supported in part by the biosolids land application program. Previously, the land application site received 1,400,000 to 1,500,000 gallons of biosolids per year.

- The biosolids sent to the third party are dewatered to a 25% solids cake and delivered to a nearby facility operated by Casella that utilizes the BioSet process.

PFAS Management Impacts

- In 2017, legislation was introduced in the Vermont House of Representatives initiating a discussion about banning land application of biosolids. At about the same time, the PFAS issue began to enter public discussion with discoveries of industrial PFAS contamination at Hoosick Falls, NY, and North Bennington, VT. Public and legislative pressure led the Vermont Department of Environmental Conservation (VT DEC) to impose one of the strictest groundwater standards in the world: 20 ng/L (ppt) for the sum of five PFAS. 50% of Vermont gets its drinking water from groundwater wells, and the state is trying to protect drinking water in particular. Regulatory change has led to a reduction in available land for local nutrient recycling via land application of biosolids.

- The reduction of land application acreage has impacts on others besides the Essex Junction WRRF. Septage land application has also been substantially impacted in Vermont because of the new PFAS groundwater standards. After site analysis many septage land applicable sites were rendered unusable after years of land application. Now septage is being be disposed of at multiple WRRFs in the area. Those facilities are now tasked with accepting the potential PFAS liability for septage from unknown sources with unknown levels of emerging contaminants. Essex Junction and other facilities are currently considering increasing the rates they charge for septage due to concerns of PFAS loads from septic haulers. This could impact the septage hauling businesses and homeowners who should be encouraged to pump out their septic systems, not discouraged by increasing prices. Few WRRF's in Vermont are required to accept septage.

Cost Impacts

- The cost for disposing of dewatered cake has not yet been impacted by PFAS regulations.
- The cost for liquid land application has increased by 35% due to PFAS specific analysis. This price increase is based on one Spring land application cycle and is not yet annualized. Permit stipulations are still pending, so Essex Junction is waiting to see what the true impacts will be.
- Though Essex Junction has not yet made any biosolids management capital investments attributed to PFAS concerns, if they are forced to haul longer distances, they would consider one of the emerging evaporative condensing drier technologies.

Background

- The Essex Junction Water Resource Recovery Facility began treating wastewater in 1965 with its original treatment plant. Since then, the facility has undergone several modifications, the most recent beginning in 2012 with a $15.3 million maintenance upgrade to rehabilitate existing equipment and adding new replacement treatment processes designed for long-term service to the community. This project included upgrades to the primary and secondary clarifiers and aeration tanks, new tertiary filters (Aqua-Aerobic Systems), an Alfa Laval G2 centrifuge for biosolids dewatering, new chemical feed pumps, refurbishment of the two existing Infilco Degremont anaerobic digesters (SUEZ), and a new grit collector system.
- The anaerobic digestion process results in the production of methane gas, which is harvested and used to run a methane CoGeneration Combined Heat and Power (CHP) system and dual fuel boilers that heat the digester and the control building. The electricity generated is used on site. Surplus heat is used for process buildings and reduces greenhouse gas emissions from the facility.
- Essex Junction is only one of a few communities in Vermont that recycle their biosolids locally. However, in 2018, by dry weight,approximately 69% of Vermont biosolids were disposed in landfills, 2% incinerated, and 29% went to land application as a Class A EQ Biosolids

3.3 Lewiston Auburn Water Pollution Control Authority, Maine

Brief Background

- 14.2 MGD plant servicing residential, commercial, and industrial sources in the cities of Lewiston and Auburn, Maine. In 2013, LAWPCA became the first municipal wastewater treatment operation in Maine to process solids through anaerobic digestion. For this, LAWPCA was recognized in 2014 with a Governor's Award for Environmental Excellence.

PFAS Management Impacts

- LAWPCA's compost facility has been in operation since 1993. Here, biosolids are converted to Class A compost ("Maine Grow") to be sold to contractors, landscapers, and the general. LAWPA has been composting and land applying their solids for 25-30 years.

- In 2013, LAWPCA moved to anaerobic digestion. This cut their biosolids production in half and they went to 100% land application. From 2013-2018, LAWPCA ran their composting facility essentially as a merchant facility, accepting in-state wastewater solids brokered by Casella Organics who supplied the materials for 5 years. Financially, the compost facility was breaking even.

- In 2018, DEP required the compost facility stop processing material due to high concentrations of nitrate in the groundwater at the compost facility, which was apparently caused by leaks from the biofilter. An alternative odor control system would have been needed to continue composting operations, and that did not make sense financially.

- In 2018, Maine Department of Environmental Protection (DEP) set the following screening standards for PFAS in Chapter 418 Beneficial Use of Solid wastes: 1,900 ppb PFBS; 5.2 ppb PFOS; and 2.5 ppb PFOA. These standards were set at one-half the risk standard used by the DEP for clean-up sites contaminated with hazardous substances. In March 2019, the Maine DEP required that all biosolids programs with licenses for beneficial reuse test their biosolids for PFOA, PFOS, and PFBS and suspend all application of biosolids. This included suspending biosolids compost sales until after sampling and analysis confirmed concentrations were below DEP standards or alternative requirements were met for cumulative loadings. As a result, LAWPCA's land application program was shut down.

- In September 2019, LAWPCA received approval from DEP to run a pilot at the compost facility (after it had been shut down for nearly a year) with LAWPCA anaerobic digested wastewater solids and no odor control (Sept 2019 – Jan 2020). The pilot was successful, and DEP put an amendment into the facility's license in June 2020 so it could continue to operate. However, LAWPCA has since paused the use of their compost facility primarily to the PFAS issue. They are currently conducting a feasibility study for the implementation of a solids dryer to reduce the volume of biosolids that may need to be landfilled moving forward.

- Because of these new PFAS requirements, in 2019 LAWPCA went from land applying and composting 100% of their biosolids, to land applying 35%, composting 52%, and landfilling 12%. Not knowing where the PFAS issue is going, they have had conversations about abandoning land application. Land application was ideal financially and environmentally, and composting was a solid "just in case we need it" backup option. Landfilling was always a last resort.

Table 3-1 Pre/Post Biosolids Management

Pre-PFAS Biosolids Management			Post-PFAS Biosolids Management		
Land Application	Composting	Landfill	Land Application	Composting	Landfill
50%	50%	0%	25-35%	52%	12% (*up to 80% during July-Dec 2020)
$30-$35/wet ton	$50/wet ton	N/A	$30-$35/wet ton	$50/wet ton	$70-$75/wet ton
$41.25/wet ton			$46.08/wet ton		

- The abrupt PFAS scare discouraged a majority of the farmers that LAWPCA had worked with for years. The mere perception of contamination on a dairy farm could ruin the farm's business. One farm caught up in the PFAS scare was forced to dump $25,000 worth of milk, which the dairy corporative that imposed the milk-dumping requirement paid for.

- During 2019 and into 2020, PFAS has taken up a large percentage of the time of several LAWPCA staff. They have been watching webinars and joining PFAS discussions with regulators and local/regional wastewater associations. It is consuming their time as they reel back from the impact on their land application program and what the changes mean for staffing and budgeting. Up until COVID-19 hit in March 2020, PFAS was the dominating hot topic.

- LAWPCA is utilizing limited landfill space, which impacts Maine and the entire region. The changes are also impacting the ~15 farmers that relied on the LAWPCA biosolids for fertilizer. During the period of July 2020 through December 2020, LAWPCA signed an agreement to take all material, with the exception of land application approved material, to landfill via a Casella contract. This means that 80% of their material will be landfilled and not composted for at least this period.

- Stopped accepting outside sludge due to PFAS (liquid sludges from two small facilities). While there was no significant impact on LAWPCA revenue, the impacts on those smaller facilities were significant. The PFAS scare has disrupted LAWPCA's important role as a larger regional facility providing essential services managing wet wastes for central Maine. A regional solution, building sustainability, has been significantly disrupted by the PFAS scare.

- While LAWPCA has not received any significant negative publicity during the PFAS scare, they have been in the newspaper a few times, with articles noting the reality that there is PFAS in LAWPCA biosolids, with the implication that this is a serious problem.

Cost Impacts

- LAWPCA spent $150,000 to change management from mostly land application to landfilling and composting. This cost consisted of the development of sampling & analytical plans, field soils testing, legal assistance, transferring of solids from land application stockpiles to landfill, paying farmers for lost crops due to not being able to land apply stockpiled material, and tipping fees for landfill disposal. This number would have been twice as great if LAWPCA had not been able to run a pilot of the compost facility without odor control from 9/1/19- 1/15/20, which took care of a considerable volume of the biosolids that could no longer be land applied.

- Cost per ton for solids management increased from $30-$35/wt for land application and $50/wt for composting to $95/wt for landfilling
- LAWPCA saw a 4% increase in their 2020 budget, or roughly $200,000 greater than 2019 budgeted. LAWPCA deferred capital projects and did a staff restructuring (eliminating a few positions) to help absorb some of the additional cost. As a result, LAWPCA leadership believes that neither customer – the City of Lewiston or Auburn Sewer District – has to increase sewer rates as a direct impact of the PFAS scare.

Background

- The Lewiston-Auburn Water Pollution Control Authority (LAWPCA) is a wastewater treatment plant servicing Lewiston and Auburn, Maine. The facility has been in operation since 1974 and is designed to handle an average instantaneous flow of 14.2 MGD with a max flow of 32 MGD. LAWPCA services over 35,000 domestic users, 23 significant industrial users, and 26 surrounding communities from which septic and holding waste is received. PFAS has not yet impacted their septage receiving, and they continue to receive 1.2M gallons/year.
- LAWPCA thickens its solids using primary gravity thickeners, gravity belt thickeners before transferring them to anaerobic digesters. In 2013, LAWPCA became first wastewater treatment facility in the state of Maine to utilize anaerobic digesters. This extra step was chosen to reduce the amount of solids that need to be dewatered, transported, and managed and created a methane-rich biogas to be converted to energy. The LAWPCA digesters have a combined capacity of 1.38 Mgal.
- Once dewatered in screw presses to about 20% total solids, the biosolids are transported to local farms, the compost facility, and landfills.

Resources Utilized:

- http://www.lawpca.org/?page_id=215

3.4 Orange County Sanitation District (OCSD), California

Brief Background

- Orange County Sanitation District (OCSD) is a public utility that provides wastewater collection, treatment, and disposal services to 2.6 million people in central and northwest Orange County, California, a 479 mi^2 area.

II. PFAS Management Impacts

- In 2018, OCSD was producing up to 825 wet tons per day of biosolids. In 2020, as a result of adding centrifuges to reduce their biosolids in 2019, OCSD produces 572 wet tons per day (WTPD) of Class B solids per day between their two treatment plants. They attempt to beneficially reuse 100% of their solids, with no material at present going to landfills.
  - The first plant produces 358 WTPD and the second plant produces 214 WTPD
- In order to achieve long-term resiliency and sustainability for the biosolids program, OCSD set the following biosolids management targets:
  - Up to 50% of biosolids can go to any one contractor or any one geographic end use market;
  - the biosolids would be managed by at least three management facilities, and
  - the biosolids would be destined for a least two end-use management practices.
  - OSCD also set targets aimed to ensure extra capacity at facilities, additional hauling capacity, and goals for developing new options.
- As of 2020, OCSD has six contractors, and 50% of their biosolids go to land application in Yuma, Arizona while the other 50% is used as compost material throughout California. As back-ups, they also have available two composting facilities and a local landfill.
- OCSD has not yet seen any impacts to their biosolids management as a result of PFAS. Their end-use sites have not changed; however, they are considering their options should land application no longer be an option, for contingency planning purposes. OCSD is working with one of their contractors to prepare additional options including transporting via railway. In addition, they are also considering the potential that PFAS might be considered a hazardous waste at some point and have identified seven possible hazardous waste disposal sites in California and Nevada.
- OCSD also identified through an RFI released in February 2020, two upcoming thermal options that can treat biosolids at high enough temperatures to they believe will bread down the constituents of concern. These facilities are scheduled to be operational within the next 2-3 years, but they can only handle a maximum of 30% of OCSD's biosolids production.
  - Pyrolysis: TBD
  - Gasification: TBD

- OCSD's existing biosolids hauling contract may be amended to include these fail-safe designations.

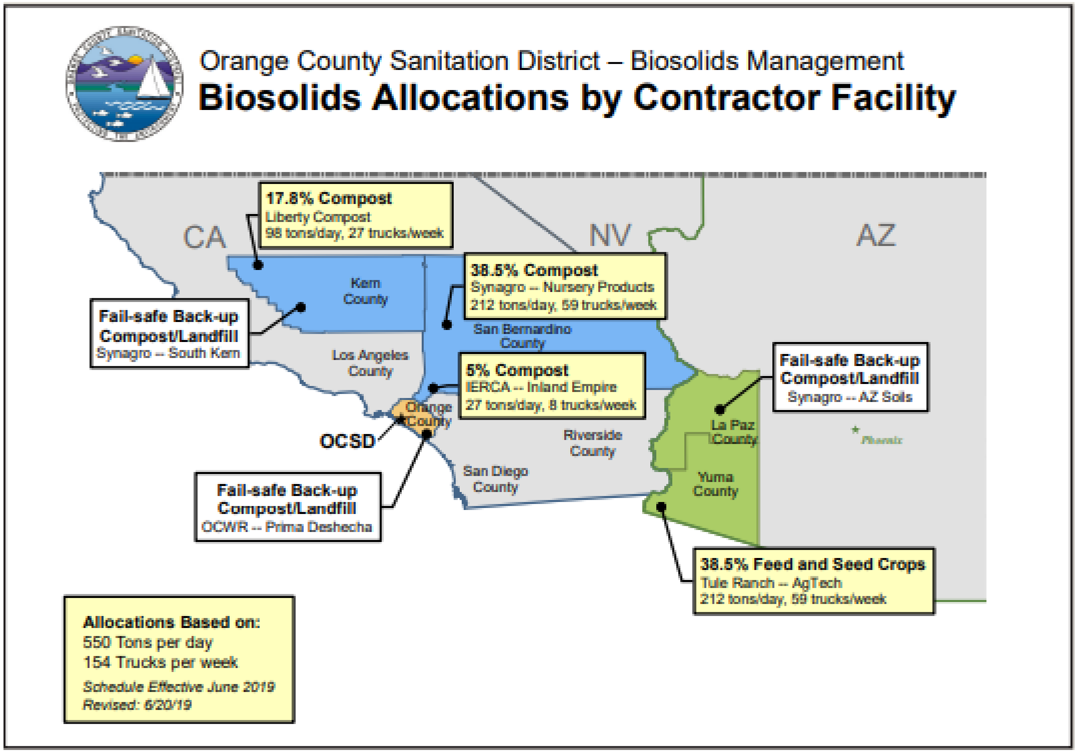

Figure 3-1 Orange County Sanitation District – Biosolids Management

Cost Impacts

- As observed in the figure below which outlines the 2015-2016 operating expenses for the facility, more than 50% of the fiscal budget goes towards solids production and hauling. This is more than the six other treatment and processing budgets combined.
- In 2018, it cost OCSD approximately $16 million to haul and recycle their biosolids. After adding centrifuges to reduce the volume of biosolids, OCSD saved $4 million in annual operating costs for a total cost of approximately $12 million for hauling and disposal in 2019 with a similar budget for 2020. This results in a per-wet-ton cost of approximately $60.
- If implemented as part of the treatment process, pyrolysis or gasification is expected to increase the overall disposal costs. The exact costs are confidential and have been excluded from this report.
- OCSD has not yet seen an impact from PFAS concerns on their programs involving receiving landfill leachate and wastewater solids from other WRRFs. Likewise, the composting operations managing OCSD biosolids have not seen disruptions related to PFAS: they continue to move compost.
- OCSD has spent between 500-600 staff hours, or 5-10% of time, participating in discussions or activities related to PFAS regulations. This has cost over $100,000.

- California recently issued a Phase Three Investigative Order for PFAS which targets wastewater treatment facilities. Sampling work to abide by this order is projected to cost OCSD over $300,000 in 2020 and 2021.

- To prepare to be able to handle testing and analysis in-house, OCSD projects a potential investment of $500,000 to prepare their lab and equipment. This cost is inclusive of both the equipment itself (Triple Quad analyzer) and staff time. The goal of this investment is to work on method develop and run PFAS tests inhouse which will allow for a faster turnaround time and prepare staff for anticipated compliance obligations. Strict clean sampling techniques and QA/QC procedures are also necessary due to stringent levels under consideration (ng/L) and these processes can be better ensured by OCSD personnel. OCSD has considered PFAS testing and contracts with labs but given the cost per sample ranging from $500-$700, a long-term investment in growing the laboratory was more advantageous.

- The Water District (OCWD), which supplies drinking water to the same 2.6 million people, has been looking to spend close to $200 million over the next 6 to 8 years on treatment systems throughout the different water retail agencies in its jurisdiction. Another $1 billion is projected for the next 30 years, which would cover the cost to operate and maintain the treatment systems in addition to replacing the water that exceeds PFAS Response Levels. Because one of the destinations for OCSD products is indirect potable water reuse, the facility has close ties to the Water District and as a result is likely to also see significant costs.

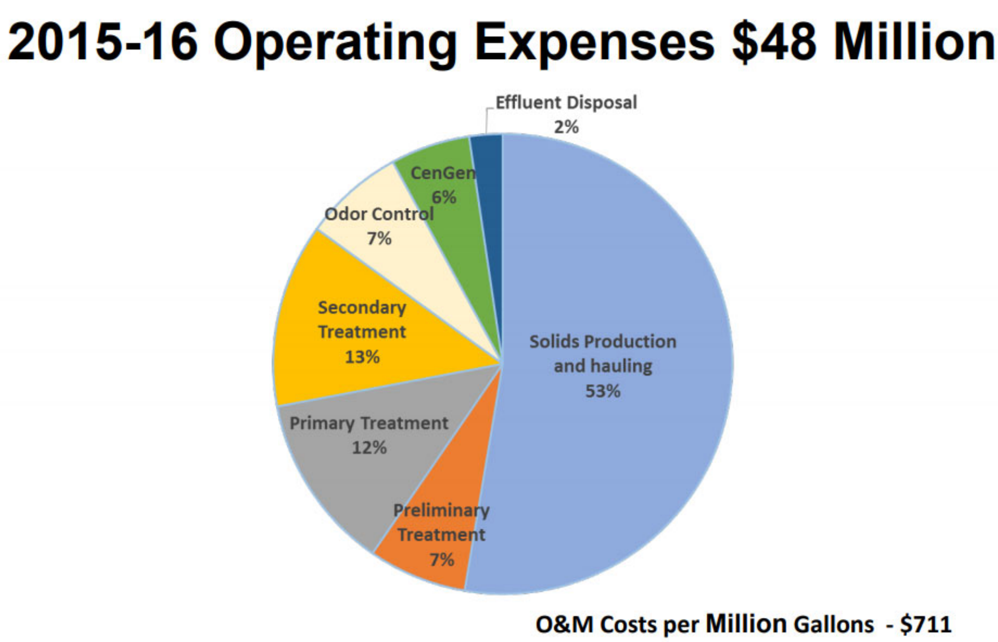

Figure 3-2 Orange County Sanitation District Operating Expenses

Background

- OCSD is governed by a board of directors from 20 cities and has two operating facilities that treat wastewater from residential, commercial, and industrial sources.

- In 2008, OCSD commissioned the Ground Water Replenishment System (GWRS) to support and manage groundwater levels in the Orange County Groundwater Basin. This is the world's largest system for indirect potable reuse. In 2017, OCSD and the Orange County Water District (OCWD) began a community outreach program to get GWRS bottled water into the hands of the public.
- Prior to the GWRS, OCSD worked with OCWD on Water Factory 21. This effort involved recycling treated wastewater, blending it with imported water, and injecting it into 23 wells to combat seawater intrusion.
- In July 2020, California issued Order WQ 2020-0015-DWQ, requiring Publicly Owned Treatment Works (POTWs) with a design capacity of 1 MGD or greater to monitor for 31 PFAS analytes in influent, effluent, biosolids, and, where applicable, groundwater.

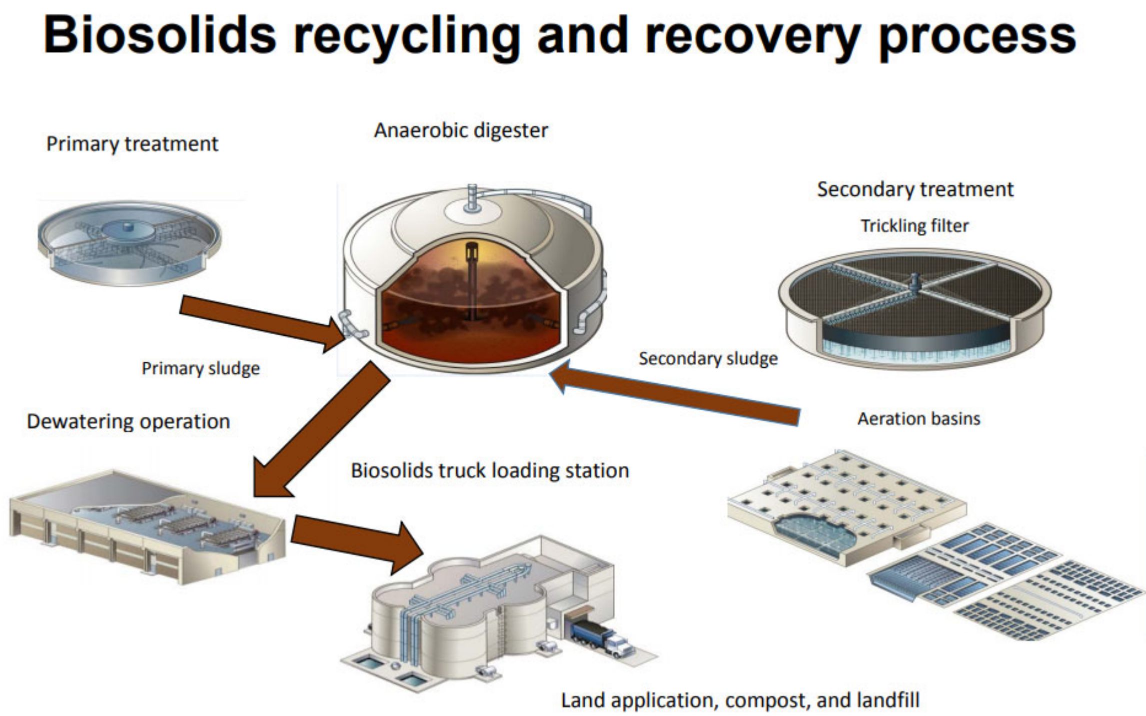

Figure 3-3 Orange County Sanitation District Biosolids Recycling and Recovery Process

Resources Utilized:

- https://www.youtube.com/watch?v=2AOAaDWPTiQ

- https://www.ocsd.com/education/biosolids-program#:~:text=How%20are%20Biosolids%20Used%3F,renewable%20alternative%20for%20amending%20soils.
- https://www.ocsd.com/home/showdocument?id=18769
- https://www.waterboards.ca.gov/board_decisions/adopted_orders/water_quality/2020/wqo2020_0015_dwq.pdf
- https://www.ocsd.com/home/showdocument?id=18769
- https://www.ocregister.com/2020/02/06/forever-chemicals-trigger-widespread-closures-of-water-wells/
- https://www.ocregister.com/2020/05/22/orange-county-water-districts-consider-massive-lawsuit-over-pfas-contamination/

3.5 Pima County Wastewater Reclamation, Arizona

Brief Background

- The Pima County Regional Wastewater Reclamation Treatment Department (RWRD) operates and maintains seven water resource recovery facilities (WRRFs) that receive, treat, and dispose of over 62 MGD of wastewater. Two of the larger facilities handle sewage from the Tucson metropolitan area and five facilities serve smaller towns and rural areas of Pima County, Arizona. Pima County began recycling its biosolids as a soil amendment and fertilizer on agricultural land in 1983 and continued through December 2019 using a single service provider.

PFAS Management Impacts

- Prior to PFAS concerns, Pima County WRRFs disposed of 100% of biosolids via land application. Due to concerns regarding PFAS in groundwater, the County's source for drinking water, Pima County administrators forced the suspension of land application operations. They began disposing of biosolids at regional solid waste landfills in January 2020.

- In response to the change in disposal methods, Pima County is partnering with the University of Arizona, NSF WET Center, and Jacobs to conduct a study of PFAS contamination, retention, and migration in farm soils where biosolids were historically land applied. The results from the study should allow for an informed decision of either continuing landfill disposal or returning to beneficial reuse of the biosolids.

Cost Impacts

- The total cost for Pima County to dispose of its biosolids via land application before PFAS policy, during the period 2017-2019, averaged $127 per dry ton, or approximately $19 per wet ton at 15% solids. At about 12,250 dry tons annually, this cost Pima County approximately $1.58M in biosolids disposal. Pima County maintained a single point biosolids management services contract with private vendors between 1983 and 2019. The service contract included receiving the biosolids from the County, transport, land registration, managing the site, bi-weekly sampling and analyses, farm scheduling, determination of agronomic rate, land applying, record keeping, and annual reporting to Arizona Department of Environmental Quality (ADEQ).

- In response to the County administration's PFAS moratorium on biosolids land application, Pima County utilized an emergency contract for disposal at the landfill during the period January 1st thru March 3rd, 2020. The emergency service included transport and tipping fee at a cost of $39 per wet ton during weekdays and $50 per wet ton on weekends and holidays.

- As of March 4, 2020, Pima County has three different private transporters available for the landfill disposal of the biosolids. The cost of transporting the biosolids to the landfills ranges between $7.90 and $26.50 per wet ton, and the tipping fees for landfill disposal range between $15.25 and $25.00 per wet depending on day of the week and proximity of the landfill. On average, the WRRF pays about $38.78 per wet ton at 15% solids. The round-trip miles to the landfills are 20, 34, and 107 miles. Additional transportation charges include demurrage, truck washing, and a surcharge when Pima County does not provide a daily minimum number of truckloads.

- The Pima County biosolids recycling program had already been challenged because of farmers being unsure of the impacts of PFAS in the biosolids. In 2020, the cost of the program increased from $1.58M annually to $3.17M annually.

Table 3-2 Pima County Biosolids Pre/Post PFAS

Pre-PFAS (2017 – 2019)	Post-PFAS (2020)
Land Application	Transportation to and Disposal at Landfills
$19/wet ton	$38.78/ wet ton
$1.58M Annually	$3.17M Annually

Background

- The Pima County Wastewater Reclamation Treatment Division operates and maintains seven WRRFs. Their metropolitan facilities include Agua Nueva WRF/Jacobs and Tres Ríos WRF. Their sub-regional facilities include Arivaca Junction WRF, Avra Valley WRF, Corona de Tucson WRF, Green Valley WRF, and Mt. Lemmon WRF.

- Agua Nueva is a new, state-of-the-art water reclamation facility that will allow Pima County to meet new strict environmental standards for effluent discharges into the Santa Cruz River. Since 2013, the RWRD has been diverting flows from the Roger Road WRF to the Agua Nueva WRF/Jacobs. In 2019, Agua Nueva pumped 29,307 wet tons of its waste activated sludge (WAS) via the sludge pipeline to the Tres Rios facility's WAS tank for thickening and digestion after mixing with the WAS sludge from Tres Rios.[1]

- The Tres Ríos facility serves the metropolitan Tucson area and treats approximately 30 MGD but has a permitted capacity of 50 MGD after undergoing a major upgrade as part of the Regional Optimization Master Plan in 2012. In 2019, Tres Ríos produced 73,827 wet tons of Class B biosolids, of which Pima County's land application contractor hauled 73,507 wet tons to land application and Pima County hauled 320 wet tons to a landfill. Tres Ríos is the centralized biosolids treatment location for all of the Pima County treatment facilities.

- In 2014, RWRD ceased operation of the Randolph Park WRRF and began diverting its wastewater to the Agua Nueva WRRF/Jacobs and Tres Ríos WRRF. The cessation of operations at Randolph Park has resulted in significant operational cost savings; however, the equipment and fixtures will be left in place should the facility be needed in the future.[2]

- In 2019, the water reclamation facilities of Avra Valley, Corona de Tucson, Green Valley, and Mt. Lemmon trucked a total of 7,227 wet tons of WAS to the Pima County Wastewater Collection System.

[1] https://webcms.pima.gov/UserFiles/Servers/Server_6/File/Government/Wastewater%20Reclamation/Biosolids/2019_AnnualReport-Vol1.pdf

[2] https://webcms.pima.gov/cms/one.aspx?portalId=169&pageId=52858

Table 3-3 2019 Annual Sludge and Biosolids Production and Disposal[3]

	WAS (wet tons)	Primary Sludge (wet tons)	Disposal
Agua Nueva WRF	29,307	Not Applicable	Tres Rios WRF WAS Receiving Facility
Agua Nueva WRF	Not Applicable	35,107	Pima County Wastewater Collection System
Avra Valley WRF	3,493	Not Applicable	Pima County Wastewater Collection System
Corona de Tucson WRF	967	Not Applicable	Pima County Wastewater Collection System
Green Valley WRF	2,753	Not Applicable	Pima County Wastewater Collection System
Mt. Lemmon WRF	11	Not Applicable	Pima County Wastewater Collection System
Tres Rios WRF	73,827	Not Applicable	Land Application: 73,507 wet ton Landfill: 320 wet ton

[3]https://webcms.pima.gov/cms/one.aspx?portalId=169&pageId=55373

3.6 Upper Blackstone Clean Water Case Study, Massachusetts

Brief Background

- Upper Blackstone Clean Water (Upper Blackstone) is designed for treatment of 45 mgd. The solids treatment process includes thickening, dewatering and incineration and in 2016 the facility received the Silver Peak Performance Award by NACWA for recognition of outstanding permit compliance.

PFAS Management Impacts

- Currently, the State of Massachusetts has yet to enact regulatory standards for PFAS in wastewater or biosolids. Therefore, Upper Blackstone has not been impacted at their treatment plant in any material way.

- However, Upper Blackstone is planning for PFAS regulations regarding the fate of PFAS compounds through their treatment facility processes. The fate is neither understood nor easy to measure.

- The facility, which accepts outside solids and septage, is on the cusp of requiring all generators of leachate to perform PFAS testing in order to allow for better management of these compounds when the time comes. Generators of the leachate reacted strongly to the initial request, because each generator already tests for everything the Massachusetts Department of Environmental Protection (MassDEP) requests them to, which is not inclusive of PFAS. If Upper Blackstone decides to move forward with required PFAS monitoring and the leachate results show elevated PFAS concentrations, Upper Blackstone may consider turning away existing leachate generators.

- Upper Blackstone has turned away new leachate producers requesting permission to dispose at the facility. This risk-based decision impacts the potential volume of accepted material and subsequent revenue that could have been achieved if not for anticipated PFAS regulations. As a result, these landfills have to look to other wastewater treatment facilities that will accept their leachate, so the problem is only being shifted somewhere else.

- Other less direct impacts from PFAS include the Upper Blackstone's hesitation to invest in necessary upgrades – especially for the incinerator – and related studies or planning until the uncertain future of PFAS is better understood. The Upper Blackstone multiple hearth sewage sludge incinerator (SSI), which is used for biosolids processing, is over 40 years old and while certain aspects of the equipment have been retrofitted over the years, the entire unit should be further evaluated. This evaluation would determine if a new piece of equipment or a new process is better suited for the facility. This future planning has taken a back seat due to PFAS and the uncertainty about the long-term effectiveness that possible upgrades, solutions, and other management methods may have if PFAS regulations proceed as proposed.

- Upper Blackstone has participated in hundreds of hours' worth of regulatory conversations regarding PFAS policies.

- Primary concerns regarding PFAS regulations include the following:
  - Regulatory limits too low given the ubiquitous nature of PFAS.
  - Receiving facilities incorrectly perceived as the polluter/source.
  - Not adequate regional capacity for sludge management.
- Upper Blackstone has participated in conversations with neighboring communities regarding a regional study and potential centralized facility, as a way to offset PFAS concerns.

Cost Impacts

- The cost to manage biosolids at the facility, which is inclusive of debt service, utilities, staff time, maintenance, consulting from engineering firms and polymer is $250 per dry ton. Of that total cost, $100 per dry ton accounts for strictly staff, lab analysis, maintenance and regulatory assistance.
- Upper Blackstone anticipates an impact on leachate capacity if the leachate can no longer be accepted, which would account for $200,000 of revenue lost.
- Depending on the regulations and limits set, Upper Blackstone may also have to turn away septage and sludge from other facilities. This would result in a loss of revenue of $800,000 and $1.9 million annually, respectively. Accepting sludge from nearby plants and septage from local haulers is an important part of the service they provide to their member communities. Upper Blackstone Clean Water represents approximately 13% of the permitted capacity to accept sludge in New England. So, if they were to limit the amount of sludge taken in from outside sources this would be a significant detriment to the sludge disposal and end use market in New England.
- While not quantifiable, the risk-based decision to turn away additional leachate prevented additional potential revenue.

Background

- The facility has provided wastewater treatment to its member communities for over 40 years.
- Member communities that Upper Blackstone provides services for include Auburn, Cherry Valley Sewer District in Leicester, Holden, Millbury, Rutland, West Boylston, and Worcester.
  - Wastewater flow from Worcester accounts for approximately 85% of the overall flow.
- Additionally, Upper Blackstone provides treatment to portions of non-member communities such as Shrewsbury, Sutton, Oxford, and Paxton.
- Treatment services for other communities include acceptance of septage, liquid waste and wastewater solids which are trucked to the plant.

- Services roughly 250,000 people in the greater Worcester area and manages biosolids for an additional 14 communities.
    - Turned away leachate producers due to PFAS concerns. This represents an impact on potential revenue, but it is not quantifiable.
- Receiving water body: Blackstone River
    - Solids Treatment:
        - *Primary settling and decant for primary sludge thickening.*
        - *Dissolved Air Flotation (DAF) and polymer addition for thickening of secondary sludge.*
        - *Belt filter presses for dewatering*
        - *Dewatered residuals to multiple hearth furnace for residual combustion*
    - Air Pollution Control:
        - *Venturi and Tray scrubbers followed by wet electrostatic precipitator for furnace emission pollution control and regenerative thermal oxidizer (RTO) and stack for final treatment before discharge to the atmosphere.*
    - Odor Control Measures:
        - *Biofilters for management of odorous air from belt filter presses, sludge mix tanks, grit facilities, and primary influent and effluent. Carbon for odors from sludge holding tanks.*

See **Figure 3-4** for process treatment schematic at the Upper Blackstone Facility.

Resources Utilized:

[1] http://www.ubwpad.org/Annual%20report%202019%20up-date.pdf

[2] http://www.ubwpad.org/

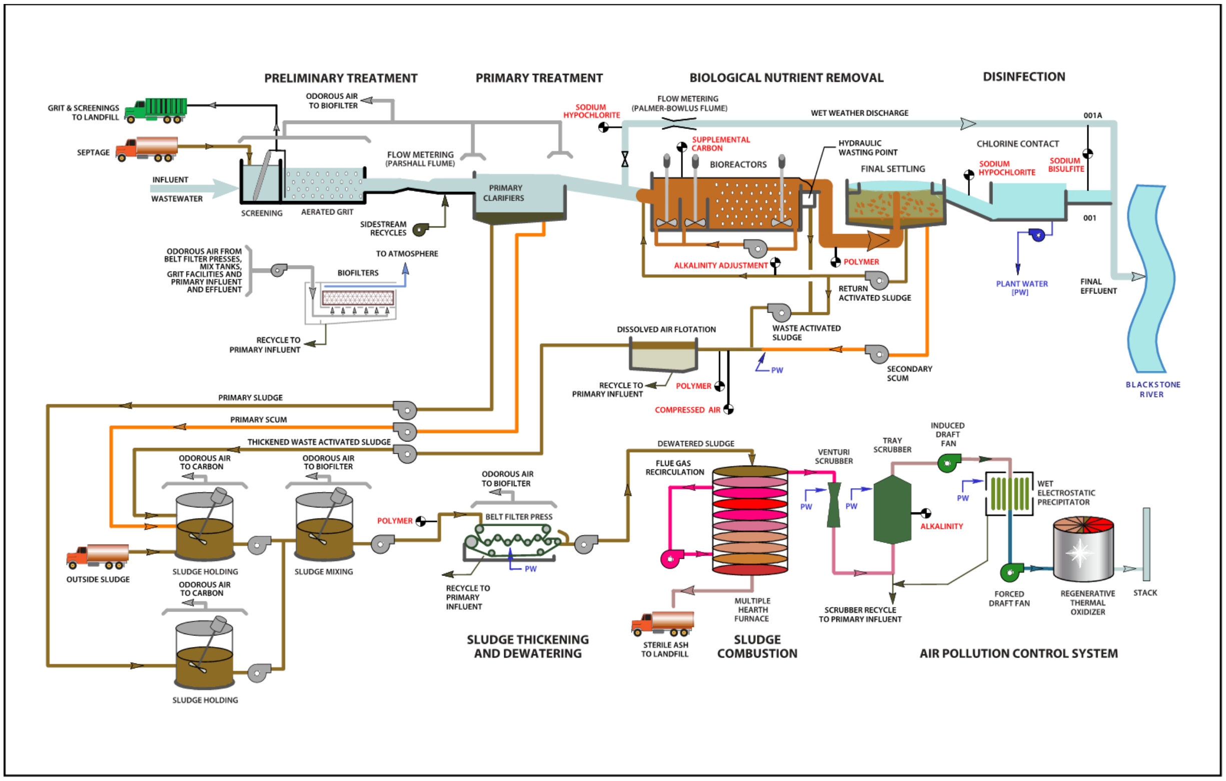

Figure 3-4 Upper Blackstone Clean Water Process Flow Diagram.

3.7 Wixom Department of Public Works – Wixom, Michigan

Brief Background

The Wixom wastewater treatment plant (WWTP) treats approximately 2.97 million gallons per day (MGD) of residential, commercial and industrial flows. The plant is under the supervision and oversight of the department of public works and operated by an independent contractor. Residuals treatment at the plant consists of two aerobic digesters with a total capacity of 1.5 million gallons, followed by two smaller storage tanks used to store the Class B biosolids at 6% total solids. Biosolids were beneficially reused at local farms via sub-surface injection. The liquid side of the plant includes oxidation ditches and new tertiary treatment systems for phosphorus removal.

In 2018 the plant purchased a dewatering screw press with the intent of dewatering their biosolids and co-mingling it with compost on-site to create a higher value fertilizer that could be beneficially reused locally.

PFAS Management Impacts

Farmers accepted the City's biosolids at little to no cost, so the majority of the City's biosolids management costs were associated with transporting the biosolids to the end use sites. In 2017/208 this accounted for approximately $100,000 at $325 dry ton per year.

Through implementation of the Industrial Pretreatment Permit (IPP) PFAS Initiative and statewide study in 2018, Michigan Department of Environment, Great Lakes, and Energy (EGLE) identified the Wixom WWTP as one of 6 WWTPs with biosolids/sludge that were classified as being industrially impacted based on PFOS concentrations in the residuals. Each of the 6 facilities had high concentrations of PFOS in their effluent. Those classified as "Industrially Impacted" were those that have PFOS concentrations of 150 ug/kg or greater and have significant industrial source(s) of PFOS in their collection system.

The City identified an industrial source (Tribar) that was discharging high concentrations of PFOS to the plant. The City's efforts to work with Tribar to address the PFOS content of their discharges to the City's Wastewater Treatment Plant (WWTP) have been successful. Tribar implemented a granular activated carbon filtration system in early October 2018 onsite at their Plant 4 location, the identified source of PFOS contamination to the WWTP. Weekly monitoring at Tribar and monthly monitoring at the WWTP have continued to show the Tribar PFAS pretreatment system is achieving its goal. The PFOS levels of the WWTP discharges, the effluent from the City plant, have declined as shown by the sampling results below:

- August 29, 2018 4,800 ppt (parts per trillion)
- September 25, 2018 2,100 ppt
- October 11, 2018 940 ppt
- October 15, 2018 530 ppt
- November 6, 2018 240 ppt
- August 2020 15-30 ppt

The current effluent limit for the WWTP is 11ppt – the Michigan surface water limit for PFOS when the surface water is a drinking water source for PFOS (24 analytes).

During the time the plant was seeing the highest concentrations of PFOS, the City stopped their biosolids land application program and did not remove any sludge from inside of their digesters. The material inside the tanks (August 2018) tested at Tank 1; 8,600 ug/kg PFOS, tank 2; 3,100 ug/kg PFOS, and 3.9 and 5.2 ug/kg for PFOA (parts per billion, or ppb).

Currently the City is bypassing its digesters until that material inside can be properly disposed. All sludge is being dewatered and sent to landfill without any intermediate processing or digestion. Current landfill costs are $380,000/yr at 20-21% solids. The Wixom WWTP produced 3,566 wt in 2018 and 3,811 wt in 2019, and, as of August 2020, the City had already sent over 2000 wet tons to landfill. The total cost sludge of leaving the plant is $850 per yard, assuming a 20-yard roll-off container sent to landfill at 17-25% total solids. Among other fees and transportation costs, this includes a $37.50/ton fee for deep well injection of leachate, plus $14/yd tip fee.

The state of Michigan plans to assist with the costs associated with emptying the existing digesters and disposing of the sludge inside. The current plan is to thicken on-site via dissolved air flotation (DAF), send filtrate through carbon filters (to remove the PFAS) and then back through the plant. Thickened sludge will then be appropriately disposed of off-site at the landfill for an approximate cost of $700,000.

The City and the Michigan Department of Environment, Great Lakes, and Energy (EGLE) have been working closely to address community concerns. The City has also worked proactively with the local industrial PFAS/PFOS sources. The industrial sources have paid for all testing described above as well as the testing of their own treatment systems to address the high concentrations entering the collection system feeding the plant.

As PFAS/PFOS concentrations decline, it is the hope that the City can go back to utilizing their digesters to create a Class B biosolids and reduce the sludge load to dewatering by 40-50%. The farms they worked with previously are open to accepting the City's biosolids provided they can continue to meet all appropriate regulations. Similarly, the addition of the screw press would allow them to compost on-site to create a higher value product that can be utilized more widely then their previous Class B liquid biosolid.

The City and WWTP received a lot of bad publicity over the past few years because they discharge to a watershed that the City of Ann Arbor uses for drinking water intake. They had a lot of public meetings and public relations in 2018 to try and mitigate fears. Ann Arbor has implemented treatment enhancements to their drinking water treatment plant to mitigate PFAS.

Department of Environment, Great Lakes, and Energy (EGLE) Michigan PFAS Response Team (MPART)

The Michigan Department of Environment, Great Lakes, and Energy (EGLE) is undertaking several efforts to address PFAS in surface waters, including monitoring municipal and industrial discharges, implementing the Industrial Pretreatment Program (IPP) PFAS Initiative, and monitoring lakes and streams.

Since implementation, significant progress has been made in identifying sources of PFAS, specifically PFOS, to WWTPs and reducing levels released to the environment.

Some key observations the WRD has made to date (February 2020):

- Sixty-six (66) of 95 of WWTPs with IPPs (or 69%) either have no sources or have sources but have discharges at or less than the PFOS WQS.
- 93 out of 95 WWTPs were able to complete the initial screening of their industrial users within one year of starting the initiative. Most were able to complete the screening within six months.
- Low levels of PFOS (approximately 3 ppt - 7 ppt) were detected in wastewater even when no significant industrial sources were present. This and other similar studies suggest that background levels of PFAS may be found in most communities due to commonly used consumer products.
- Source reduction efforts have resulted in substantial drops in PFOS concentrations being discharged at the WWTPs. (See Table 3-4)

Table 3-4. Substantial PFOS Reduction at WWTPs with Exceedances (Michigan.gov/PFASresponse)

Municipal WWTP	PFOS, Effluent (ppt, as of February 2020)	PFOS Reduction in Effluent (highest to most recent)	Actions Taken to Reduce PFOS
Ionia WWTP	< 7.6	99%	Treatment (GAC) at source (1)
Lapeer	11	99%	Treatment (GAC) at source (1)
Wixom	40*	99%	Treatment (GAC) at source (1)
Howell	3.7	97%	Treatment (GAC/resin) at source (1)
Bronson	13*	95%	Treatment (GAC) at source (1)
Kalamazoo	3.1	92%	Treatment (GAC) at source (2), change water supply
K.I. Sawyer*	13*	95%	Eliminated leak PFOS-containing fire-fighting foam
GLWA (Detroit)	32*	62%	Treatment (GAC) at sources (8)
Belding	7.2	49%	Restricted landfill leachate quantity accepted

*Effluent exceeds WQS of ppt

Data for each plant can be found here: https://www.michigan.gov/egle/0,9429,7-135-3313_72753---,00.html

Summary

Working with EGLE, the City has been able to successfully identify and monitor the major PFOS sources observed at the WWTP. Through implementation and enhancement of their IPP program they were able to work with local industrial sources to have their flows treated such that PFOS concentrations to the plant have been reduced by more than 99%. It is the City's goal and hope to continue working with their community to educate them on PFAS sources and reduce the concentration of PFAS/PFOS coming to the plant such that they can meet the drinking water standards of 11 ppt, and re-start the biosolids beneficial use program.

At the time of this case study the plants biosolids end use costs have increased over 300%. To-date the local industries and EGLE have assisted with the cost of PFAS sampling, however if the City were to take on the cost for sampling and monitoring in the future, this will be a substantial increase in their overall operating costs. The long-term financial impact to the farms who previously utilized the biosolids as a low-cost fertilizer has not been fully realized yet, nor has the impact on local industry and jobs associated with those industrial producers of the PFAS/PFOS containing materials.

3.8 Resource Management Inc. (RMI) Case Study

Brief Background

- Resource Management Incorporated (RMI) provides an array of services consisting of project management, consulting, residuals management, field services and transportation – including serving the biosolids management needs of numerous WRRFs throughout the northeastern U. S. For the purposes of this study, RMI provided commentary on their residual hauling and management operations in the New England area. RMI manages raw solids at their facility in New Hampton, NH. The resulting product is a Class A biosolids that is distributed to local farms for reuse. RMI also manages Class A and B biosolids direct from the WRRF to land application. For these programs, RMI handles the distribution, permitting, and quality control measures, linking the WRRFs supplying these materials to the farmers and other facilities who beneficially reuse the products. RMI prides themselves on not participating in disposal as a biosolids management method.

PFAS Management Impacts

- RMI has been significantly impacted by PFAS regulations. The company has a rare perspective as they operate across different New England states and are thus required to keep up with different and changing PFAS regulations proposed and enacted in different states.

- The New England residuals end-use market has been increasingly stressed over the past several years due to the reliance on aging incinerators in southern New England. Stricter air emission regulations enacted in the 2010s reduced the overall incineration capacity in the region due to incinerators shutting down or being forced to run leaner and accept less sludge/solids. Urban sprawl has also caused an increase in sensitivity to odors generated at landfills that accept residuals and biosolids. Compost facilities have also seen the impacts of urban sprawl. And political pressure in some areas has forced biosolids management facilities to send their residuals farther afield, further stressing the region's capacity to process material. All of these issues already existed and were nearing crisis level before PFAS regulations became an issue in New England.

- RMI has seen both sides of their marketplace impacted by concerns about PFAS: on the generator side – those producing biosolids and other residuals – and on the end user side – those that participate in the beneficial reuse program, such as farmers.

    - Generators lacking available management

    - End users turning away biosolids acceptance due to risk and liability concerns

- Another impact RMI has observed is the impact to the paper fiber and septage industry, which is less widely known or discussed.

    - Paper fibers produced from paper mills accounts for approximately 40,000 tons of the material RMI manages each year, 57% of RMI's total material each year. The Northeast has far fewer paper mills than it did 30 years ago, and those that remain serve special niches, are small, and are challenged by international competition. Several of them provide the important environmental service of locally recycling paper. But with that comes traces of PFAS. PFAS regulations could put the some of these local mills out of business.

- The WRRFs serviced by RMI also accept septage at their facilities. Septage is the semi-solid material pumped from the septic systems of homes and businesses in rural areas. All septage contains traces of PFAS, because PFAS are ubiquitous in our daily lives. If there was a need to turn this product away from WRRFs, RMI would suffer loss of that septage/biosolids business income and the area's septage haulers and homeowners would have one fewer option for how to deal with their septage.

- As of summer 2020, RMI is uncertain whether beneficial reuse programs will be able to continue. Several New England states are creating groundwater standards that even some home septic systems can not meet. RMI could be put out of business. Then the concern is that generators – WRRFs – will have even fewer outlets for biosolids.
- In total, over 2019 and 2020, RMI has experienced a 50% loss of throughput at their New Hampton facility due to PFAS. Material that was once able to be stored outside is now required to be disposed of elsewhere.
- In response to the PFAS issue, RMI made a risk-based decision to invest in and be a distributor of a new biosolids drying system, the Shincci dryer - a belt dryer developed in Guangzhou, China that utilizes a unique heating and moisture control system to produce a 90% dry Class A fertilizer. After great success with the first dryer purchased, RMI purchased a second. The dryers are placed in Brattleboro, VT and Hooksett, NH and RMI is responsible for maintaining the equipment and hauling the resulting Class A biosolids. While the dryer does not remove or destroy PFAS, it significantly reduces the mass and volume of material that has to be transported and managed. The goal is that by reducing the volume of the material and producing a high-quality fertilizer, the biosolids have more options for end use – land application, horticultural use, or as a renewable energy fuel. It does not make the PFAS problem go away but makes it less expensive to manage because there is less total material.
- Primary concerns for RMI if PFAS regulations continue as enacted are as follows:
  - The beneficial reuse market utilizing biosolids for a fertilizer has been a delicate market to grow and manage. Given the origin of biosolids, there is an inherent stigma that has taken decades to overcome, working with environmentalists, regulators, legislators, the media, and the public. RMI has helped develop beneficial use programs that have aided in the success of many farms throughout New England. Now the bad publicity associated with PFAS has damaged the reputation of biosolids and the end use markets.
  - RMI notes that, for example, PFAS regulations in several New England states have been enacted without cost benefit analysis. The EPA health advisory level for drinking of 70 parts per trillion (ppt) was based on a thorough epidemiological study. No studies have been completed to-date with comparable scientific backing supporting the low drinking water and groundwater levels established in MA, ME, NH, and VT in 2019 and 2020. These standards are some of the lowest in the world, and they may not be possible for

land application programs to meet. Even septic systems and some small business operations will not be able to meet them. The regulations are at or close to background levels of PFAS found in the environment because of decades of widespread PFAS use. Wastewater and biosolids programs are just one of a number of programs that will see large impacts from low PFAS limits.

- If RMI goes out of business, 70,000 wet tons of biosolids and other residuals will be without a place to go. Much of this material will likely have to be trucked outside New England or to Canada at significantly greater cost to the communities who produce it. That will leave the ratepayers of those WRRFs paying more for solids management.

Cost Impacts

- RMI has seen revenue losses from the generator (WRRFs) and end-use (farmer) sides of the business.
  - One specific example is the City of Concord biosolids program which has been managed by RMI since June 1996. In April 2020, the City decided to shift their program out of NH and haul to Quebec Canada due to the PFAS limits in NH and uncertainty about potentially responsible parties. This amounted to an immediate loss of $210,000 annually.
  - RMI has lost over $200,000 in sales annually on the farmer side as a result of PFAS concerns and Concord disruption. In general, since 2018 RMI has seen a 75% decline in end user revenue for biosolids throughout the northeast due to PFAS concerns.
- The cost increase that RMI has implemented for generators in response to PFAS regulations is hefty, typically at least double the original rate and sometimes as much as three to four times what the generator used to pay.
  - Generators who have felt the impact of rate increases are understandably upset – especially when these increases are not anticipated and result from new regulations and uncertainty in the market.
  - RMI has implemented a PFAS surcharge of $20-$35/wet ton to deal with lost revenue from end-users and increased work needed to manage for the PFAS situation. RMI is also covering some costs for hauling to Canada when outlets in the northeast are not sufficient for daily production.
- RMI invests significant staff time to PFAS, easily 50% or more of one employee's time since January 2017. Other employees – which total 30 – continue to invest time as well, but to a lesser extent. A conservatively low estimate of that staffing cost is $70,000 per year.
- RMI's staff time invested consists of meetings with regulators (NH, ME, VT, MA, and at national level with EPA), conferences (both attending seminars and giving presentations), trade group meetings (NEWEA, NYWEA, NHWPCA, NHMA, etc.), dedicated an enormous amount of bandwidth to PFAS, technical work and committees for research support, WEF Convening Meetings, DC Fly-Ins and Legislative outreach, press relationships and

interviews (NHPR, AP, trade articles), legal challenges to NH limits, and many other PFAS related engagement.

- RMI, has made capital investments on the order of $1,000,000 in 2018 – 2020, inclusive of capital investments, time, evaluation of dryer technology, sending staff to China, etc.

Background

- RMI establishes management strategies for agriculture, gravel pit operation, compost operations, landscapers and municipalities
- RMI is a small, 40-person full-service company that manages biosolids and other residuals from start to finish

Resources Utilized:

[1] http://www.rmirecycles.com/

3.9 Central Maine Farm

Brief Background

- This 5th-generation family-owned dairy farm is located in central Maine and is managed with conservation principles. They have participated for many years in the USDA Natural Resources and Conservation Service (NRCS) Environmental Quality Incentives Program (EQIP), a program that includes such things as adequate manure storage capacity, proper manure and nutrient management, and erosion control measures. The farm has been recognized for its stewardship, excellent management, high production levels, and quality milk. Over the years it has hosted Farm Days and other teaching and learning events aimed at sharing best practices and educating the public about dairy farming.
- In 1984, the farm began using biosolids as a one of its soil management options. Biosolids increase organic matter in the soil and provide macro- and micro-nutrients, reducing the need for chemical fertilizers. The farm saved money while improving its soil year after year.
- Milk prices are historically low, so using low cost, high value fertilizers such as biosolids have been critical to the survival of many dairy farms throughout the country.
- Biosolids are trucked to the farm from a nearby WRRF and placed in a contained bunker constructed by the WRRF. The treatment plant can haul biosolids to the farm in any season, even in winter, when they aren't able to go other places, because they can store it in the bunker, and the farmland applies it in the summer.

PFAS Management Impacts

- In the spring and summer of 2019, the Maine Department of Agriculture and NEBRA analyzed forage and milk from four farms that have used biosolids as a soil amendment on a regular basis. Although low levels of PFAS typical of long-term biosolids land application sites were found in the farm's soils, testing found no detections of PFAS in the farm's milk or the feed (corn) grown on the farm. After decades of biosolids use, no PFAS impacts were evident in the farm's products.
- However, because the levels of PFAS found in the soil of some of the farm's fields exceeded the low screening values imposed by Maine DEP, the farm was unable to apply the biosolids they had stockpiled for Fall 2019 application and were forced to purchase commercial fertilizer. In 2020, they were able to spread some of the 2019 biosolids stockpile on fields that did not exceed the Maine screening standards for PFAS, but they were unable to accept any new solids.
- During the PFAS scare in spring of 2019, while milk, feed, and water samples were being analyzed, the farm was forced to dump their milk – nearly $25,000 worth. This is a scary process for a family farm, seeing their income erased. Initially, it appeared the farm would have to absorb that significant loss in revenue. But, eventually, the dairy cooperative that imposed the milk-dumping requirement, paid the farm for the lost milk, in accordance with the contract between the farm and the co-op.

- The farm will be forced to continue using commercial fertilizer if they can no longer use biosolids. The benefits of the organic matter in the biosolids are lost. (To add insult to injury, at the same time in 2020, the farm is concerned that the chicken manure they use as a soil amendment may be also become unavailable soon.)

- The farm has invited Maine DEP to install monitoring wells in their fields to determine if the PFAS in the applied biosolids has contaminated groundwater, and if so, how it might be migrating.

Cost Impacts

- As part of the agreement with the WRRF that supplied the biosolids, the farm was paid to spread the biosolids, which equated to approximately $5.65 per cubic yard, or about $5,000 per spreading cycle.

- In Spring 2019, the farm put biosolids on their corn ground and in the fall, they put it on their grass ground, but had to supplement with $6,000 worth of chicken manure. The cost of the chicken manure plus the loss of revenue from spreading the biosolids equated to a $11,000 financial loss.

- In Spring 2020, the farm was only able to apply less than half of the biosolids they normally put on their corn ground.

- The total increase in this one farm's costs due to the PFAS scare was $46,000 in 2019 and 2020. And yet testing has found no PFAS impacts on the farm's products. The PFAS scare and perceptions led to troubling impacts and high costs for this family farm.

Section 4

Task 3 – Summary of Indicator Costs and Technology Information

4.1 Description of PFAS Treatment Technologies

4.1.1 Drinking Water Treatment Technologies

Commonly used treatment methods for removing PFAS in drinking water have been implemented, studied and examined since PFAS became emerging contaminants of concern in the early 2000s. The same cannot be said of treatment methods for wastewater or biosolid matrices containing PFAS, for which many of the treatment technologies are still emerging and being further investigated. As a result, the following section presents common PFAS treatment technologies for drinking water conditions, which could be amendable to wastewater conditions but would likely require some level of additional study to determine the level of pre-treatment required; coagulation, sand filters, membrane filters, etc., otherwise the PFAS treating technologies may become prohibitively large.

Because of the stability of the C-F bonds present in PFAAs, such as PFOA and PFOS, they are not amenable to many conventional destructive treatment technologies. However, several technologies have been investigated for the effectiveness of PFAS removal by academia and industry. **Figure 4-1** summarizes the PFAS removal effectiveness of various conventional (e.g. coagulation, flocculation, sedimentation, and filtration) and non-conventional drinking water treatment processes (e.g. nanofiltration, reverse osmosis). Similar to conventional wastewater treatment, the effectiveness of these conventional drinking water processes show little ability to remove PFAS. These conventional processes would need to be paired with PFAS removal or destruction methods in order to achieve appreciable PFAS removal.

Compound	Molecular Weight (g/mol)	Aeration	Coagulation/Dissolved Air Flotation	Coagulation/Flocculation/ Sedimentation/Granular Filtration or Microfiltration	Anion Exchange	Granular Activated Carbon Filtration	Nanofiltration	Reverse Osmosis	Permanganate/Ozone/ Hypochlorous/Hypochlorite/ Chloramination/UV photolysis
PFBA	214	● (Assumed)	● (Assumed)	●	●	●	■	■	●
PFPeA	264	●	●	●	●	▼	■	■	●
PFHxA	314	●	●	●	●	▼	■	■	●
PFHpA	364	●	●	●	▼	■	■	■	●
PFOA	414	●	●	●	▼	■	■	■	●
PFNA	464	●	Unknown	●	■ (Assumed)	■ (Assumed)	■	■	●
PFDA	514	●	Unknown	●	■ (Assumed)	■ (Assumed)	■	■	●
PFBS	300	●	●	●	▼	■	■	■	●
PFHxS	400	●	●	●	■	■	■	■	●
PFOS	500	●	▼	●	■	■	■	■	●
FOSA	499	Unknown	Unknown	●	Unknown	■ (Assumed)	Unknown	■ (Assumed)	Unknown
N-MeFOSAA	571	● (Assumed)	Unknown	●	■ (Assumed)	■ (Assumed)	■ (Assumed)	■	Unknown
N-EtFOSAA	585	●	Unknown	●	■ (Assumed)	■ (Assumed)	■ (Assumed)	■	Unknown

From Dickerson & Higgins, 2016 (WRF, #4322)

● Removal <10% ▼ Removal 10-90% ■ Removal >90% ☐ Unknown ☐ Assumed

Figure 4-1 Summary of PFAS Removals for Various Treatment Processes (adopted from Dickenson et al., 2016)

Granular Activated Carbon

Granular activated carbon (GAC) is the most common treatment method in both drinking water and remediation as its application for PFAS removal has been practiced over 17 years (NGWA, 2017). Granular media for GAC is produced from carbonaceous material, such as bituminous coal, lignite coal, coconut shells, and wood, which is then activated by heat.

GAC is used in water treatment to remove a wide variety of dissolved contaminants, such as natural organic compounds, synthetic organic chemicals, taste and odor precursors, color forming organics, and disinfection by-product precursors. GAC removal of the target contaminants, including PFAS, from liquid streams occurs through primarily physical adsorption. With its large porous internal surface area from the activation process, GAC gains the adsorption capacity to accumulate a substance on the surface of the media. Adsorption of contaminants in water by GAC occurs mostly by nonspecific physical adsorption, which is caused by binding mechanisms from the electrons shared between the GAC media adsorbent and the contaminant adsorbate (Westerhoff et al., 2012). The dissolved adsorbate migrates from the liquid stream through the pore channels of the GAC media to reach the area where the strongest attractive forces are. Contaminants adsorb onto the GAC media because the attraction of the carbon surface area is stronger than the attractive forces that keep them in solution. GAC can be added to the treatment process through gravity filters and pressure contactors. For using either setups, the critical parameters of GAC systems for PFAS removal are loading rate, empty bed contact time (EBCT), and media replacement frequency. It should be noted that the loading rate and EBCT are functions of the flow rate and the volume provided by the GAC vessels. Also, treatment effectiveness depends on the structure of PFAS (e.g. carbon chain length). Possible competitive adsorption with other compounds present in the water could hinder the PFAS removal by GAC, and removal effectiveness for shorter-chained compounds is more limited than for longer-chained PFAS but should be confirmed through testing to determine optimized conditions for maximum removal, which can include coupling with different treatment technologies (such as anion exchange resin).

Anion Exchange

Ion exchange involves the use of synthetic resins with a fixed charge, which are used to remove charged contaminant ion through the exchange sites of the resin beads. PFAS are generally present in the environment in their anionic form with a negative charge, and therefore, anion exchange is capable of removing PFAS from water. Factors that influence anion exchange (AIX) performance include influent contaminant concentration, treatment design (e.g., EBCT, flow rate, resin bead size, and material), resin media changeout frequency, and competing ion concentrations, such as sulfate, nitrate, bicarbonate, etc.

Although used less extensively than GAC, AIX has shown effectiveness at removing long-chain PFAS (Du et al., 2014; McCleaf, et al., 2017). Similar with GAC, low effectiveness of short-chain PFAS removal has been reported with AIX by some researchers, but contradictory study results exist, which indicate faster kinetics and higher capacity with removing the short-chain PFBS than PFOS (Dickenson et al, 2016). CDM Smith's bench-scale testing evaluations have observed high effectiveness of removal of long-chain and short-chain PFAS in low-organic groundwater (Schaefer et al., 2019).

While AIX resin is more expensive than GAC media, AIX systems have higher capacities, which can lead to lower operating costs at optimal changeout frequencies. Also, AIX systems have been tested to perform at much shorter empty bed contact times (EBCT) than GAC, resulting in smaller equipment footprint and capital cost. Ion exchange treatment typically accompanies a resin regeneration step and corresponding management of brine waste. However, the anion exchange systems that have been tested in recent years for PFAS treatment comprised single-use selective resins in a set-up similar to single-use GAC systems, and therefore, no brine disposal provisions are required.

Membranes

The applications of pressure-driven membrane technologies are widely applied in water treatment, but their applications in PFAS removal still require more thorough investigation. Microfiltration and ultrafiltration are unsuitable for PFAS removal, due to their molecular weight cut-off (MWCO) values being too high. Therefore, reverse osmosis (RO) and nanofiltration (NF) with lower MWCO properties have been studied for PFAS removal application, with RO having demonstrated significant removal of all the PFAS, including the short-chain compounds (Appleman et al, 2014; Yao et al., 2017). Data on NF performance are more limited, but positive bench-scale test results have been reported for removal of PFAS with a range of molecular weights (Appleman et al, 2013; NGWA, 2017). However, the MWCO properties may vary from different NF membrane materials, so NF's applicability needs to be confirmed through testing.

RO membranes have the same MWCO properties across manufacturers and thus should offer very high removal efficiency compared to other treatment alternatives. RO membrane technologies may also offer multi-contaminant removal beyond PFAS. However, despite RO's effectiveness, it would be costly, due to high capital cost and energy demand. Importantly, both RO and NF generate a waste stream containing high concentrations of reject contaminants, and the management and treatment of the waste stream must be addressed in design and operation. Overall, like GAC and anion exchange, treatment with membranes would need to be investigated further and validated at bench- or pilot-scale.

Oxidation

PFAS are generally resistant to advanced oxidation processes (AOP) that use generated hydroxyl radicals to transform contaminants. AOPs with hydrogen peroxide or peroxydisulfate have been demonstrated to be ineffective at breaking down organic compounds, generally showing less than 10% removal of PFASs at the expense of significant energy input (Dickenson et al, 2016; NGWA, 2017). However, other emerging oxidation and reduction technologies (e.g., photocatalytic oxidation, photochemical oxidation and reduction, persulfate radical treatment, thermally induced reduction) have the potential to degrade PFAS, but they are presently not practiced in water treatment applications and are still in early stages of development.

4.1.2 Wastewater and Biosolid Emerging Treatment and Processing Technologies

It has been confirmed by various studies that conventional wastewater and biosolids processing methods do not remove PFAS in the matrix. However, unconventional processing methods and emerging PFAS treatment methods have yet to be sufficiently evaluated and as such, warrant additional research. While many studies and investigative initiatives are underway to evaluate these technologies and their applicability to PFAS removal, there is not enough hard data to confidentially state all methods described below successfully remove PFAS, if at all. However, many of these emerging treatment technologies do appear promising based on typical operating temperatures, pressures, and other process-specific features further defined below.

Biosolids Processing Technologies

Vitrification

Vitrification is an advanced incineration process that melts the inorganic fraction of biosolids and produces a glass like product rather than a conventional ash product. The glass sequesters many metals and other contaminants and has reuse applications including construction backfill, roofing shingles, and asphalt pavement. The process requires higher operating temperature than conventional incineration which results in enhanced rates of combustion and combustion of some recalcitrant compounds that may not be readily oxidized in a multiple hearth furnace.

Additionally, the higher operating temperature requirement could aid in destroying PFAS, although not yet proven.

The process is fed dried solids (>85% TS) rather than dewatered cake and high purity oxygen (>90%) rather than ambient air. The vitrifier consists of three zones: melter, phase separation, and gas cooling/heat recovery. In the melter the dried product is injected with pure oxygen and heated to 2,400-2,700°F. These temperatures result in the organic content of the sludge combusting to produce CO_2 and water and the mineral content melts. The temperature commonly referenced as the minimum necessary to destroy PFAS is 1,400°F, so while vitrification would need to be evaluated for substantial PFAS destruction, it's operating temperature does appear to be promising.

In the phase separator, the molten material exits the reactor to a quench tank and is cooled into a glass product. The offgas is captured and directed to the gas cooler/heat recovery unit where the gas is cooled to 700-1,600°F. Thermal energy is recovered as steam or hot oil to be reused in upstream drying. Offgas is recycled through the process to increase oxygen utilization efficiency; excess gas is sent to a condenser and downstream air pollution control.

Plasma Assisted Sludge Oxidation

Similar to vitrification, plasma assisted sludge oxidation appears to be a promising biosolids managing process for destroying PFAS due to the high operating temperatures. However, this technology is an area of active research in the field of municipal solid waste but there are limited applications to wastewater biosolids.

An electrical arc gasifier generates a very high voltage between two electrodes. An inert gas (argon at small scale, nitrogen at large scale) passes through the voltage and ionizes into a plasma at a temperature that ranges from 4,000-14,000°C which varies based on the voltage between the electrodes and the flowrate of gas feeding the plasma generator. When exposed to such high temperatures, the feedstocks melt and vaporize producing a gaseous product rich in carbon monoxide and hydrogen. Inorganic materials are melted and vitrified in a glass-like slag product.

The gas is cleaned of any contaminants (e.g. hydrogen chloride gas) and burned in any engine that can burn natural gas. Heat from the reaction can be captured to produce steam and generate electricity in a steam turbine.

Pyrolysis

Pyrolysis is a thermal process in which biosolids are converted into biochar, along with pyrolysis gas and bio-oil, which can be used as energy sources. Biochar's resistance to biological and physical degradation when incorporated into soils makes it a valuable soil amendment but higher value markets may include being used as a raw material for 3D printers. The pyrolysis process involves the thermochemical decomposition of organic material by heating in the absence of oxygen or any other reagents. Possible concerns with this process include handling of the oil, char, and gas products and the possibility of combustion once contacted with oxygen. Pyrolysis has limited operational experience and is considered a developing technology when applied to biosolids.

Hydrothermal Liquefaction

Hydrothermal liquefaction of wastewater sludge involves heating dewatered cake to 350°C while maintaining a pressure of 3,000 psig. These conditions promote the reactions that occur within the center of the Earth that convert organics to crude oil to occur in minutes rather than millions of years. The technology has been tested a variety of feedstocks including: paper, wood, food waste, wastewater sludge, plastics, and algae. The organic content of the feed material is essentially eliminated with 99% of the influent organic solids converted to biocrude oil. Inert matter passes through the process and will need to be handled in downstream processes. Likely thickened and/or dewatered and hauled offsite.

The process has been tested on a variety of wet waste materials including dense organic cellulosic products (paper, wood, cellulosic food), wastewater solids, plastics, and food (proteins, carbohydrates, and fats) waste with promising results. The biocrude product can be used in an onsite catalytic hydrothermal gasifier (CHG) for production of a high heating value gaseous product (600-900 BTU/cf) or directly reused after blending with diesel fuel. Application to biosolids is an area of active research.

Supercritical Water Oxidation

When water is heated above the critical point (374°C; 3,600 psig) it exists as a supercritical fluid which has properties opposite that of conventional liquid water. For example, under normal conditions, water is incompressible, but under supercritical conditions it is highly compressible. Additionally, normal liquid water is a poor solvent of non-polar material (e.g. oil) but an excellent solvent of electrolytes (e.g. salt) whereas supercritical water will preferentially dissolve non-polar organic material.

Sludge is pressurized and pumped into the reactor where pure oxygen is injected at multiple points to control the reaction temperature. The sludge must have a fuel density of at least 50 g COD/L for the process to be economically viable and must have small regularly shaped particles for favorable reactor kinetics. Oxidation in the reactor increases reactor temperature and heat off the backend is used to preheat the influent material. Excess heat is recovered energy production through a steam turbine or organic Rankine cycle engine.

If the process is able to destroy halogenated solvents, it would be beneficial to investigate supercritical water oxidation’s ability to destroy PFAS.

Emerging Technologies for PFAS Treatment

Granular Activated Carbon and Ion Exchange (AIX)

GAC and AIX treatment methods for PFAS removal in drinking water were described above and the adsorptive and general properties hold true for wastewater matrices as well. However, as previously mentioned, the main disparity between either treatment method’s applicability are the high concentrations of total organic carbon and other molecules present in higher concentrations than the PFAS molecules that would consume the absorptive capacity of the GAC and exchange capacity of AIX preferentially to the potentially low concentrations of PFAS. As such, the size of the vessels (bed volume) required to effectively treat PFAS down the double- or single-digit part per trillion levels would be prohibitively large and uneconomical without pretreatment.

Reverse Osmosis

Reverse Osmosis (RO) treatment methods for PFAS removal in drinking water were described above and the same properties for membrane treatment hold true for wastewater matrices as well. However, similar to GAC and IX, to treat PFAS to the single- or double-digit part per trillion levels and maintain the desired flux in a wastewater matrix, would require prohibitively large RO systems that would not be economical.

Foam Fractionation

CDM Smith is investigating the use of conventional sparge trench technology coupled with the recent development of foam fractionation technology and foam recovery/reconstitution to remove PFAS from groundwater. For PFAS, the sparging bubbles provide a high air-water interfacial area that facilitates "stripping" of the surface-active PFAS from the groundwater. This sparging process results in formation of a foam on the water surface, which can be subsequently removed via a vacuum and/or skimming system, resulting in orders of magnitude decreases in bulk groundwater PFAS concentrations. The recovered PFAS waste can then be treated via conventional high temperature incineration or treated via promising technologies such as electrochemical oxidation (ECO) or enhanced contact plasma (ECP).

PerfluorAd

CDM Smith is investigating the use of PerfluorAd, a proprietary coagulant/flocculant that binds with PFAS to form flocs, as a cleaning agent and as a rinsate (/rinse-aide/) technology. PerfluorAd is being used in Germany to clean out firefighting vehicles and shows dramatic improvement over triple water rinsing. PerfluorAd is also being used to pre-treat the produced rinsate, along with a GAC polish. CDM Smith's investigation involves removing residual PFAS from a surrogate system using PerfluorAd and a single potable water rinse. The rinsate is then be treated with PerfluorAd, a particle filter, and goes through optional polishing using GAC. The remaining PFAS concentrate is destroyed using electrochemical oxidation. This process has been proven for the cleanout of aqueous film forming foam (AFFF) vehicles and delivery systems and is currently in use in Germany at full scale.

Electrochemical oxidation is an established PFAS destruction technology for groundwater treatment. The technology utilizes electrode(s) to break the carbon-flourine bonds within the PFAS molecule. This technology is being researched heavily for use in wastewater and other applications. Based on the state of knowledge around this technology it is anticipated that some pre-treatment would be required to make this a viable technology.

Electrocoagulation (EC) is a process that runs a direct current through an anode and cathode creating a circular current that causes the anode to form a hydroxide flocculent. This flocculent can absorb PFOA molecules. This technology is still in the bench scale research phase of development. Based on the state of knowledge around this technology it is anticipated that some pre-treatment would be required to make this a viable technology.

4.2 Drinking Water PFAS Treatment Cost Analysis

While the anticipated costs for PFAS treatment in wastewater and biosolids matrices are difficult to scale from drinking water, general cost tendencies can be developed. From these trends, a scalable value cannot be adequately developed as the relationship between wastewater and drinking water treatment for PFAS is not linear. However, drinking water costs of PFAS removal provide insight into the magnitude of which treatment in wastewater and biosolids could be anticipated. **Table 3-1** outlines projects that CDM Smith has completed within the past two years pertaining to PFAS treatment at WTPs.

Table 4-1. Construction Costs for Drinking Water Treatment of PFAS

Project Location	Capacity (MGD)	Approximate Cost (Millions of Dollars)	Project Specific Notes	Cost per Gallon Treated
Spectacle Pond WTP, Ayer, MA	2	$5.5	▪ GAC pressure vessels ▪ New building for PFAS treatment ▪ Existing sand filters upstream of GAC	$2.75
Grove Pond WTP, Ayer, MA	2	$3.1	▪ AIX pressure vessels ▪ New building for PFAS treatment ▪ Existing sand filters upstream of GAC.	$1.55
Westfield, MA	4	$5.6	▪ GAC pressure vessels ▪ New building for PFAS treatment	$1.40
Middlesex, NJ	12	$30		$2.50
Confidential Client in Mid-Atlantic Region (Two Groundwater Well Sites)	2.5	$5.4 (GAC) $4.9 (AIX)	▪ PFAS treatment at individual groundwater well sites ▪ Planning study to evaluate GAC vs. AIX at each well station ▪ Some include new building requirements	$2.16 $1.96
	3.7	$6.4 (GAC) $6.1 (AIX)		$1.73 $1.65
Brunswick, NC	50	$120	▪ Reverse osmosis for PFAS and other contaminant removal ▪ Includes in-plant improvements and expansion for PFAS ▪ Existing upstream sand filters.	$2.40
			Average Treatment Cost/ Gallon	**$2.00**

Table 4-1 presents data on completed design projects which range from planning phase facilities to those which have been fully constructed and are operational. These projects cover and array of capacities, ranging from 2 mgd to 50 mgd and include various PFAS treatment technologies such as GAC, AIX and RO. The average cost per gallon to treat drinking water for PFAS is $2.00, which is inclusive of only the capital costs of the infrastructure and not general operation and maintenance costs. Additionally, it should be noted that many of these projects include project-specific requests and considerations in the overall cost. These considerations could include impacts such as additional chemical systems, permitting, new building requirements, and other items essential for implementation of PFAS treatment.

For perspective, Operation and Maintenance (O&M) costs from the planning phase of two PFAS treatment evaluations for drinking water facilities are presented in **Table 4-2**.

Table 4-2. Annual O&M Estimates for Drinking Water Treatment of PFAS

Project Location	Capacity (MGD)	GAC O&M Estimate	AIX O&M Estimate
Confidential Client in Mid-Atlantic Region (Two Groundwater Well Sites)	2.5	$113,200	$80,100
	3.7	$282,800	$211,800

The cost per gallon of treatment presented and the O&M costs estimated, while representative of an array of PFAS treatment technologies for drinking water would increase substantially if applied to wastewater or biosolids matrices. As mentioned previously, the factor by which the cost would increase is not quantifiable and would need to be evaluated for the site-specific water matrix and other project requirements, but it could be orders of several times larger in some cases. It is important to remember that when it pertains to wastewater or biosolids, additional treatment requirements and other considerations substantially influence the overall cost but that without these considerations, the PFAS treatment methods described above might not be feasible at all. For example, without pre-treatment GAC and AIX would be extremely challenging and likely not cost advantageous to work with.

The costs presented in Table 1 are intended to provide the reader with a reference point for the cost implications of treating PFAS in drinking water but should not be interpreted or applied to any other matrices.

4.3 Financial Implications

Water treatment technologies such as AIX, GAC and RO are difficult to scale and relate to wastewater treatment standards due to the high total organic carbon (TOC) content in wastewater effluent when compared to typical ground water or surface water influent to a drinking water treatment plant. As a result, to implement any of these technologies may require some level of additional treatment; coagulation, sand filters, membrane filters, etc., otherwise the PFAS treating technologies may become prohibitively large. For example, to compare the Brunswick County RO improvements, for a total cost of $120,000 to treat 50 MGD. That results in a cost to treat of $2.40/gpd (capital expense) in addition to a facility normal operating costs and any operating expense associated with those new facilities. At a wastewater treatment facility, the $/gpd, may be two or three times that due to the wastewater matrix and increased TOC concentration and other components of the wastewater effluent that would be removed upstream of the RO membranes before the PFAS molecules were successfully removed down to the parts per trillion level.

As an example, Lewiston Auburn Water Pollution Control Authority (LAWPCA)_has an average daily design capacity of 14.2 million gallons per day (MGD). If they were to implement RO treatment assuming $2.00/gpd, that would result in a capital cost of $57 to $85 million to treat the liquid side of the plant to meet drinking water standards for PFAS. The debt service on this capital expenditure would be approximately $2.9 to $4.3 M per year at 3% over a 30-year term, doubling the Authorities 2019/2020 annual operating budget of $3.4M. This does not include operating costs associated with the new facilities or any increase in sludge disposal costs. The Authorities sludge disposal costs have already increased 153% from 2017/2018 (pre-PFAS), to their 2019/2020 budget (post PFAS). As a result, the Authority's community fees would have to be increased accordingly, which would in turn increase individual home owns sewer bills 2 to 3 times their current fees.

Entities described in the Section 2 case studies reported their annual sludge end-use costs were 8 to 17% of their total annual operating budget. For those entities in states where PFAS was regulated below the EPA health advisory level of 70 ppt, plants that rely on off-site sludge outlets saw an increase in sludge end use cost of 80 to 230%. So the PFAS that partitions to the solids phase and remains in the sludge would still require disposal alternatives discussed in Section 1, or if practical, one of the treatment technologies discussed in Section 3.1.

Section 5

Relevant Studies and Articles

PFAS Cleanup Backers Face Unexpected Foe: Water Utilities

> https://news.bloomberglaw.com/environment-and-energy/pfas-cleanup-backers-face-unexpected-foe-water-utilities

Expensive waste — Why Hall County is getting out of the sludge-processing business; Florida

> https://www.gainesvilletimes.com/news/government/expensive-waste-why-hall-county-is-getting-out-of-the-sludge-processing-business/

Presque Isle to spend $15.6M fixing its wastewater sludge problem; Maine

> https://bangordailynews.com/2020/08/20/news/aroostook/presque-isle-wastewater-sludge-problem-to-get-multi-million-dollar-solution/

Local legislators tackle sewer, water issues; Massachusetts

> https://www.recorder.com/Sewer-and-water-30894094

Proposed energy park could spark revenue for Yarmouth; Massachusetts

> https://www.capecodtimes.com/news/20200315/proposed-energy-park-could-spark-revenue-for-yarmouth

Local legislators tackle sewer, water issues; Massachusetts

> https://www.recorder.com/Sewer-and-water-30894094

Marquette County Board approves study to find how to dispose of 1.2 million gallons of PFAS contaminated biosolids; Michigan

> https://www.uppermichiganssource.com/2020/07/08/marquette-county-board-approves-study-to-find-how-to-dispose-of-12-million-gallons-of-pfas-contaminated-biosolids/

NYC waste company drops plan to import 'sludge' to Wayne County; New York

> https://fingerlakes1.com/2020/07/07/nyc-waste-company-drops-plan-to-import-sludge-to-wayne-county/

Sulphur Springs City Council To Consider 4 Ordinances At March 3 Meeting; Texas

https://www.ksstradio.com/2020/03/sulphur-springs-city-council-to-consider-4-ordinances-at-march-3-meeting/

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Appendix A
Participant Summaries

Burlington Wastewater Treatment Facilities, VT

The City of Burlington, VT operates three wastewater treatment facilities and the group negotiates biosolids management as an entire county. Of the three facilities, two are smaller and truck liquid sludge to the main, larger facility for dewatering. Currently, all dewatered sludge is trucked to a lime stabilization facility in upstate New York where the sludge is treated and turned into a Class A, reusable material. Originally, the dewatered sludge was supposed to be accepted at the landfill however the Burlington product was turned away due to odor control concerns. PFAS concerns have impacted the facility in ways outside typical regulatory impacts. A couple years ago the City considered taking leachate, which they had once accepted, at the main facility. There had been some local interest but this investment, which would've been necessary to adequately accept leachate and make a profit, was put on hold due to PFAS concerns and anticipated regulations.

Burlington's WWTF is most concerned about achieving a long-term, reliable residuals management plan. The biggest challenge is going to be what to do with their residuals seeing that land application has been and will never be an option for the raw sludge product they produce. If regulations make it difficult or impossible to do anything locally for sludge, the resulting travel cost will be exponential.

Casella

Casella Organics specializes in the management of biosolids and residuals, servicing nearly 100 wastewater treatment and water treatment facilities in the Northeast, many of them municipally owned or operated. Casella operates composting facilities and landfills and has felt the stress of PFAS in the capacity of their network of sludge handlers. In order to maintain sustainable operations, Casella continues to grow their management network to allow them to take solids to locations that are willing to receive them, though that often equates to a higher price point. Because of PFAS, they also now sell more blended products to meet customer demand and lower the total amount of PFAS in the final product that is being distributed. Casella has had to increase the fees paid by their customers as a result of increased solids management expenses.

Central Maine Farm

This 5th-generation family-owned dairy farm is located in central Maine and is managed with conservation principles. In 1984, the farm began using biosolids as a one of its soil management options. Through this, the farm saved money while improving its soil year after year. In the spring and summer of 2019, the Maine Department of Agriculture and NEBRA analyzed forage and milk from four farms that have used biosolids as a soil amendment on a regular basis. After decades of biosolids use, no PFAS impacts were evident in the farm's products. However, because the levels of PFAS found in the soil of some of the farm's fields exceeded the low screening values imposed by Maine DEP, the farm was unable to apply the biosolids they had stockpiled for Fall 2019 application and were forced to purchase commercial fertilizer. In 2020, they were able to spread some of the 2019 biosolids stockpile on fields that did not exceed the Maine screening standards for PFAS, but they were unable to accept any new solids. The total increase in this one farm's costs due to the PFAS scare was $46,000 in 2019 and 2020.

Clinton River Water Resources Recovery Facility, MI

The Clinton River Water Resources Recovery Facility (CRWRRF) is located in the City of Pontiac, Michigan and serves multiple communities in Oakland County, Michigan. The facility treats approximately 30 MGD and has been recognized by NACWA with three Peak Performance Gold Awards, a recognition highlighting facilities that have unblemished compliance with their NPDES permits for an entire calendar year. WRRF dewaters their biosolids, treats them as Michigan Class B product, and land applies. They also newly have thermal hydrolysis with the capability to produce Class A product. For a period of time, the WRRF reverted to landfilling while they took their digestors offline for rehabilitation but are now back to full land application. Within the last year, their projected landfilling costs saw a major increase with costs per ton approximately twice that of land application. With landfilling serving as their backup to land application, the potential need to switch to landfilling due to PFAS is a major financial concern. If PFAS becomes a concern, the WRRF hopes to tackle it at the source.

Concord Wastewater Treatment Facility, NH

As of June 2020, the Concord WWTF has a contract with a recycling company in Canada which takes raw sludge from the facility and composts the product in Quebec. Concord has had to move to this management strategy within the past year due to push back from the New Hampshire Department of Environmental Services (NHDES) regarding Concord's previous land application program. This program, which was in place since the 1980s was concluded when Concord was the first to be identified as a PFAS contributor to a nearby drinking water well. As a result, and after a PFAS contamination management plan issued by NHDES was completed, Concord decided to make a risk-based decision and abate the site. After the change in end use site, Concord is now paying $600,000 more per year.

Concord continues to have concerns about anticipated surface water standards for PFAS and whether their current disposal site in Canada is a reliable, long-term option. In the meantime, Concord plans to participate in an incinerator study to help solidify a better long-term biosolids management option.

Denali Water Solutions/WeCare Denali

Denali operates several organic residuals management facilities across the United States which they have done for more than 20 years. These facilities utilize a variety of different management strategies for biosolids processing such as land application, alkaline stabilization, composting and more recently, involvement in gasification and pyrolysis through a partnership. In total, Denali processes more than one million tons of residuals per year and has a diverse portfolio of service offerings. As of June 2020, the facilities that Denali operates have yet to be quantifiably impacted by current or anticipated PFAS regulations. One minor impact to date was at a facility in Michigan where the compost was tested for PFAS and came back with detectable levels. This resulted in The City informing residents, through a sign at the front gate - that the facility has tested positive for PFAS. The facility has yet to see a significant impact from this.

Representatives from Denali voiced their primary concerns regarding PFAS in biosolids as body politics getting out in front of the science and urged that the industry needs to let the science dictate the regulatory response.

Essex Junction, VT

The Village of Essex Junction Water Resource Recovery Facility is a 3.3 MGD advanced treatment facility that serves the Village of Essex Junction and the towns of Williston and Essex, VT. Sludge at this facility is anaerobically digested to create Class B biosolids, as defined under EPA Part 503. The resulting biosolids are managed in two ways - liquid biosolids are land applied, and the remaining biosolids are dewatered and transported off-site to a contractor for further processing to create a Class A biosolid. Public and legislative pressure led the Vermont Department of Environmental Conservation (VT DEC) to impose one of the strictest groundwater standards in the world: 20 ng/L (ppt) for the sum of five PFAS. Regulatory change has led to a reduction in available land for local nutrient recycling via land application of biosolids. The cost for Essex Junction's liquid land application has increased by 35% due to PFAS specific analysis. This price increase is based on one Spring land application cycle and is not yet annualized. Permit stipulations are still pending, so Essex Junction is waiting to see what the true impacts will be.

Grand Rapids WRRF, MI

The Grand Rapids WRRF uses volute thickeners and dewaters their biosolids using up to three centrifuges. After the biosolids are dewatered, the material is trucked to one of three landfills for disposal. GVRBA is a biosolids authority and Grand Rapids is a partner, along with the City of Wyoming, MI. As of August 2020, sources of PFAS which are above the Michigan water quality standards are under compliance schedules to reduce and/or eliminate PFAS discharges in accordance with the standards set. In all cases so far, the sources are installing GAC treatment systems to accomplish this. The Grand Rapids facility accepts landfill leachate from the locations where their biosolids are sent for disposal, creating a PFAS cycle that is of concern for the facility. In the future, the facility may need to consider different disposal options as a way to limit the landfill leachate accepted at the facility. The facility has not yet experienced an impact to revenue due to PFAS. However, the PFAS plant sampling is an added cost which the facility has spent approximately $50,000 on since June of 2019. The facility has also made a capital investment by providing funding for a Michigan State University/Fraunhofer PFAS study to evaluate if boron doper diamond tipped electrodes could be used to destroy the carbon-fluorine bond in a real-world application. The goal of this $300,000 investment was to shed light on the future of PFAS destruction and avoid shifting PFAS to different media.

Grand Rapids greatest concerns regarding PFAS include their biosolids end use outlet and associated costs, potential PFAS regulations specific to biosolids being enacted, and other water quality standards and/or limits for additional PFAS compounds. The facility has had conversations with the State of Michigan regarding their acceptance of landfill leachate and the impact it may have on anticipated biosolids regulations. The effort to prepare for this is ongoing and will require open discussions to develop solutions for the issues described.

Greater Lawrence Sanitary District (GLSD), MA

The Greater Lawrence Sanitary District (GLSD) is a wastewater treatment facility located in North Andover, Massachusetts. GLSD serves the communities of Lawrence, Methuen, Andover, North

Andover, and Dracut, Massachusetts, as well as Salem, New Hampshire. In 1999, GLSD began a contract with the New England Fertilizer Company (NEFCO) to permit, build and begin managing the biosolids drying and pelletizing facility. Since 2003, GLSD has sent 100% of its biosolids to the biosolids facility, producing three to four trucks of pellets per week. In 2018, Synagro was contracted to operate the biosolids drying facility. GLSD has not seen an impact to their cost as a result of PFAS as of yet, however they are concerned about the sustainability and diversity of the pelletization program, especially they financial impacts PFAS regulations will have on the reuse of GLSD's fertilizer pellets.

Great Lakes Water Authority, MI

The Great Lakes Water Authority (GLWA) is located in Detroit, Michigan and provides water and sewer services to southeast Michigan communities in Wayne, Macomb, and Oakland counties. GLWA's wastewater treatment plant is the largest single-site treatment facility in North America with a treatment capacity of 1,700 MGD and an average flow of 686 MGD. GLWA is transitioning its Wastewater Treatment Plant to a Water Resource Recovery Facility that will ultimately be energy neutral. Additionally, a new biosolids dryer facility has the capacity to turn about one billion gallons of biosolids into fertilizer. Currently, 75% of biosolids are dried and turned into Class A materials to be land applied, mostly in Canada, and 25% of biosolids are disposed of in multi-hearth incinerators. Though their management practices have not yet been impacted by PFAS, GLWA is focusing on their volume minimization programs and are considering what direction they may go once their current contracts have concluded.

Greenfield Wastewater Treatment Facility, MA

The Greenfield Water Pollution Control Plant (WPCP) is a secondary wastewater treatment plant that serves the town of Greenfield, Massachusetts. The WPCP treats an average of 3.4 MGD and is a trickling filter plant. The WPCP has not yet seen significant impacts on their biosolids management costs due to PFAS and are currently focusing a majority of their attention on nitrogen and phosphorus removal.

Hooksett Wastewater Treatment Facility, NH

The Hooksett, NH WWTF had been hauling their biosolids to Merrimack, NH for beneficial reuse until recent. As of July 2020, they are in a pilot program with RMI who takes the WWTF's biosolids off the belt filter press and feeds the product into their dryer. The end product is a 90% Class A biosolids product and it is trucked to New Hampton, NH for beneficial reuse. Hooksett decided to participate in the pilot program after concerns regarding their original outlet in Merrimack came to light. While the facility is pleased with the dryer's performance and end product, representatives from Hooksett WWTF are still concerned with anticipated PFAS regulations. Primary concerns consist of if PFAS will be designated a hazardous waste, lack of treatment methods for removing PFAS in biosolids, and not having a reliable outlet for their biosolids long term.

Inland Empire Utilities Agency, CA

Inland Empire Utilities Agency (IEUA) is a regional agency that produces approximately 70,000 wet tons per year of biosolids from two solids processing facilities. The biosolids are hauled to a composting facility where it is composted to a Class AEQ material and sold locally, within 60 miles, to agricultural and commercial customers. With exception to the grit and screening material, all biosolids are sent to the composting facility and beneficially reused. The facility has not yet been impacted by PFAS regulations but has been impacted by concerns. Primarily, IEUA is aware that these regulations are anticipated and are preparing alternative end use sites in response but have yet to take formal action. The lab, on the other hand, has been impacted by requirements for the recycled water (tertiary treated) water that IEUA produces which is used for groundwater recharge, landscaping, industrial processes, etc. The lab has seen an increase in lab costs due to California State Water Resources Control Board mandatory to conduct weekly testing implemented in September 2019.

Though the impacts to the Agency have not come to fruition in a material way, the partner responsible for managing the compost has been running some tests on the material. With the new investigative order implemented in July 2020, the Agency anticipates more internal biosolids testing and the costs associated with such., though the costs themselves may be absorbed by wastewater activity. The Agency also plans to do some testing on feed stock and compost products after more data has been gathered on matrices throughout the process train, with the goal of determining how the acceptance of outside materials impact PFAS concentrations.

IEUA's primary concern regarding PFAS is that regulatory levels will become so restrictive that they may be unable to recycle the material. If this were to happen, the Agency would likely need to haul the product away because California has an organics diversion from landfills law as well a Greenhouse Gas Emission Reduction Act. This may prove difficult, especially for the recycled water programs, and it could completely change the current business model. Other concerns are liability and use restrictions, rate increases being unaffordable and the lack of consistent or uniform rules across the board. For example, days prior to IEUA's interview a new notification for response level in drinking water was released, which impacts their recycled water receivers. These levels outlined for individual compounds were some of the most stringent observed to date.

Lewiston Auburn Water Pollution Control Authority, ME

The Lewiston Auburn Water Pollution Control Authority (LAWPCA) is a 14.2 MGD plant servicing residential, commercial, and industrial sources in the cities of Lewiston and Auburn, Maine. In 2013, LAWPCA became the first municipal wastewater treatment operation in Maine to process solids through anaerobic digestion. For this, LAWPCA was recognized in 2014 with a Governor's Award for Environmental Excellence. In 2019 LAWPCA went from land application and composting to landfilling and only 25% land application. Without knowing where PFAS was going, they have had conversations about abandoning land application. PFAS scared a majority of their farmers away. Many farmers fear that contaminated soils are deadly. Cost per ton increased from \$30-\$35 per wet ton for land application and \$50 per wet ton for composting to \$70-\$75 per wet ton for landfilling.

In September 2019, LAWPCA received approval to run a pilot at compost facility (after it had been shut down for nearly a year) with strictly digested sludge and no odor control. This pilot was successful, and they had to put an amendment into their license to be able to operate compost facility long-term without odor control and using only digested sludge.

Lowell, MA

The Lowell Regional Wastewater Utility (LRWWU) transports, treats, and disposes of wastewater, stormwater, and domestic septage from the City of Lowell and the surrounding towns of Chelmsford, Dracut, Tewksbury, and Tyngsborough. The facility receives an average of 25 MGD, with peak flows often exceeding 100 MGD. LRWWU processes its biosolids in a centrifuge and has a contract with Casella for trucking and disposal that will be up in December 2020. Though their solids management has not been affected by PFAS yet, they anticipate changes but are limited in their options. They are currently putting together a bid package for January 2021 but are concerned that the limited disposal outlets and limited bidding competition will result in a major price increase. One loss they have felt is their inability to accept landfill leachate due to PFAS, losing nearly $1M per year in revenue.

Manchester Wastewater Treatment Facility, NH

The Manchester WWTF currently utilizes a fluidized bed incinerator, which they operate on site, as their biosolids management method. With an average throughput of approximately 4.5 wet tons per hour, the by-product of this combustion process is ash which RMI is contracted to pick-up and beneficially reuse for landfill cover material and as a mixture for road base. During the instances where the incinerator is down for maintenance purposes the product is trucked to Canada and any biosolids which are not incinerated are managed by Casella Organics.

The City of Manchester WWTF has been collaborating with various regulatory bodies to be on the forefront of PFAS monitoring. They have participated in and have ongoing studies which include testing several different trains throughout their wastewater management program as well as outlets. The goal is to better understand the stages and concentrations of PFAS as it travels through the process, which will allow for a better management strategy for PFAS regulations as enacted. Primary concerns for Manchester include regulations not being promulgated on sound science and how biosolids will be managed in the future without proven treatment technologies and the cost associated with each.

Orange County Sanitation District, CA

Orange County Sanitation District (OCSD) is a public utility that provides wastewater collection, treatment, and disposal services to 2.6 million people in central and northwest Orange County, California, a 479 mi^2 area. In 2018, OCSD was producing up to 825 wet tons per day of biosolids. In 2020, as a result of adding centrifuges to reduce their biosolids in 2019, OCSD produces 572 wet tons of Class B solids per day between their two treatment plants. They attempt to beneficially reuse 100% of their solids, with no material at present going to landfills. OCSD has not yet seen any impacts to their biosolids management as a result of PFAS. Their end-use sites have not changed, though they are considering their options should land application no longer be an option. OCSD works closely with the Orange County Water District (OCWD) to support water recycling, and in 2018 celebrated the ten-year anniversary of their joint effort, the Ground Water Replenishment System – the largest system for indirect potable reuse in the world.

In July 2020, California issued Order WQ 2020-0015-DWQ, requiring Publicly Owned Treatment Works (POTWs) with a design capacity of 1 MGD or greater to monitor for 31 PFAS analytes in influent, effluent, biosolids, and, where applicable, groundwater.

Passaic Valley Sewerage Commission (PVSC), NJ

Passaic Valley Sewerage Commission (PVSC) is one of the largest wastewater treatment plants in the US, designed to treat an average flow of 226 MGD and a wet weather treatment capacity of 400 MGD. PVSC services 1.5 million residents in the 48 municipalities of Bergen, Essex, Hudson, Union and Passaic, New Jersey Counties. All biosolids at PVSC are processed using the following treatment methods: initial thickening thru gravity thickeners, thickening centrifuges, heat treatment (Zimpro Process), decanting, filtering through plate and frame filter presses and eventually stored. The biosolids are then loaded into container trucks and transported to various landfills and used as Alternative Daily Cover. PVSC has been operating the Zimpro Process for over 30 years. This process enables PVSC to generate a Class A biosolids which is widely accepted at disposal sites. There has always been a concern with the longevity and diversity of the outlets that accept our sludge, past, present and future. As of now, PVSC is not expecting a change in disposal locations, however their biggest concern would be modifications to its existing Federal and State permits. These modifications may ultimately lead to the development and construction of additional sludge treatment processes. This would in turn increase the capital and O&M costs of the plant.

Pima County, AZ

The Pima County Wastewater Reclamation Treatment Division operates and maintains seven Water Reclamation Facilities (WRF) that receive, treat, and dispose of over 62 MGD of sanitary sewage. Two of the larger facilities handle sewage from the Tucson metropolitan area and five facilities serve smaller towns and rural areas of Pima County, Arizona. Pima County began recycling its biosolids as a soil amendment and fertilizer on agricultural land in 1983 and continued through December 2019 using a single service provider. Due to concerns regarding PFAS in groundwater, the county's source for drinking water, Pima County was forced to halt land application operations. They began disposing of biosolids at regional solid waste landfills in January 2020. In response to the change in disposal methods, Pima County is conducting a study of PFAS contamination, retention, and migration in farm soils where biosolids had been historically land applied.

Plymouth Village Wastewater Treatment Facility, NH

As of June 2020, the Plymouth Village facility produces a Class B material which they land apply after dewatering with a rotary screw press and lime stabilization. Plymouth Village Water and Sewer District (PVWSD) receives septage from 72 towns in the region and have been asked to look upstream as a way to minimize PFAS in the septage accepted. While the District has not yet had to turn away septage, if these concerns persist, they may need to consider screening or ultimately turning away septage producers and associated revenue. The District has been following PFAS concerns since the initial drinking water and groundwater regulations were proposed in January 2019 by NHDES. The District's biggest concern regarding PFAS is having the responsibility of managing these contaminants placed on the municipalities and management facilities. Under the guidance of NHDES, the District has collected samples of their sludge and results show an elevated PFAS concentration – though it is important to note that an approved EPA method for testing PFAS in a biosolids matrix has not been established. While the District's end use site has not changed in response to PFAS concerns, they are looking towards a back-up plan, which would likely be shipping their residuals out of the country. PVWSD has identified potential outlets and evaluated equipment capable of minimizing the overall product volume, but these alternatives all come at a much higher cost.

As of June 2020, PVWSD was in an ongoing lawsuit with the NHDES, claiming an inadequate cost and benefit analysis was completed prior to regulations being proposed. In July 2020, New Hampshire Legislature a passed law placing MCL's (and AGQS) for PFAS contaminants into statute, essentially relieving NHDES from its requirement mandated by law to conduct a cost and benefits analysis and dissolving the preliminary injunction on PFAS drinking water and groundwater rules.

The District has increased rates by almost 40% due in part to PFAS concerns but also primarily from planned infrastructure work. The current and future PFAS impact fees, surcharges, and other capital and operational investments resulting from drinking water, groundwater, surface water and residuals regulations in addition to the 40% rate increase will likely become unaffordable for the District without federal and state funding assistance. Other concerns that PVWSD has related to PFAS regulations as enacted are the limited treatment technologies, not having an approved testing method resulting in not reliably data, public perception and support, and ultimate liability.

Portland Water District, ME

Portland Water District (PWD) operates and maintains four wastewater treatment plants and provides wastewater services to Cape Elizabeth, Cumberland, Gorham, Portland, Westbrook, and Windham, Maine. Between its four plants, PWD sees an average flow of about 25 MGD. Before PFAS, about one third of PWD's biosolids were composted and another 5% were digested at a small digester facility. However due to the stress of PFAS on land application capacity, these resources have dried up and PWD has been forced to divert their solids to a landfill. The landfill needs to stockpile enough trash to mix with the sludge, and this often creates a logistical bottleneck. PWD's contract with this landfill will expire in 2020, but PWD is struggling to find a facility interested in a contract that is longer than one year due to PFAS fears. They expect their disposal costs to potentially double as a result of PFAS. The District also expects their sludge processing time will be impacted by the limited landfill capacity, and may result in capital investment to allow trucks to be loaded to accommodate the landfill's schedule and operation instead of their own. Similarly, landfills are starting to monitor odors more closely then ever before, so a deodorant system may be required at the plants.

Presque Isle Wastewater Treatment Facility, ME

As of July 2020, the Presque Isle facility in Maine dewaters their biosolids using a centrifuge and sends the dewatered cake to a landfill. Prior to this, the facility had been land applying in the summer months and storing the biosolids in their lagoons during winter months. The district, which had been land applying biosolids for close to 40 years had to halt this operation in February of 2019 after being mandated to test for PFAS compounds before continuing land application. This resulted in the lagoons continuing to fill during the summer months and ultimately running out of available storage, requiring dewatering which the plant was not equipped to do. Results of PFAS testing showed elevated levels and the district was asked to perform PFAS testing on nearby homeowner drinking water wells. The District has made a risk-based decision to opt out of land applying and continues to monitor the possibly impacts residential wells. The District plans to purchase a permanent centrifuge so they no longer have to operate under a contracted piece of equipment, this centrifuge will be included in the ongoing upgrade to the facility.

Resource Management Incorporated

Resource Management Incorporated (RMI) is a biosolids management company that participates in direct land application of Class A and Class B biosolids in additional to raw solids management at a local New Hampton, NH facility they own and operate. The end product from the New Hampton facility is a Class A biosolids product that is then distributed to farms for land application. RMI is strictly a beneficial reuse company as they do not participate in disposal, nor do they plan to. If beneficial reuse becomes a biosolids management tool that can no longer be utilized due to PFAS, this could put RMI completely out of business. While this would be an unfortunate fate for the small New England-based company, another significant impact would be that the approximate 70,000 tons of material they currently accept from generators in the area that would no longer have a home. Representatives from RMI shared how PFAS has rocked the marketplace, both on the generator side, or those producing the material and also on the end user side, such as farmers and gravel pit owners. RMI also noted that impacts to the paper mills and septage suppliers should not go unnoticed. Approximately 2/3 of RMI's source material is from paper fibers, with only the remaining 1/3 being from biosolids.

RMI has already felt the brunt of PFAS policies. The primary concern is damage to the end user markets, which is already observed by their rates doubling and, in some cases, increasing by four times. RMI has decided to take on a risk mitigation strategy by investing in two dryers which they hope will make PFAS policies as enacted easier to manage.

South Essex Sewerage District, MA

South Essex Sewerage District (SESD) is currently under contract with Casella and Synagro to process their biosolids either by incinerator or disposal up north. This long term agreement has protected SESD from being significantly impacted by PFAS concerns yet. While representatives have spoken with Casella about PFAS concerns, they have not experienced a management impact yet. SESD has been involved in PFAS testing as a proactive measure and the results came back as not having elevated PFAS levels in their sludge. SESD voiced concerns regarding PFAS regulations such as what this will do to the sludge marketplace and the cost implications as well as who holds the liability.

Springfield Regional Wastewater Treatment Facility, MA

The Springfield Regional Wastewater Treatment Facility (SRWTF) is located on Bondi's Island in Agawam, Massachusetts. It is owned by the Springfield Water and Sewer Commission and currently maintained and operated by SUEZ through a 20-year service agreement. SRWTF processes approximately 40 MGD but is designed to handle a maximum flow of 67 MGD. Biosolids are managed by their contract operator, SUEZ, and associated risks and costs are covered in their service contract which is currently in its last year of term. SRWTF's biosolids are sent to up to seven different locations in the northeast between landfills and incinerators. Casella manages the product for SUEZ and is responsible for finding facilities to receive the biosolids. As they work on a proposal for a new contract, SRWTF is considering including equipment such as a digester or additional centrifuge to obtain drier solids and increase biosolids handling capacity as a result of PFAS.

Upper Blackstone Clean Water, MA

The Upper Blackstone Clean Water uses incineration to process biosolids from their facility as well as other smaller facilities in Massachusetts. While the facility has yet to be impacted by PFAS in a material way, there are several concerns including anticipated regulations being too low given the ubiquitous nature of the compounds and the perception of facilities, such as Upper Blackstone being considered a polluter or source rather than the receiver. Upper Blackstone has been in discussion with local communities to perform a regional study to prepare themselves for anticipated PFAS regulations.

Wixom, MI

The Wixom, MI wastewater treatment plant aerobically digests sludge generated at the plant to produce a Class B biosolids that is beneficially reused at local farms through subsurface liquid injection. As a results of the states PFAS response the Plant is no longer able to continue its beneficial use practices and dewaters all sludge onsite before sending it to landfill. The Michigan PFAS Action Response Team (MPART) and Michigan Department of Environment, Great Lakes, and Energy (EGLE) have been proactive in working with the plant assist with sampling and identify upstream industrial source. As a result, a significant industrial user has installed a granular activated carbon (GAC) system on their own effluent, which has led to significant reduction in PFOS concentrations in the WWTP influent and biosolids. Through source reduction and public education., the plant hopes to further reduce is influent concentrations of PFOA and PFAS and get back to its beneficial reuse program so they can continue working with local farms and reduce their current sludge handling costs.

Appendix B

Additional Data

Table B-1. Frequency table of key words used to make the Figure 2-4 word cloud.

Frequency of Mentions	Word	Frequency of Mentions	Word
15	limits	4	programs
14	concern	4	restrictions
14	cost	4	testing
14	regulations	3	analysis
13	impact	3	challenge
11	biosolids	3	compounds
10	liability	3	control
10	science	3	disposal
10	treatment	3	far
9	people	3	plan
8	state	3	significant
8	water	3	uncertainty
7	political	2	capacity
7	recycle	2	chemicals
6	facilities	2	contract
6	source	2	deal
5	agencies	2	domestic
5	data	2	hazardous
5	landfill	2	incinerator
5	numbers	2	panic
5	response	2	receivers
5	sludge	2	residential
4	compost	2	study
4	health	2	waste
4	local		

Table B-2. Frequency table of key words used to make the Figure 2-5 word cloud.

Number of Mentions	Word	Number of Mentions	Word
13	cost	3	treatment
13	regulations	2	challenges
8	testing	2	communication
6	material	2	compliance
5	biosolids	2	disposal
5	concern	2	implications
4	management	2	limits
4	problem	2	local
4	source	2	modifications
3	discharge	2	perception
3	forever	2	plant
3	issue	2	processes
3	method	2	quality
3	outlets	2	receiver
3	policies	2	regional
3	public	2	sludge
3	reduce	2	state
3	science		

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