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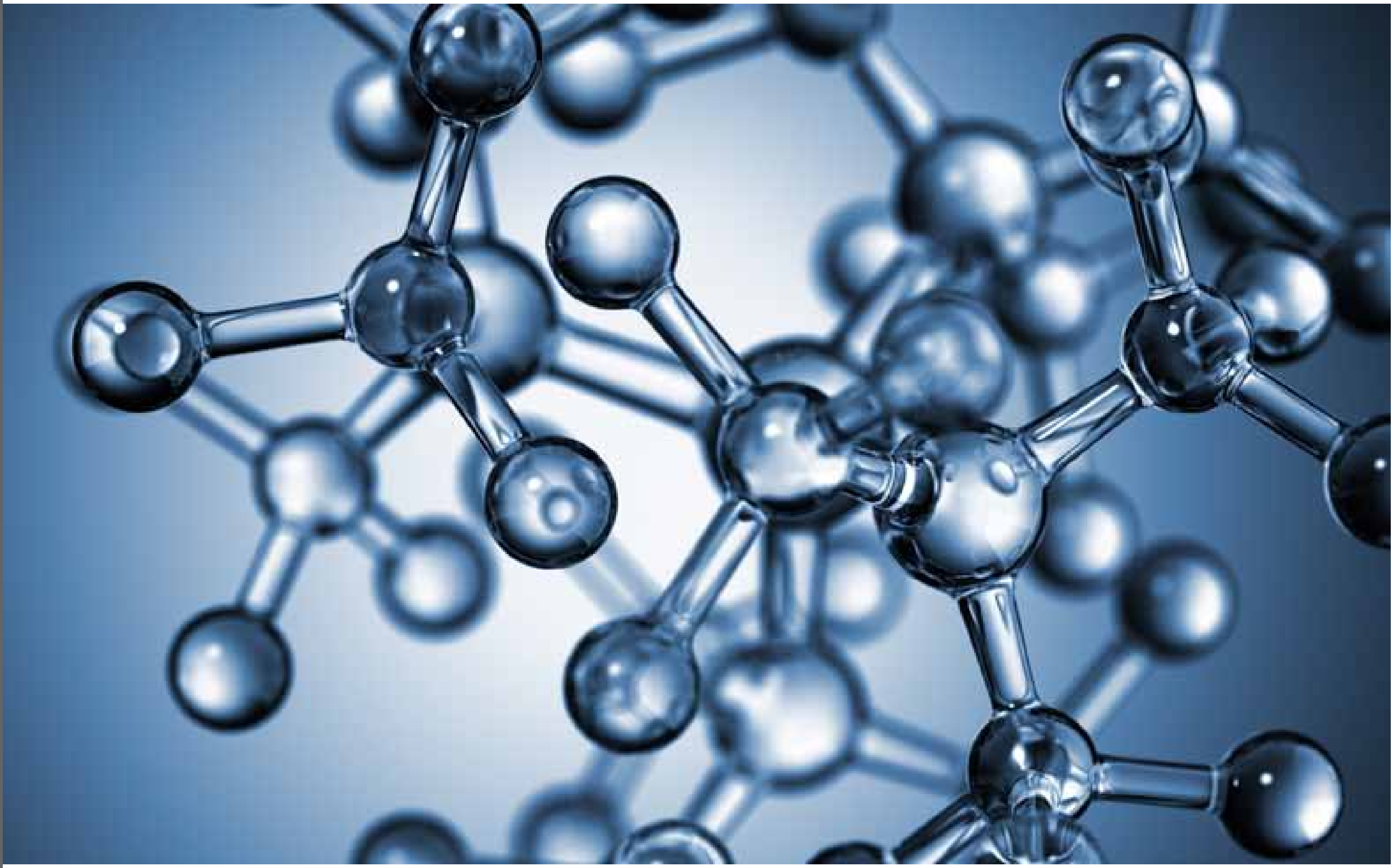

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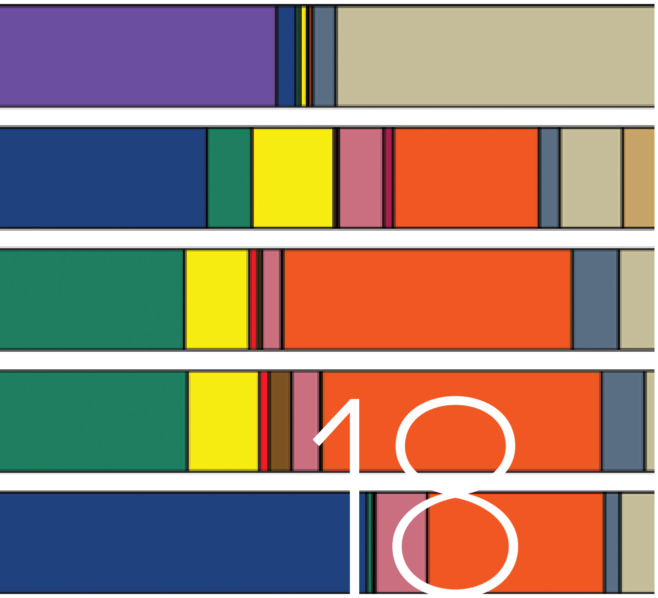
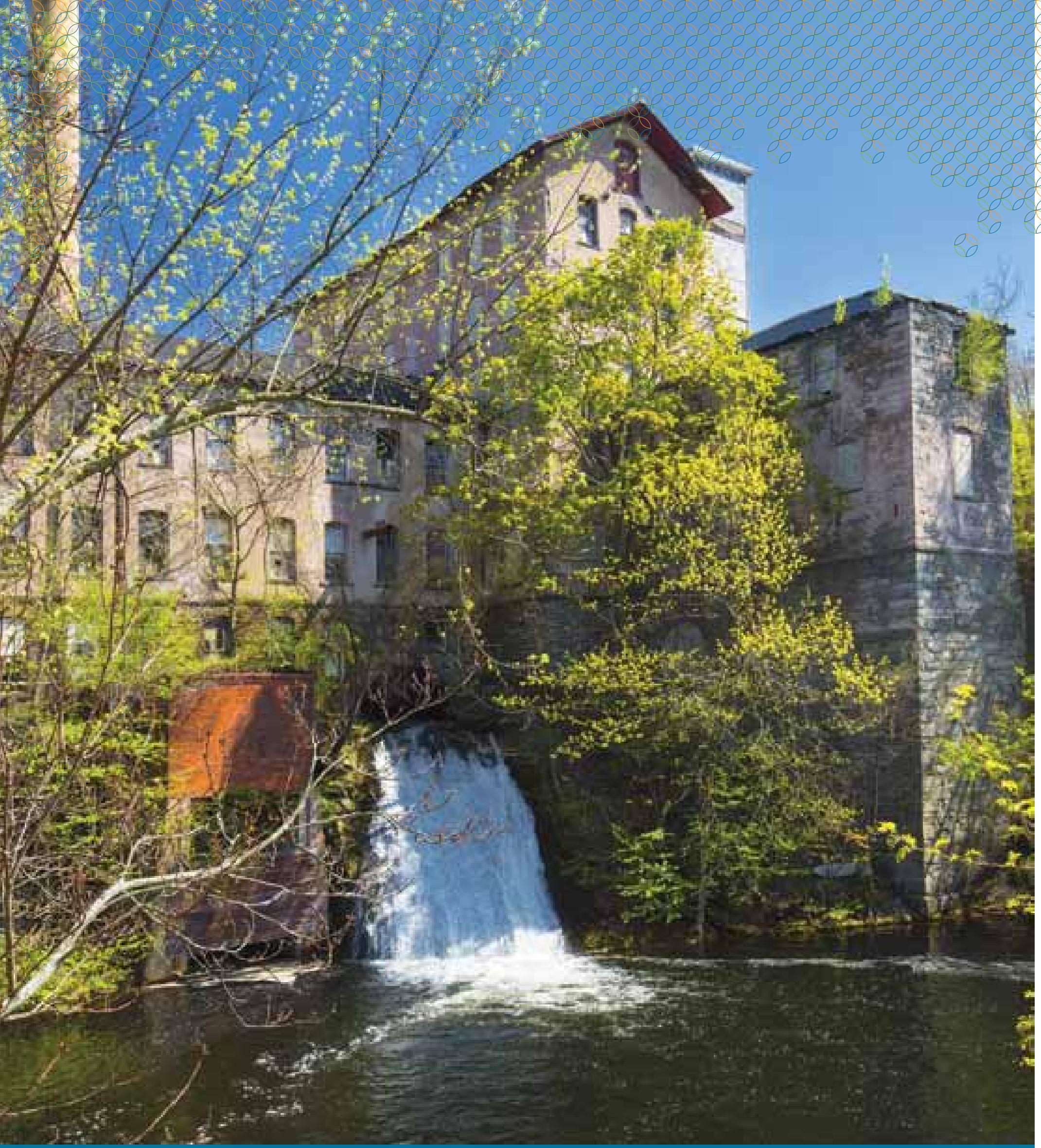


On the cover: 3-D rendering of PFAS molecule

Page 61: Measurement unit conversions and abbreviations



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2021 RATES ($)

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Corporate	420
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Academic	185
Young Professional	70
PWO	110
Dual	45
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Total paid and/or requested circulation		2,208	2,208
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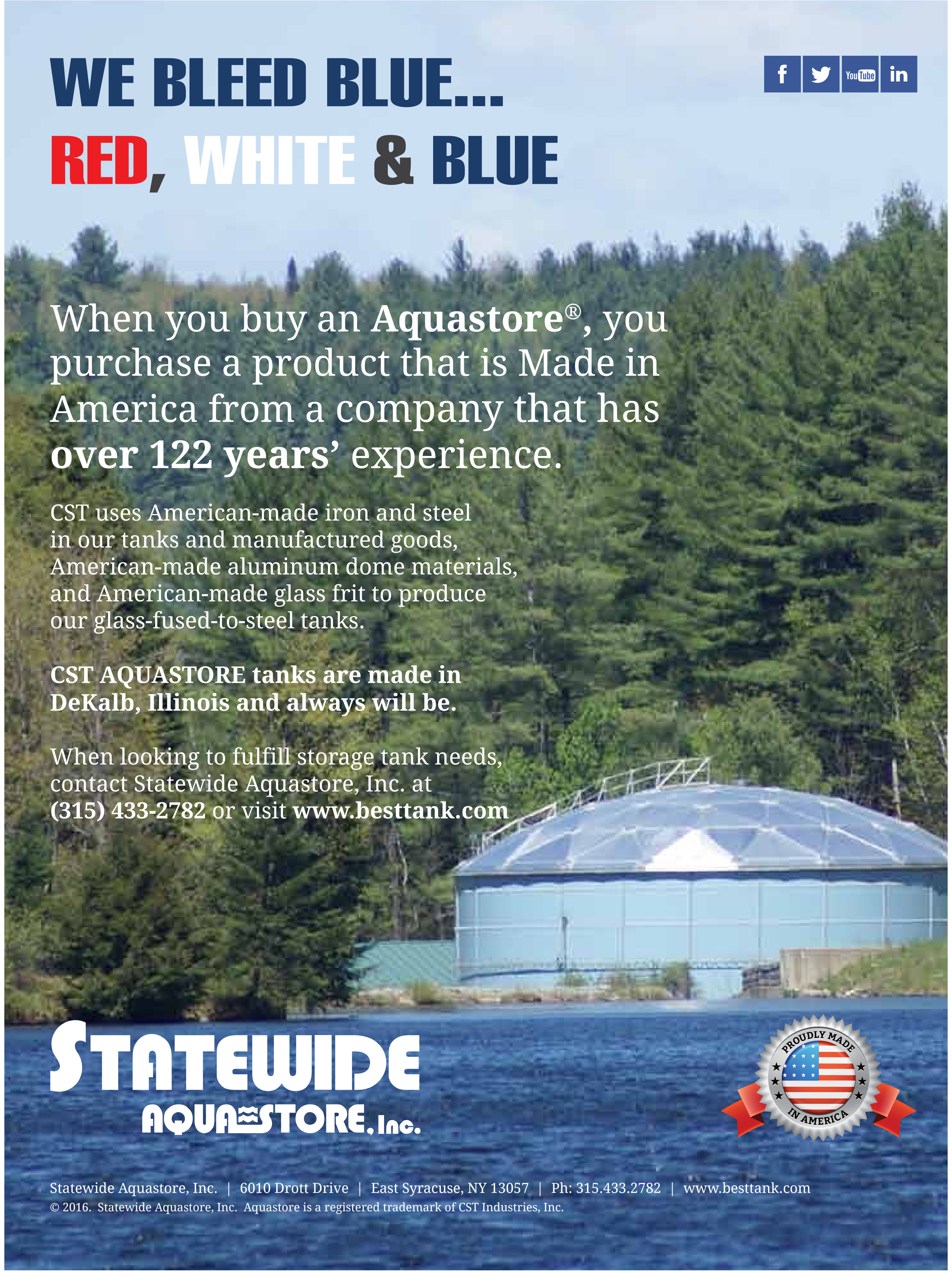

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President's Message

Greetings to my fellow NEWEA colleagues! I am honored to accept the gavel and serve as the president of this distinguished organization for 2021. When I think of the many brilliant and professionally accomplished individuals who have held this position, I am truly humbled to follow in their path, and I pledge to do my best to maintain NEWEA's role as a nationally recognized leader in our industry.

Today, we look around our industry and observe that we are surrounded by an ocean of change—change in how we conduct conferences; change in how we work, where many of us now work remotely and probably will continue to do so, even after COVID; change in the workforce, through retirements and more deliberate, focused recruitment efforts; change in technology and sustainability. And a new administration is in Washington that will likely pass an infrastructure bill and other legislation, profoundly affecting our industry and bringing further need for us to adapt to change.

As we gaze upon this sea of change that surrounds us, we also see a building desire to look inwardly, both personally and within our organizations, including NEWEA, to confront inequities and a need to better foster diversity and inclusivity. We have made progress, but we can do better. Long ago (in the 1980s) when I attended my first Annual Conference as a young professional (incidentally the phrase YP would have to wait another decade or two to be coined!), not much diversity could be seen at NEWEA events, even with respect to age: in fact, the attendees skewed inarguably toward an older, predominantly white, all-male crowd.

By contrast, fast forward to our recent Annual Conference, where on the first Thursday we experienced a wildly successful and energized Forum on Diversity, Equity, and Inclusion (DE&I) that was prepared by our new ad hoc DE&I Committee. Kudos to Chairperson Marina Fernandes and her committee for arranging an outstanding group of panelists that included General Manager OJ McFoy of the Buffalo Sewer Authority. Mr. McFoy opened the day with a candid and inspiring keynote address and finished it by conducting a piercing and honest forum question-and-answer session. More than 170 attendees participated in this online discussion forum, and many appeared deeply moved and inspired (as am I) to continue this discussion and participate in turning words into positive actions.

Screenshot from the 2021 Annual Conference's Women in Water Forum: (l to r) Fredie Kay, Phyllis Arnold Rand, Liz Levin, (bottom row) Elisa Speranza, Megan Yoo Schneider

We saw that same spirit again on the second Tuesday of the Annual Conference with the Women in Water Forum, "Commemorating the 100th Anniversary of the 19th Amendment." My heartfelt compliments go to Angela Moulton and Michaela Bogosh and their work group for arranging this forum, which featured more than 200 attendees! Fredie Kay provided a fascinating history of women's suffrage and the passage (barely 100 years ago) of the 19th Amendment to the U.S. Constitution that at long last guaranteed women the right to vote. The personal highlight of this forum for me was the inspiring panel discussion, where the four panelists shared deeply personal experiences of overcoming obstacles and attitudes to establish themselves in our water industry. These challenges I did not have to face while coming up through the industry, and, frankly, I wonder if I would have handled them with the same grace and poise or level of success.

An important concept was heard at both these forums: Let us not be afraid of change, but rather let us embrace it. Or, to use the imagery heard during these forums: Sharing the pie with more people does not mean there will be smaller slices with less to go around; it means that together we will create and all share in a bigger and more flavorful pie. There has been progress, but it has been stiflingly slow. Both forums underscored that the time is now for more meaningful and effective action.

So, NEWEA colleagues, I ask that we work together to navigate NEWEA among these tides of change, to foster healthful diversity, and to be leaders of change—in NEWEA as well as in our own organizations, in our culture, and indeed even in our lives. In the coming months the DE&I Committee will announce many activities, such as outreach and educational programs, and I urge you to participate and lend support. For us to succeed, we all need to be "all-in" on this change together.

> ***I ask that we work together to navigate NEWEA among these tides of change, to foster healthful diversity, and to be leaders of change—in NEWEA as well as in our own organizations, in our culture, and indeed even in our lives***

By making NEWEA an organization where everyone feels empowered, valued, respected, and safe, we will bring more people into the discussion, with more diverse backgrounds and more varied points of view. This will make us a stronger, more creative, more innovative, and more dynamic organization. Including this diversity of talent, creativity, and thought will enable us to build a more robust association, with a self-sustaining formula for success.

Finally, I thank my employer, Fuss & O'Neill, for its enthusiastic support over the years, both for me personally and for recognizing the value that NEWEA provides to our staff. And I thank you, NEWEA colleagues, as well, and ask for your support in navigating the moving tides about us: Let us all strive to be industry leaders in fostering diversity and welcoming change.

From the Editor

Hello NEWEA! I hope all were able to enjoy the virtual Annual Conference, even though it was different. Major kudos to all the speakers, moderators, and, especially, the NEWEA staff for the hard work to make the most of this year's Annual Conference experience. I enjoyed having the chance to chat "hello" to many of you, and I look forward to being all together sometime soon. In addition to boasting an impressive slew of technical presentations covering a comprehensive cross-section of our industry's most pressing challenges, the program also covered discussions surrounding other more human-like challenges faced by our industry and country: diversity, equity, and inclusion.

The Women's Environmental Network (WEN) hosted a Women in Water Forum organized by Angela Moulton and Michaela Bogosh. This event showcased the centennial of the 19th Amendment granting women the right to vote and presented many of the challenges faced by women since then during our fight toward equality. The forum was moderated by the wildly enthusiastic and knowledgeable Fredie Kay, founder of Suffrage 100 MA. Ms. Kay related the largely unknown history of the women's suffrage movement to a crowd or more than 200 industry professionals. She described many events shaped by extremely brave influential women, many of whom are from our region. It's sobering to reflect on how far we've come, and even with that reflection in mind, it's astoundingly evident how far we have yet to go.

The impressive group of panelists included Liz Levin, Megan Yoo Schneider, Elisa Speranza, and our very own past NEWEA president, Phyllis Arnold Rand. These four industry professionals each come from uncommon backgrounds with their own stories and experiences that have shaped them into the empowered leaders they are today. Ms. Kay posed questions to the panelists, each of whom responded with insightful, honest, and, at the time, vulnerable responses. Ms. Levin reflected on her time on the then newly merged board of directors for the Massachusetts Department of Transportation (MassDOT) and Massachusetts Bay Transportation Authority (MBTA); the board initially consisted of five persons, only one of whom was a white man. It was a diverse board, and it was impressive how well it functioned because the board members respected each other's differences. When reflecting on women in leadership roles, Ms. Schneider suggested that it's not just about creating more seats at the table, it's about creating a bigger table so that there can be more seats; this allows us to consider all perspectives when making important decisions about water and the environment that affect everyone. When asked how to ensure diverse representation in the water industry and in leadership roles, Ms. Speranza challenged the group to "look around your network, and if everyone looks like you, it's your responsibility to fix that." Ms. Rand reflected on her career progression through various leadership roles within NEWEA and attributed those accomplishments to her drive and passion for the field. Regarding a particularly vulnerable moment, she admitted that "even though at the time I was the only black woman in the room, I didn't feel like the only black woman in the room, because I had a role to play and things to say." She added that she is pleased about the push toward improving diversity but noted that there is always room for more.

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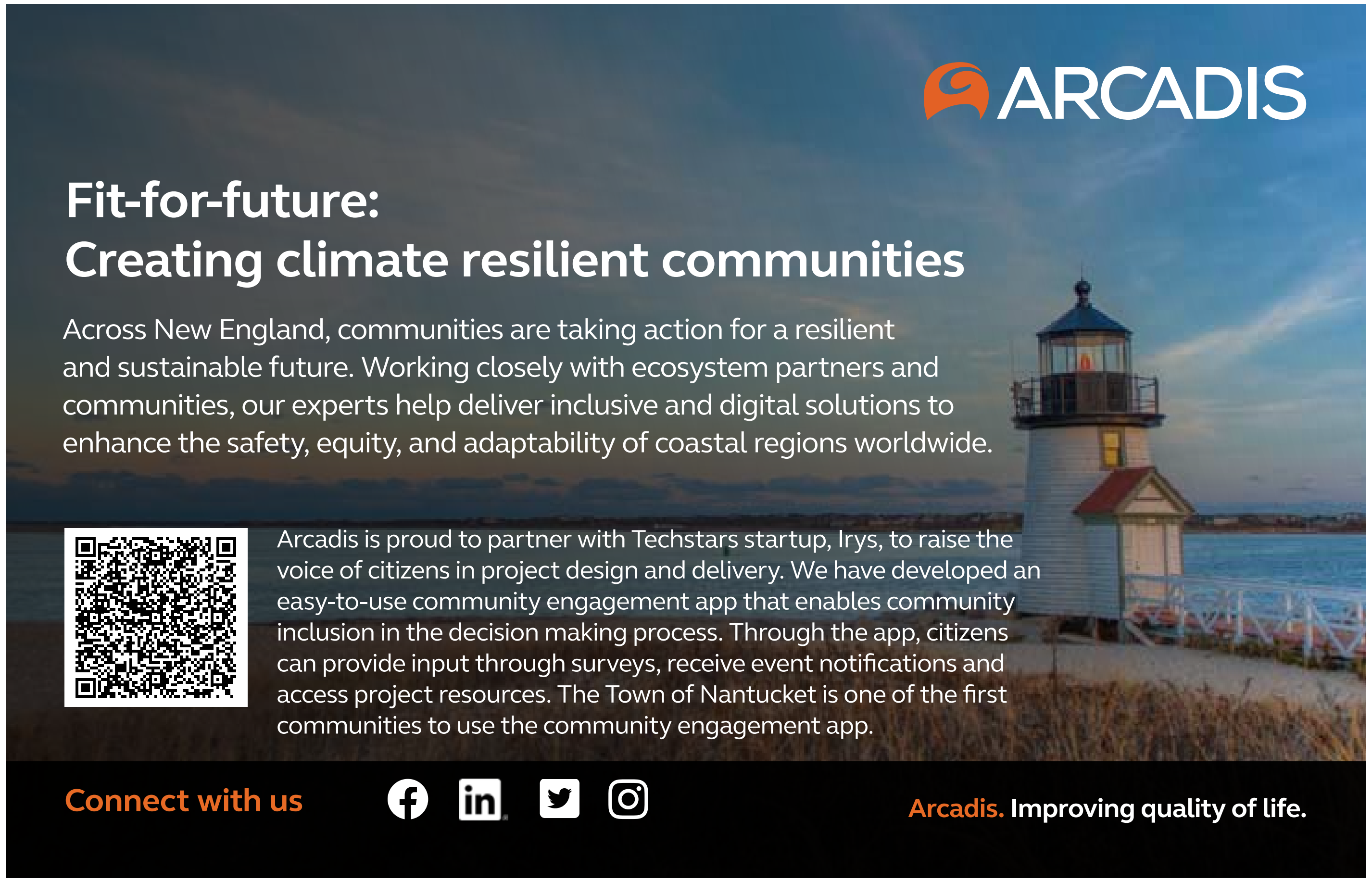
The feedback and praise after the forum were reassuring. Some participants commented that they found the panel to be empowering. Common feedback contained themes of positivity, wisdom, hope for the future—themes indicative of a well-received forum. Some participants suggested that they would welcome more visibility around WEN and its networks, as it offers opportunities of which some people may not be aware. More information about WEN can be found at newea.org/WEN/. The recorded Women in Water Forum is also posted to WEN's homepage on the NEWEA website. WEN looks forward to its next event in April. Stay tuned for more information as the date approaches.

Lastly, I thank Jennifer Kelly Lachmayr for her leadership through this past year as president. Surely, none of us could have predicted the complex circumstances of your year in this role. Your leadership throughout the year was much appreciated, and your guidance will continue in years to come. I also offer a warm welcome to our incoming president, Virgil Lloyd, who is dedicated to fostering an environment that promotes diversity, equity, and inclusion. As I hope you read in his debut President's Message, Mr. Lloyd's wise words resonated with me, especially the following: "By making NEWEA an organization where everyone feels empowered, valued, respected, and safe, we will bring more people into the discussion, with more diverse backgrounds and more varied points of view." This is exactly how great things happen; after all, no one of us is as smart as all of us.

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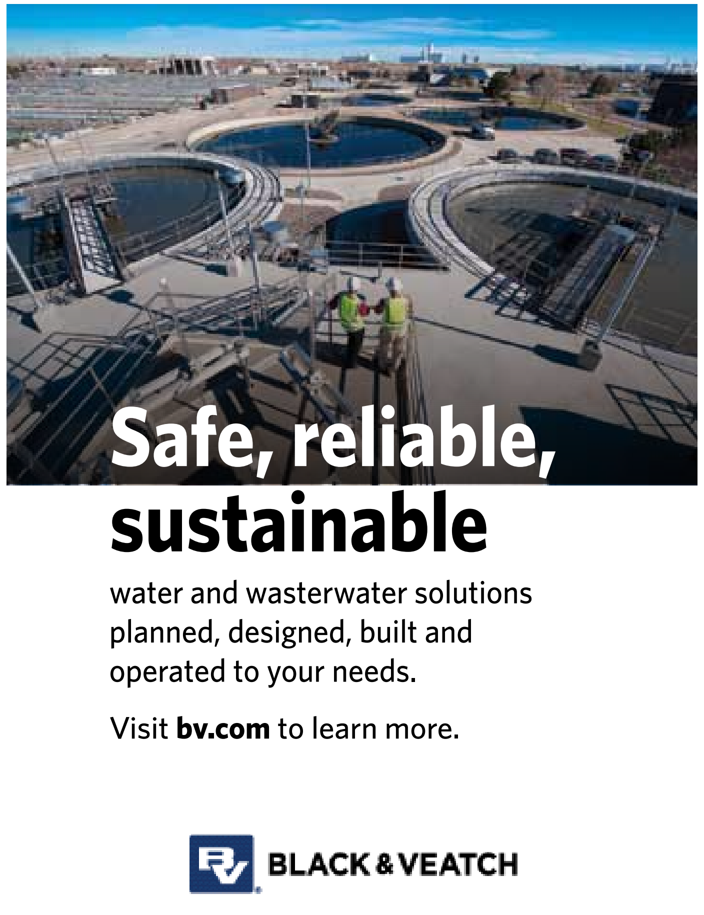
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Industry News

EPA is observing the 25th anniversary of using targeted grading methods to improve water quality in the Charles River, Boston

Ongoing water quality needs in the Charles River on 25th anniversary of initiative

EPA is observing the 25th anniversary of using targeted grading methods to improve water quality in the Charles River. This year, as in earlier years, EPA is announcing a report card for the river in coordination with the Charles River Watershed Association (CRWA). The two organizations have developed a new grading system to document water quality for the length of the Charles River, rather than solely the lower basin (Watertown to Boston), and other enhancements to the grading methodology to provide additional information to the public.

"EPA is proud of our 25-year history of collaboration and partnership to improve water quality in the Charles River," said EPA New England Regional Administrator Dennis Deziel. "Thanks to a long-term commitment by many organizations and dedicated individuals, we have seen real improvement in the Charles River and its value as a recreational hub in the Boston metro area, and in upper reaches of the river system. However, more work needs to be done, especially to reduce phosphorus pollution."

Charles River Report Card

Since 1995, EPA has issued an annual grade based on water quality in the lower basin of the Charles River, using *E. coli* data from monthly water samples by CRWA volunteers. Starting last year, CRWA expanded the assessment to include all 80 miles (129 km) of the river and two tributaries, based on data from 39 sampling sites rather than eight. The current assessment evaluates water samples from 2019 and looks at six sections of the river: the upper watershed (Hopkinton to Medfield), the upper middle watershed (Sherborn to Dedham), the lower middle watershed (Newton to Waltham), the lower basin (Watertown to Boston), the Stop River, and the Muddy River.

The new grading system continues to measure the percentage of time bacterial water quality meets swimming and boating standards. Boating standards continue to be met most of the time throughout the watershed, while swimming standards are typically met in dry weather but continue to be affected by precipitation events. In addition to *E. coli* bacteria, the river is also being graded on cyanobacteria (toxic blue–green algae) blooms and combined sewer overflows (CSOs), which are both public health hazards, especially for boaters and anyone who contacts the water. Cyanobacterial blooms, which have occurred with greater frequency in the lower basin, are caused partly by excess phosphorous washing into the watershed from pavement and other impervious surfaces. CSO discharges occur when heavy precipitation events overwhelm the sewer system and discharges to the river of sewage mixed with stormwater become necessary to prevent sewage backups into streets and residences.

Note: All EPA industry news provided by EPA Press Office

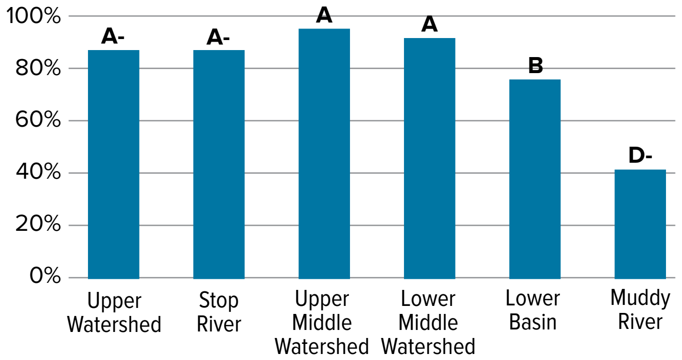

Figure 1. 2019 Charles River report card
(courtesy Charles River Watershed Association)

"While *E. coli* bacteria levels are an important public health indicator, they do not tell the whole story," said Emily Norton, executive director of CRWA. "People have a right to know about the additional risks caused by toxic algae blooms and raw sewage discharges. The more people know what is happening to the river, the more motivated they'll be to support the investments necessary to clean it up. The data make it very clear: We have this beautiful resource sitting in our backyard. If we want to protect it, we have to step it up."

The new grading system demonstrates the wide variability in water quality in different river stretches. Based on 2019 data, grades range from an A in the middle reaches of the Charles River (Sherborn to Waltham) to a D- in the Muddy River, a tributary in Boston. The upper watershed, while experiencing reduced water levels and encroaching development in the area, received an A-. The popular lower basin of the Charles River received a B.

Another change in the grading is that a three-year rolling average will now be used to calculate the grade for each segment. The current year's grade is averaged with the prior two years to produce the rolling three-year average. Such a system will enable a more complete and accurate assessment of recent water quality, better address precipitation variability from year to year, and allow real data trends to be more easily discerned.

EPA has taken two additional actions to address elevated levels of nutrients harming water quality throughout the Charles River watershed. First, EPA has finalized a municipal stormwater permit that will improve stormwater management in Massachusetts communities. Stormwater is the leading source of the river's phosphorus pollution, which causes annual blooms of toxic algae in the river. Second, EPA is gathering stakeholder input about how to address stormwater runoff from commercial, industrial, institutional, and residential properties in the watershed that is not currently regulated. EPA expects a decision this year.

"The Commonwealth is proud to partner with EPA, CRWA, and local communities to help achieve the water quality improvements that we've seen in recent years along the Charles River," said Kathy Baskin, assistant commissioner for water resources in the Massachusetts Department of Environmental Protection (MassDEP). "MassDEP will continue to provide hands-on assistance with stormwater and water quality issues to help to fully restore this historic waterway."

Final MS4 Permit

On December 9, 2020, EPA finalized targeted modifications to the 2016 Small Municipal Separate Storm Sewer System (MS4) general permit for 267 Massachusetts communities. The permit, which will apply separately to 34 communities in the Charles River watershed, updates stormwater management across urbanized areas that will better protect rivers, streams, ponds, lakes, and wetlands from harmful pollutants. While updating ecological protection, the permit also maximizes flexibility for municipalities to tailor efforts to their needs and local conditions.

Landmark cleanup plan for Housatonic River

EPA has issued a Revised Final Permit for the *Rest of River* cleanup plan of the Housatonic River. The Revised Final Permit, issued under the Resource Conservation and Recovery Act (RCRA), spells out the required cleanup measures to be followed by General Electric Company (GE) to remove contamination caused by polychlorinated biphenyls (PCBs). The Revised Final RCRA Permit Modification (Revised Final Permit) updates EPA's 2016 cleanup plan for the river, its floodplains, and other surrounding areas.

EPA's remedy as outlined in the Revised Final Permit protects human health and the environment and will result in more contaminated sediment removed from the river and surrounding areas than EPA's previous 2016 decision. The cleanup plan has specific provisions to expedite cleanup, significantly enhance the PCB removal in the cleanup, and provide for safe, effective disposal of the excavated materials. Additionally, the Revised Final Permit reiterates the Adaptive Management requirements of the 2016 permit.

EPA's 2016 cleanup plan was challenged by various parties before the EPA Environmental Appeals Board. In a 2018 decision, the board endorsed EPA's decisions on the PCB cleanup but raised questions about EPA's decision to dispose of all excavated material at off-site facilities. In response to the board's decision, EPA initiated mediated negotiations with eight parties to the appeal to see if there was one solution that provided a more effective cleanup that parties could agree to. Those discussions led to the February 2020 Settlement Agreement entered into by EPA, the State of Connecticut, the Rest of River Municipal Committee (comprising the towns of Lee, Lenox, Great Barrington, Stockbridge, and Sheffield, Massachusetts), the City of Pittsfield, Massachusetts Audubon Society, Berkshire Environmental Action Team, C. Jeffrey Cook, and GE. The cleanup plan in the Revised Final Permit is consistent with the 2020 Settlement Agreement.

Housatonic River

"EPA is proud of the hard work and commitment of all stakeholders to achieve a cleaned-up Housatonic River that will remain a scenic and recreational foundation in Berkshire County and Connecticut for generations to come," said Dennis Deziel. "This cleanup plan will protect public health and restore a cleaner, healthier and more robust ecological community in and near the river."

The Revised Final Permit requires GE to clean up contamination in river sediment, banks, and floodplain soil that pose unacceptable risks to human health and the environment. The excavated material will be disposed of in two ways—materials with the highest concentrations of PCBs will be transported off-site for disposal at licensed disposal facilities, and the remaining lower-level PCB materials will be consolidated on-site at a location in Lee. The cleanup is estimated to cost $576 million and will take approximately two to three years for initial design and 13 years for implementation. As part of the agreement, GE will initiate sampling and design activities during any appeals, allowing for remediation to begin two to three years earlier than if these design activities were suspended during appeals. Most of the sediment and floodplain cleanup is targeted within the first 11 miles (18 km) in Pittsfield, Lee, and Lenox. Phasing the work will disperse the effects of construction over time and locations.

Finalizing and issuing the Revised Final Permit follows a lengthy and robust process where EPA solicited and considered public input on the proposed revised cleanup plan. Additionally, in February and March 2020, EPA participated in three public information sessions held in Lee, Great Barrington, and Pittsfield on the 2020 Settlement Agreement.

Following these sessions, EPA issued a proposal to modify the 2016 cleanup decision and held a public comment period lasting over two months. EPA has entered all comments received into the Administrative Record. It has responded to all significant comments and has modified several permit provisions, including additional language regarding commitments on coordination and consultation with stakeholders throughout the design and implementation of the cleanup.

EPA recognizes that many of those who commented were opposed to the construction of the upland disposal facility (UDF) in Lee. After evaluating the comments, EPA confirmed its conclusion that the selected plan in the Revised Final Permit is the best approach to the cleanup, that it can and will be done safely and effectively, and that it addresses the primary risks at the site—PCB contamination in the river and floodplain.

The Revised Final Permit resembles the Draft Revised 2020 Permit issued for public review and comment on July 9, 2020. Many of the comments during the public comment period highlighted issues already addressed in the draft permit and which remain in the Revised Final Permit. These include air sampling, effective PCB remediation alternatives, and extensive coordination between EPA and the communities.

Together with the Revised Final Permit, EPA continues to support the investigation and development of alternatives to address PCB contamination in the Housatonic River, especially technologies that will render the PCBs non-toxic or significantly reduce their toxicity. To that end, EPA committed in the February 2020 Settlement Agreement to facilitate research and testing of innovative treatment and other technologies and approaches for reducing PCB toxicity and/or concentrations in excavated soil and/or sediment before, during, or after disposal in a landfill.

To follow up on its commitment, EPA will discuss with stakeholders designing and issuing a "Challenge" competition (such as those found at challenge.gov), to identify innovative technology strategies and solutions that may apply to this site. EPA's planned "Challenge" for PCB remediation solutions will likely be in stages, with the first stage a competition to identify potential technologies that meet the requirements. The winning solutions will move to the next stage, site-specific testing. Such testing could take place at or near the UDF location or another appropriate location. Testing will include evaluating treatment applicability to the soil/sediment from the river, implementation ability, cost-effectiveness, operational challenges, treatment residuals management, and other factors. EPA will incorporate steps for public involvement throughout this process.

EPA signed the Revised Final Permit on December 16, 2020, and elected to make the "notification date" of the permit on January 4, 2021, meaning the Revised Final Permit became effective on February 3, 2021.

All documents related to the Revised Final RCRA Permit Modification are part of the Administrative Record and available at epa.gov/ge-housatonic.

Springfield organization invited to apply for EPA WIFIA loan to improve water quality

In early January 2021, EPA announced that 55 new projects in 20 states were being invited to apply for approximately $5.1 billion in Water Infrastructure Finance and Innovation Act (WIFIA) loans. This funding will help finance $12 billion in clean water and drinking water infrastructure projects. One invitation was to be extended to the Springfield Water and Sewer Commission in Springfield, Massachusetts, to apply for a loan of $252 million for its Water and Wastewater Infrastructure Renewal Program.

Since the first WIFIA loan closed in 2018, EPA has announced 41 WIFIA loans that are providing $7.8 billion in credit assistance to help finance $16.8 billion for water infrastructure. EPA received 67 letters of interest from both public and private entities in response to the 2020 WIFIA Notice of Funding Availability (NOFA). After a statutorily required review process, the WIFIA Selection Committee asked for submission of loan applications from borrowers representing 55 prospective projects and placed three prospective projects on a waitlist.

To learn more about the 55 projects that are invited to apply, visit epa.gov/wifia/wifia-selected-projects.

EPA finalizes municipal stormwater general permit modifications for New Hampshire and Massachusetts communities

EPA has finalized targeted modifications to the 2017 Small Municipal Separate Storm Sewer System (MS4) general permit for 46 communities in New Hampshire and 267 in Massachusetts.

The changes reflected in these final permits are limited to modifications to permits already in effect and being implemented. The modifications either clarify permit terms or make them more flexible in implementation. Modifications include a provision whereby municipalities can seek implementation schedule flexibilities, streamlined reporting and requirements for new development and redevelopment sites, and more time for meeting post-construction stormwater control milestones. They either clarify language in the General Permits or provide new, targeted flexibilities for certain permit requirements.

"EPA appreciates the hard work and input from stakeholders on this municipal stormwater permit," said Mr. Deziel. "When fully implemented, the MS4 permit will protect our environment and adhere to the law, while also allowing municipal leaders the flexibility to make strategic decisions about investments that make sense in their communities."

The modified permit became effective on January 6, 2021. Municipalities and other regulated entities do not need to submit a new Notice of Intent (NOI) for continued coverage under the modified permit.

New Bedford harbor cleanup leading to economic development

Rapid progress has been made in addressing PCB contamination in New Bedford Harbor in the past several years. After 17 years, the Superfund dredging of PCB-contaminated sediments in both the upper and lower harbor below the low tide line was completed in March 2020. EPA has removed 1 million yd^3 (765,000 m^3) of PCB-contaminated sediment from the harbor, ending the subtidal dredging.

This cleanup has resulted in EPA transferring control to the City of New Bedford of a 5 ac (2 ha) industrial port facility with rail access, formerly used as a sediment dewatering facility within New Bedford's working waterfront. The site is one of the only heavy-duty, rail-accessible port facilities in New England. The marine bulkhead is reinforced for berthing large cargo ships and can support heavy cranes and other shoreline equipment abutting the future North Terminal site. This valuable commercial/industrial resource will now be transferred to the city for beneficial reuse.

"EPA is proud that our lengthy history addressing industrial pollution in New Bedford Harbor has achieved substantial results. EPA is making good on our commitment to see this project through to completion for the residents of New Bedford," said Mr. Deziel. "Through our cleanup work, EPA is ensuring that the Harbor does not pose health risks to people contacting sediments or, in the long-term, eating fish in and around the harbor."

The expedited work to remove and safely dispose of contaminated sediment from New Bedford Harbor was made possible by a historic 2012 settlement reached between the federal and state governments, and AVX Corp. for $366.25 million, plus interest, for cleanup costs at the Superfund site. The settlement paved the way for expedited implementation of the cleanup at full capacity, providing more rapid protection of public health and the environment in addressing PCB-contaminated sediment in the harbor.

"I thank Regional Administrator Dennis Deziel for his strong partnership with the city the last two years that has led to significant progress in the cleanup of New Bedford Harbor," said City of New Bedford Mayor Jon Mitchell. "While much work remains in intertidal areas, the city can now take control of the EPA's former dewatering facility, which is ready to be used as a port facility to support a variety of marine commerce."

"Today is a proud day for the (U.S. Army) Corps of Engineers as we have partnered with the EPA on the clean-up of this harbor for more than 30 years," said Col. John A. Atilano II, Commander, U.S. Army Corps of Engineers, New England District. "Contaminated since the 1940s, the New Bedford Harbor is one of the largest and most complex cleanups our District has ever undertaken, and this project has been full of challenges since day one. Our team rose to meet those challenges, and now we are turning this valuable piece of real estate back to the people of New Bedford."

New Bedford Harbor

Now that the subtidal Superfund dredging is complete, and transfer of the dewatering facility finalized, remediation will focus on those shoreline/saltmarsh areas in the upper harbor and Acushnet River north of Route 195 that have not yet been remediated. During 2020, the two northern-most shoreline zones immediately south of the Wood/Slocum Street bridge have been remediated, resulting in over 20,000 yd^3 (15,000 m^3) of shoreline and saltmarsh sediment being excavated and shipped off-site.

During 2021, EPA and the U.S. Army Corps of Engineers will continue to remediate areas south of Pleasant Street in Fairhaven and south of Belleville Road in New Bedford. The shoreline remediation follows similar procedures: All removed soil/sediment will be thickened with Portland cement at EPA's Sawyer Street facility and then disposed off-site at a licensed Toxic Substances Control Act landfill. The excavated shoreline areas will be backfilled with clean topsoil and planted with thousands of native salt marsh grasses, trees, and shrubs. Air monitoring occurs throughout to ensure it is being performed safely.

Even though the subtidal Superfund dredging is complete, fish and seafood caught in and around the harbor will remain contaminated with PCBs for some time. Local fishing professionals and hobbyists should familiarize themselves with applicable fishing restrictions and advisories to ensure harvested seafood is safe to eat.

EPA held a virtual public meeting on January 13, 2021, to discuss the status of the harbor cleanup, including remedial work planned for 2021. For more information, visit epa.gov/superfund/newbedford.

NEWEA Events—Coming Fall 2021

- CSO/WWI Conference
- Laboratory Practices Seminar
- Joint Collection Systems & Pacific Northwest Clean Water Association (PNCWA) Webinar
- Northeast Residuals & Biosolids Conference

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Fate of long- and short-chain PFAS, pharmaceuticals, and personal care products in wastewater biosolids

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ABSTRACT | Contaminants of emerging concern (CECs), including pharmaceutical and personal care products (PPCPs) and per- and polyfluoroalkyl substances (PFAS), are widely present in the environment due to decades of use in industrial, commercial, medicinal, and household products. For some of these compounds, municipal wastewater treatment facilities (WWTFs) are important collectors, concentrators, and conduits of CECs to the environment. Undegraded CECs partition into aqueous and sludge phases based on their physical and chemical properties, including hydrophobicity and solubility. Here we evaluated changes in 24 PFAS and 21 PPCPs during wastewater treatment and assessed the composition of PFAS in biosolids post-stabilization treatment. Shorter-chain PFAS were abundant in wastewater effluent, while precursor and longer-chain PFAS dominated in sludge. Antibiotics, anticonvulsants, and flame retardants were three common PPCPs found in effluent and sludge.

The composition of PFAS in sludge that had not undergone pathogen or vector reduction treatment processes showed similar relative abundances of short-chain, long-chain, and precursor PFAS across New Hampshire and Vermont facilities. Sludge stabilization processes did not influence total PFAS concentrations. However, biosolids treatment approaches altered PFAS composition based on structure and/or chain length. Of the 39 biosolids considered, 29 had perfluorooctane sulfonate (PFOS) concentrations above Maine Department of Environmental Protection screening levels for beneficial use (5.2 µg/kg), indicating that the adoption of similar regulatory limits in New Hampshire and Vermont would significantly constrain biosolids end uses or require changes in the management of wastewater and/or sludges to reduce PFAS levels. This work provides insight into the fate of PFAS and PPCPs in municipal wastewater facilities and highlights knowledge gaps for CECs in wastewater residuals.

KEYWORDS | PFAS, PPCPs, micropollutants, biosolids, sludge, wastewater treatment

INTRODUCTION

Municipal wastewater treatment facilities (WWTFs) serve many important functions, including the removal of solids, pathogens, nutrients, and regulated contaminants before water is discharged to receiving water bodies and groundwater. These treatment facilities collect and concentrate waste products from industrial, commercial, and residential sources, and they are conduits back into the environment for these undegraded contaminants through effluent discharge or land application of biosolids (Angeles et al., 2020; Higgins et al., 2005; Kovalakova et al., 2020; Sinclair & Kannan, 2006). Unless they are part of a water reuse system, municipal WWTFs are generally not optimized to remove organic micropollutants such as per- and polyfluoroalkyl substances (PFAS) and pharmaceuticals and personal care products (PPCPs). PFAS and PPCPs represent two large and distinct classes of contaminants of emerging concern (CECs) present in low concentrations (parts per trillion to parts per billion), are unregulated, and may adversely affect humans and ecological systems (Domingo & Nadal, 2017; Gaballah et al., 2020; Kovalakova et al., 2020; Liu & Gin, 2018; Yin et al., 2017). Information is scarce on the diversity and concentration of CECs in WWTFs, particularly within residuals. Recently, land application using biosolids from WWTFs has been associated with PFAS contamination in agricultural products (García-Santiago et al., 2016; Petrie et al., 2015; Vestergren et al., 2013; Walters et al., 2010), raising public health concerns because of the potential toxicity and bioaccumulation of these constituents. Better characterizing the fate of CECs in WWTFs is important for identifying their sources and sinks and understanding human and ecological health risks from receiving water bodies.

PFAS contain a characteristic carbon–fluorine backbone and are known for their chemical and thermal stability (Sun et al., 2012), resistance to biochemical degradation (Lindstrom et al., 2011), environmental mobility (Brendel et al., 2018), bioaccumulation potential (Giesy & Kannan, 2001; Lindstrom et al., 2011; Presentato et al., 2020), and toxicity (Das et al., 2015; Koskela et al., 2016). The physical–chemical properties of PFAS are heavily influenced by chain length and functional groups. Longer-chain PFAS, and PFAS that contain a sulfonate moiety, are increasingly toxic and bioaccumulative, and have a higher affinity for solids over their short-chain and carboxylic acid-containing counterparts (Sepulvado et al., 2011). Research has revealed that WWTFs are ineffective at removing PFAS using traditional activated sludge technologies (Gallen et al., 2018), with some facilities reporting little removal or even an increase between influent and effluent (Tavasoli et al., In Review). Some evidence suggests that unintended reactions occur during secondary (biological) treatment, potentially increasing the concentration of terminal PFAS (e.g., PFOA and PFOS) due to the enzymatic oxidation of unmeasured fluorotelomer or precursor compounds in the influent (Schultz et al., 2006; Sinclair & Kannan, 2006; Sun et al., 2012; Yan et al., 2012; Yu et al., 2009). The separation of specific PFAS into solid or aqueous phases may also occur, driving accumulation of more hydrophobic constituents into wastewater solids and more hydrophilic constituents into the effluent (Huset et al., 2011; Ma & Shih, 2010; Sinclair & Kannan, 2006; Zhou et al., 2010). To this end, municipal wastewater sludge has been shown to contain many perfluorinated carboxylic acids (including PFHxA, PFOA, PFNA) at concentrations 100 to 1,000 times higher than those measured for these constituents in the effluent (Dauchy et al., 2017; Sun et al., 2012). This highlights a potential solids-liquids "fractionation" of PFAS within the facility (Arvaniti et al., 2012).

PFAS represent only one category of CECs in wastewater. PPCPs are diverse and sometimes biologically active compounds that, when discharged to the environment, may pose a risk to human health or aquatic ecosystems (Baran et al., 2011; de Jesus Gaffney et al., 2017). PPCPs have been detected in both wastewater effluent and receiving water bodies due to their incomplete removal within WWTFs (Archer et al., 2017; Kovalakova et al., 2020; Yin et al., 2017). They have also been known to accumulate in municipal wastewater sludge (Huang et al., 2019; Oberoi et al., 2019), with sorption affinity influenced by pH (Hörsing et al., 2011), temperature (Hörsing et al., 2011), and solids retention time (Hidrovo et al., In Review; Huang et al., 2019). Understanding how design factors influence the behavior of both PFAS and PPCPs within WWTFs will improve our ability to predict their fate.

Residuals are a large unknown concerning the overall PFAS and PPCP load from wastewater facilities. Sludges may be disposed of in landfills or beneficially used after stabilization (e.g., composting, digestion, or dehumidification). Several recent studies suggest PPCPs and PFAS from land-applied biosolids may accumulate in soils (Ma & Shih, 2010; Pan & Chu, 2016; Sepulvado et al., 2011), agricultural crops (Al-Farsi et al., 2017; Blaine et al., 2013; Wu et al., 2013), and food products (Domingo & Nadal, 2017; Knutsen et al., 2018; Vestergren et al., 2013), with potential implications up the food chain. In 2019, more than half (51 percent) of WWTF residuals produced in the United States were beneficially used in land application (US EPA, 2016), suggesting the possible ubiquitous presence of PFAS or PPCPs in agricultural lands and urban plots receiving biosolids-based products. Knowledge is limited as to how differing stabilization approaches (e.g., pH manipulation, temperature modification, or microbial digestion) influence the composition and concentration of CECs in biosolids derived from WWTF sludge. Short-chain PFAS increased in residential compost (Choi et al., 2019), while certain PFAS congeners increased as a result of heat treatment (Lazcano et al., 2019). On the other hand, composting decreased certain PPCP concentrations (Brown et al., 2019).

Previously, we analyzed PPCPs and PFAS in WWTFs serving New Hampshire seacoast communities. PFAS were assessed using an isotope dilution method combined with a total oxidizable precursor (TOP) assay, with season influencing the concentration of terminal products (Tavasoli et al., In Review). PPCPs degraded at different rates depending on secondary treatment design and solids retention time (Hidrovo et al., In Review). Here we extend this analysis to consider the relationship of PFAS and PPCPs in aqueous and solid phases. We classify compounds based on chain length and functional group moiety, and estimate distribution coefficients (K_D) that describe the affinity of these compounds for the sludge. Composition and concentration of PFAS are further compared to samples collected in WWTFs and biosolids processing facilities in New Hampshire and Vermont and placed in the context of Maine residuals screening levels. With several New England states considering PFAS regulation in wastewater effluents and biosolids, this work has implications for the characterization and research needed to better understand this issue in municipal WWTF biosolids.

METHODS

Sampling and Analysis of University of New Hampshire-Collected Samples

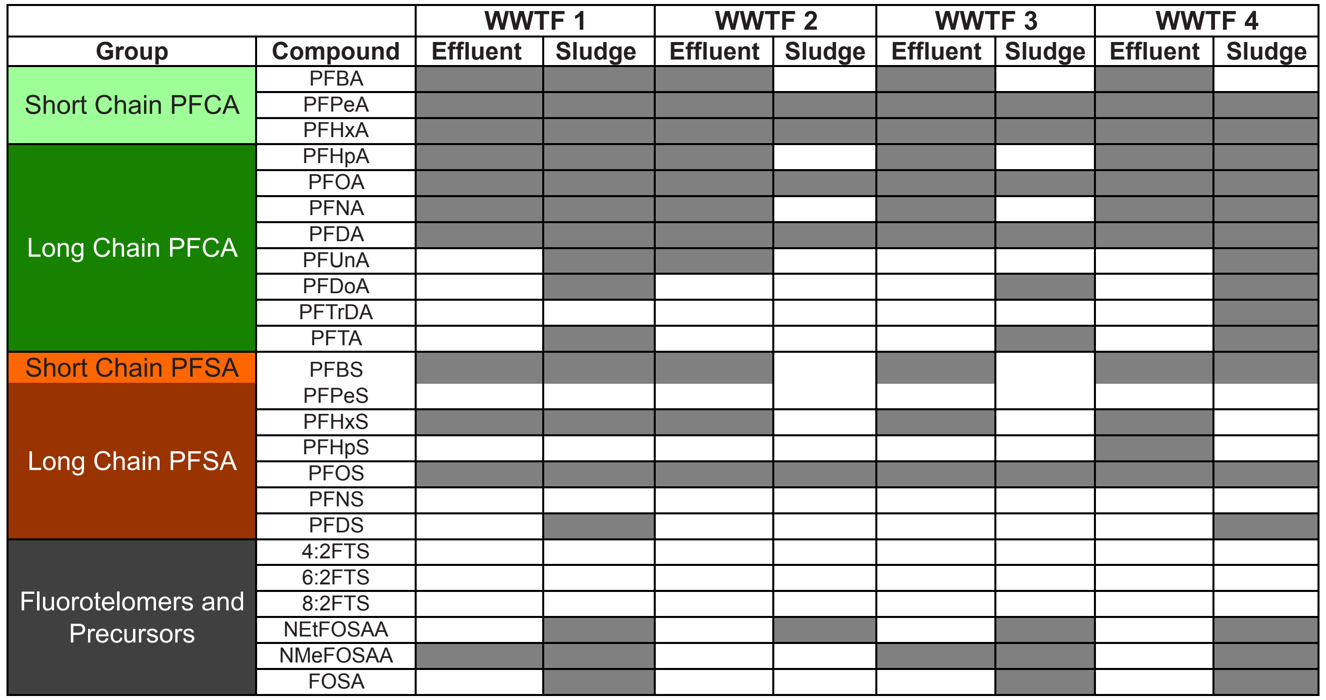
Samples for PFAS and PPCP analysis were collected from five locations within four WWTFs in southeastern New Hampshire in July 2019. Collection points included secondary influent, secondary effluent, chlorination basin, dechlorination basin (representing facility "effluent"), and dewatered sludge. Discrete aqueous grab samples were taken using sampling procedures and precautions described in EPA Method 537.1 for PFAS in drinking water samples. PFAS samples were collected into 1 L polyethylene bottles with no preservatives, while PPCP samples were collected into 1 L amber glass bottles containing sodium azide and ascorbic acid. A field blank for both PFAS and PPCPs was collected at one facility for quality assurance and quality control. Sludge samples were collected into 120 ml jars using a dedicated metal scoop. Samples were placed immediately on ice and held at 39°F (4°C) until shipment. PFAS were analyzed using solid-phase extraction followed by liquid chromatography/tandem mass spectrometry (LC/MS/MS) analysis with isotope dilution at Alpha Analytical Laboratory (Portsmouth, New Hampshire), quantifying 24 PFAS congeners. Samples for PPCP analysis were shipped overnight to Weck Laboratories (Hacienda Heights, California) for extraction and LC/MS analysis with electrospray ionization following EPA Method 1694.

Analysis of PPCP and PFAS Data

Concentrations of PFAS and PPCPs in aqueous and solid samples were converted into molar concentrations for abundance analysis based on their individual molecular weights. PFAS were classified as short chain, long chain, and precursor/fluorotelomers based on carbon chain length (Tavasoli et al., In Review, Buck et al. 2011) and information from the Interstate Technology and Regulatory Council (ITRC) as shown in Table 1. Short-chain PFAS were defined as carboxylic acid compounds (PFCAs) with perfluoroalkyl chains of six or fewer CF_2 moieties and sulfonic acid compounds (PFSAs) with five or fewer CF_2 moieties. Long-chain PFAS included PFCAs and PFSAs with up to 14 and 10 perfluoroalkyl chain lengths, respectively. The precursors quantified in this study included three fluorotelomers and three sulfonamides. PPCPs were classified based on application (pharmaceutical versus personal care product) and specific use (e.g., antibiotic, antihistamine, or insecticide). Adsorption–desorption distribution coefficients (K_D in L/kg) were calculated by dividing the dewatered or wet sludge concentration (ng/kg or ppt) of the analyte by its concentration in effluent (ng/L). PFAS and PPCP composition comparisons, as well as concentration and K_D comparisons, were analyzed in Systat SigmaPlot 14.5 using a Kruskal–Wallis one-way analysis of variance on ranks, with Dunn's method for pairwise multiple comparisons.

Metadata Analysis of Publicly Available Data

Publicly available sludge and biosolids data collected by or reported to state regulatory agencies in New Hampshire, Vermont, and Maine were analyzed WWTFs were chosen based on having similar influent sources to University of New Hampshire (UNH) samples. We sought data for both PFAS and PPCPs but could only obtain information on PFAS in publicly available wastewater treatment and biosolids samples. PFAS data for New Hampshire facilities collected between March 2017 through July 2020 were obtained from the New Hampshire Department of Environmental Services OneStop database (NHDES Onestop-Search, 2008). Data from Vermont facilities collected between September and October 2019 were from published reports (Poly- and Perfluoroalkyl Substances at Wastewater Treatment Facilities and Landfill Leachate Summary Report 2019, 2020), with insight by Vermont Department of Environmental Conservation (VTDEC) personnel and the report author. Samples reported by NHDES and VTDEC were analyzed using solid-phase extraction followed by LC/MS/MS analysis with isotope dilution at Alpha Analytical Laboratory quantifying 24 PFAS congeners. Database samples for New Hampshire, Vermont, and Maine that did not report all 24 PFAS constituents were excluded from this analysis. This resulted in the exclusion of all Maine samples and the 2018 New Hampshire samples from our analysis.



Group	Compound	WWTF 1		WWTF 2		WWTF 3		WWTF 4	
		Effluent	Sludge	Effluent	Sludge	Effluent	Sludge	Effluent	Sludge
Short Chain PFCA	PFBA	■	■	■	□	■	□	■	□
	PFPeA	■	■	■	■	■	■	■	■
	PFHxA	■	■	■	■	■	■	■	■
Long Chain PFCA	PFHpA	■	■	■	□	■	□	■	■
	PFOA	■	■	■	■	■	■	■	■
	PFNA	■	■	■	□	■	□	■	■
	PFDA	■	■	■	■	■	■	■	■
	PFUnA	□	■	■	□	□	□	□	■
	PFDoA	□	■	□	□	□	■	□	■
	PFTrDA	□	□	□	□	□	□	□	■
	PFTA	□	■	□	□	□	■	□	■
Short Chain PFSA	PFBS	■	■	■	□	■	□	■	■
Long Chain PFSA	PFPeS	□	□	□	□	□	□	□	□
	PFHxS	■	■	■	□	■	□	■	□
	PFHpS	□	□	□	□	□	□	■	□
	PFOS	■	■	■	■	■	■	■	■
	PFNS	□	□	□	□	□	□	□	□
	PFDS	□	■	□	□	□	□	□	■
Fluorotelomers and Precursors	4:2FTS	□	□	□	□	□	□	□	□
	6:2FTS	□	□	□	□	□	□	□	□
	8:2FTS	□	□	□	□	□	□	□	□
	NEtFOSAA	□	■	□	■	□	■	□	■
	NMeFOSAA	■	■	□	□	■	■	□	■
	FOSA	□	■	□	□	□	■	□	■

Table 1. Diversity of PFAS detected in the effluent and sludge of four New Hampshire WWTFs. Compounds are classified based on chain length and functional group. Detected compounds are shown in gray, while compounds that were not detected are shown in white.

RESULTS

PFAS are Fractionated along the Wastewater Treatment Train

Chain length is often used as a classifier for PFAS chemical stability (Lindstrom et al., 2011; Sun et al., 2012), mobility (Brendel et al., 2018), and solubility (Huset et al., 2011; Zhou et al., 2010). Short-chain PFAS are generally more soluble and mobile in aqueous systems, while PFAS with a longer perfluoroalkyl chain are less soluble and have an increased affinity for solids. UNH collected and analyzed 24 PFAS in four WWTFs discharging into tributaries connected to New Hampshire estuaries and color-coded the measured PFAS based on their structure and chain length. Fluorotelomers and precursors are shown in gray; short- and long-chain PFCAs are shown in light or dark green, while short- and long-chain PFSAs are shown in orange or dark red, respectively (Table 1). Among the constituents analyzed that exit the facility in aqueous or solid phases, 13 were detected in at least one effluent sample, while 18 were detected in at least one sludge sample (Table 1). A greater diversity of compounds belonging to PFCAs were consistently detected, whereas most PFSAs and precursors were sporadically detected across the media. Specifically, four PFCAs (PFPeA, PFHxA, PFOA, and PFDA) and one PFSA (PFOS) were found in all samples. In contrast, three long-chain carboxylic and sulfonic acids (PFDoA, PFTA, and PFDS) and two PFSA precursors (NEtFOSAA and FOSA) were detected in sludge only.

As the wastewater moved through the treatment train, we observed a shift toward increased relative abundance of short-chain compounds in the effluent (Figure 1—next page). In contrast, sludges were dominated by higher relative abundance of long-chain PFAS and fluorotelomer and precursor PFAS. Moreover, average ∑PFAS concentrations in sludge were 878- to 1,871-fold higher than average ∑PFAS measured in the effluent (Figure 1). This partitioning to sludge is consistent with previous work showing an increased affinity for solids and a correspondingly higher adsorption–desorption distribution coefficient (K_D) in PFAS congeners with a greater perfluoroalkyl chain length (Arvaniti et al., 2014; Gallen et al., 2017; Guerra et al., 2014) or containing a sulfonate moiety (Higgins et al., 2005).

The dominance of long-chain and precursor/fluorotelomer structures in sludge was also observed in sludge samples analyzed from other WWTFs across New Hampshire and Vermont (Figure 2). Total ∑PFAS concentrations across New Hampshire

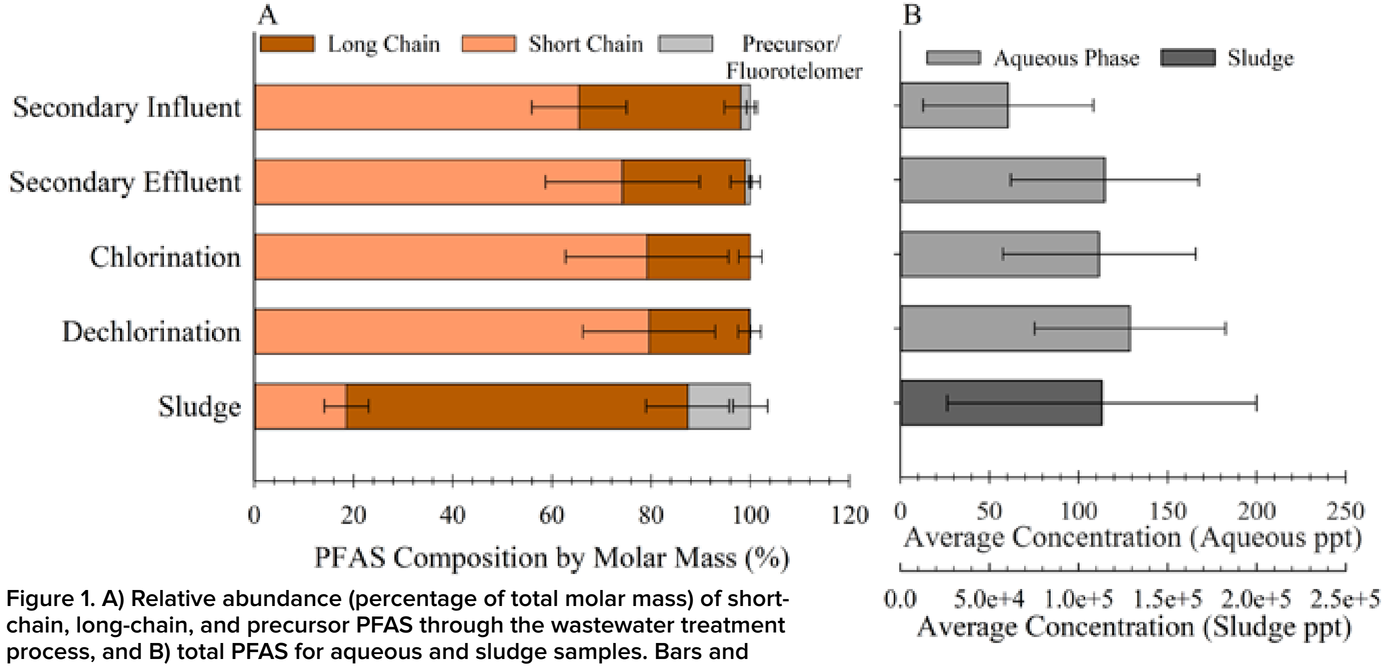


Figure 1. A) Relative abundance (percentage of total molar mass) of short-chain, long-chain, and precursor PFAS through the wastewater treatment process, and B) total PFAS for aqueous and sludge samples. Bars and whiskers represent average and standard deviation for four WWTFs.

and Vermont samples analyzed here ranged from 12 to 204 μg/kg. Samples collected by UNH showed long-chain compounds made up 56 to 82 percent of total measured PFAS based on molar mass, with precursors composing an additional 14 to 36 percent (Figure 1). Similarly, samples collected by others in New Hampshire and Vermont showed long-chain PFAS comprised up to 84 percent with precursors/fluorotelomers up to 60 percent. Consistently, long-chain PFSAs were higher in relative abundance and concentration than PFCAs in sludge, with average PFOS concentrations (11 ng/kg) about threefold higher than that of PFOA (3.9 ng/kg)—Figure 2 (Arvaniti et al., 2014; Gallen et al., 2018; Guerra et al., 2014; Higgins et al., 2005; Yu et al., 2009).

PPCPs are Primarily Degraded During Treatment, but Some Accumulate in Sludge

The relative abundance of compounds classified as pharmaceuticals versus personal care products remained consistent through the treatment train (Figure 3A), with pharmaceutical compounds composing 54 to 69 percent and personal care products composing 31 to 50 percent relative abundance by molar mass. In contrast to PFAS, where the total concentration remained relatively unchanged during treatment, total measured PPCP concentrations diminished greatly from an average total 7,216 ppt to 165 ppt between secondary treatment and dechlorination (Figure 3B). Most of this reduction occurred during secondary treatment, with further removal from chlorination, indicating many of the measured PPCPs were transformed during biological treatment and, less so, during disinfection (Hidrovo et al., In Review). Total PPCP concentrations entering secondary treatment were on average 12 times higher than measured in the sludge, while sludge concentrations were 3.7 times higher than concentrations exiting the facility after dechlorination. This suggests that PPCPs are not concentrating in the sludge to the same degree as PFAS; however, overall concentrations of total measured PPCPs in sludge (6x10^5 ppt) are about 6 times higher than those measured PFAS (1.1x10^5 ppt).

All 21 PPCPs were detected at one or more locations in the treatment train; however, their relative distribution varied by location. Compounds classified as analgesics and stimulants dominated within the primary effluent; flame retardants and an anticonvulsant had the highest relative abundance in the facility effluent; and antibiotics dominated within the sludge (Figure 4A—page 24). Other PPCP classes commonly detected in the sludge included a selective serotonin reuptake inhibitor (SSRI), an anticonvulsants, an insecticide, and a stimulant. Substantial variability was observed in the number of PPCPs detected in sludge across these four facilities (Figure 4B—page 24). Flame retardants (TCPP and TDCPP) were detected in all sludge samples. Commonly detected antibiotics included ciprofloxacin and trimethoprim. Other PPCPs detected in one or more sludges included azithromycin, sulfamethoxazole, and methadone.

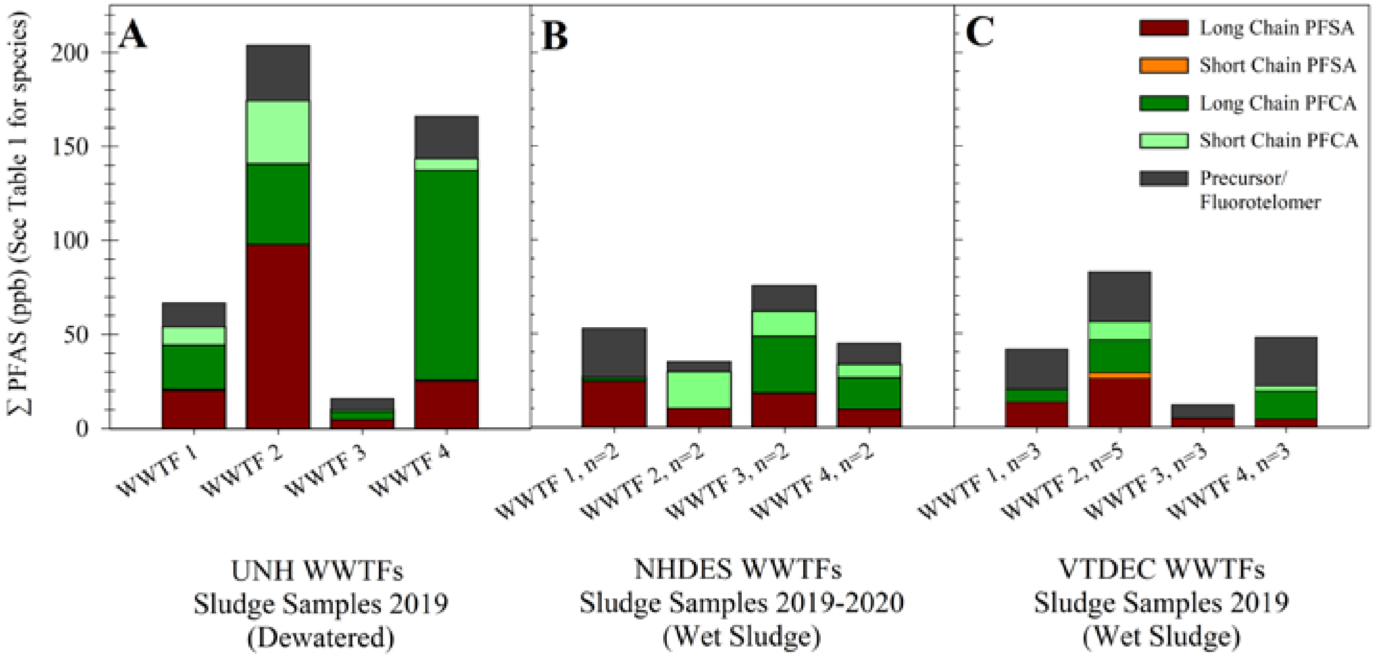


Figure 2. PFAS concentrations in WWTF sludge in samples reported by (A) UNH, (B) NHDES, and (C) VTDEC. PFAS are classified as long- and short-chain compounds belonging to PFCA or PFSA and precursor/fluorotelomer compounds, as noted in the methods. Dewatered sludge samples were collected from sludge cake, while NHDES and VTDEC were wet sludge samples.

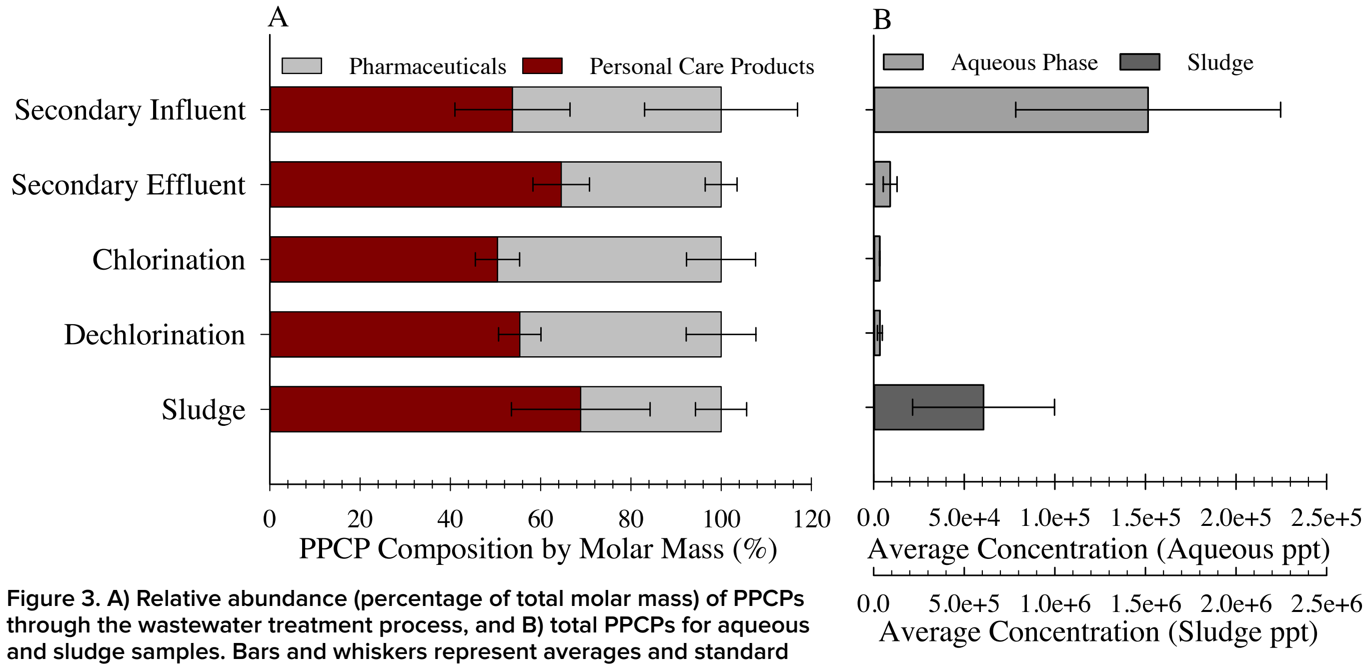


Figure 3. A) Relative abundance (percentage of total molar mass) of PPCPs through the wastewater treatment process, and B) total PPCPs for aqueous and sludge samples. Bars and whiskers represent averages and standard deviations for four WWTFs.

Distribution of PFAS in Sludge Varies with Fluoroalkyl Chain Length and Functional Group

To assess whether PFAS chain length or functional group influenced compound fate in these WWTFs, we calculated an adsorption–desorption distribution coefficient (K_D) based on measured concentrations in sludge and secondary effluent for four New Hampshire treatment facilities and four Vermont facilities. In general, the log K_D increased with higher fluoroalkyl chain length (Figure 5—page 25). PFAS having the same chain length (e.g., eight CF_2 units) but containing different functional groups (carboxylic versus sulfonic acids) differed considerably in their log K_D. For example, the mean log K_D for PFOA was 2.6 compared to 3.5 for PFOS, indicating a 10 times higher affinity for sludge compared to PFOA in these systems.

The range of K_D values observed here is consistent with previous data for secondary sludge, with PFOS K_D values typically an order of magnitude larger than PFOA, although reported distribution coefficients for each range over several orders of magnitude (Arvaniti et al., 2012; Yu et al., 2009). Sorption of several PFAAs and precursors to sediments have been shown to be positively correlated with the fraction of sediment organic carbon and calcium in solution, and negatively correlated with solution

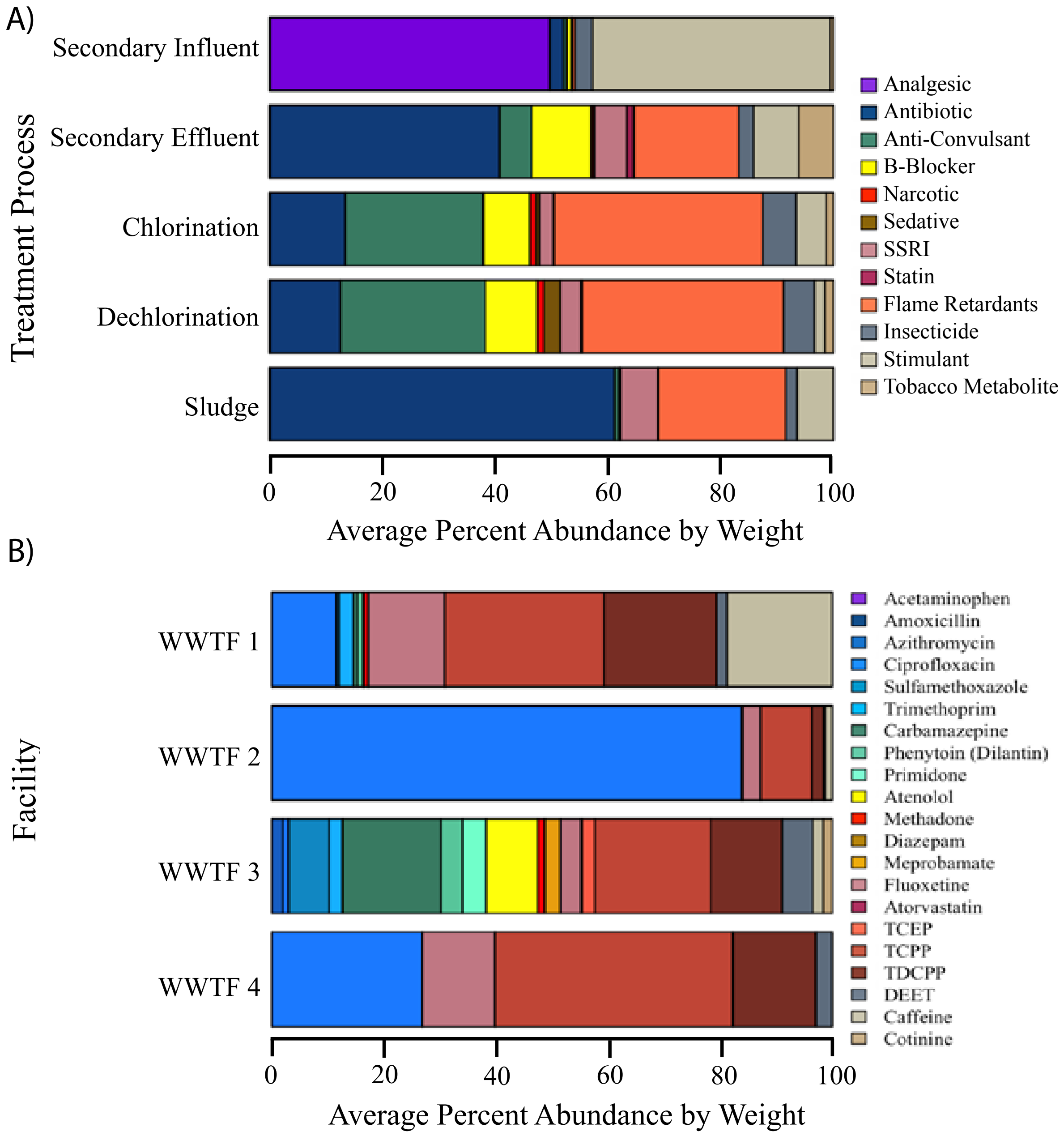


Figure 4. Average percent abundance by weight (mol/L for liquid and mol/kg for sludge) for A) 12 classes of PPCPs along the treatment train and B) individual PPCPs measured in the sludge.

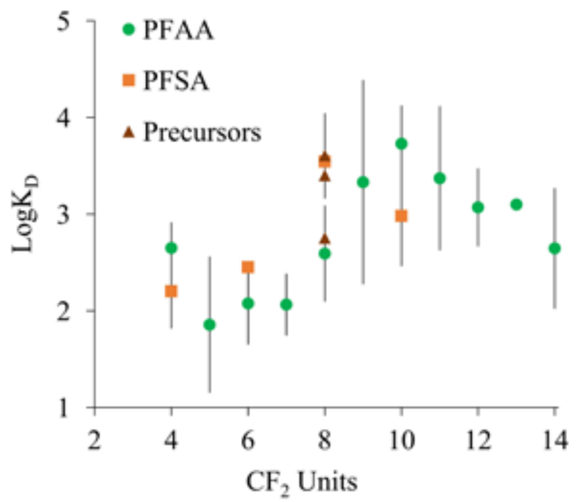
pH (Higgins et al., 2005). Hydraulic retention time is also expected to affect the measured distribution constant, with longer exposure time enabling PFAS to approach equilibrium between the aqueous phase and sludge solids; indeed, primary and secondary sludge has been shown to exhibit different PFAS distribution coefficients (Arvaniti et al., 2012).

Adsorption–desorption distribution coefficients were also calculated for PPCPs for the four New Hampshire WWTFs where sufficient data were available for the calculation. Only TCPP, TDCPP, and DEET had quantifiable sludge and secondary effluent values for all four facilities, enabling calculation of log K_D values (1.5–2.3, 0.5–2.4, and 0.5–3.0, respectively); the remaining analytes have log K_D values based on only one or two facilities. Additionally, ciprofloxacin was frequently detected in sludge but was below detection limits in secondary effluent, indicating substantial partitioning to sludge, consistent with literature (log K_D 2.6–7.3 [Fairbairn et al., 2015]). The high abundance of TCPP and TDCPP in sludge relative to secondary effluent is consistent with literature log K_{ow} values indicating their hydrophobicity; log K_D values were not identified in the literature.

PFAS Composition is Influenced by Biosolids Stabilization Treatment

Although we understand that more extensive sampling is underway, limited data exist in upper New England states on the concentration and diversity of emerging contaminants, including both PFAS and PPCPs in stabilized biosolids. Using sample data for biosolids processing facilities in New Hampshire and Vermont between 2019 and 2020 (some of which accept residuals from Massachusetts), we applied the same PFAS categorical classification to the data (short chain, long chain, and precursors/fluorotelomers). Data gathered included composted biosolids (n=9), anaerobically digested biosolids (n=8), lime-stabilized biosolids (n=5), and sludges with no processes to significantly reduce pathogens or vector attraction (No PSRP or VAR, n=13). Samples for several other stabilization approaches were available but were not included due to insufficient sample size.

Significant differences were observed in the relative abundance of short-chain compounds and precursor/fluorotelomers for these biosolids samples (Figure 6a). Composted samples had a much higher percent composition of short-chain PFAS relative to all other stabilization treatment samples (one-way ANOVA, $p<0.001$); this predominance of short-chain PFAS was observed in seven of the eight composted samples. Conversely, the relative abundance of precursors in both lime-stabilized and anaerobically digested samples was significantly greater than that in composted samples (one-way ANOVA, $p=0.012$). No significant differences were observed in the abundance of long-chain compounds or in the average ΣPFAS by biosolids treatment (Figure 6B, Kruskal–Wallis ANOVA, $p=0.270$). The predominance of short-chain compounds in compost is consistent with a recent study evaluating an increase in short-chain PFAS in municipally composted food and yard waste (Choi et al., 2019) and another identifying an increase in PFAA concentrations for commercially available biosolids products undergoing thermal treatment (Lazcano et al., 2019).



Calculated adsorption–desorption distribution coefficient (K_D) based on sludge and secondary effluent concentrations. Each CF_2 unit indicates one carbon and two fluorine molecules (fluoroalkyl chain length).

Several variables within these stabilization processes may influence the PFAS composition in biosolids products, including moisture content, temperature, pH, oxidation-reduction potential, and biological activity (Choi et al., 2019; Dinglasan et al., 2004; Guerra et al., 2014; Lazcano et al., 2019). Controlled laboratory and field studies that characterize PFAS in all sources used (e.g., residuals or compost inputs) and produced during stabilization (including biosolids and condensates, gases) would greatly improve our understanding of the factors influencing these preliminary trends and overall mass balances. The sludge and biosolids samples collected were somewhat dewatered, but the efficiency of dewatering in each WWTF or biosolids handling facility was not used as a normalizing factor in reporting PFAS concentrations. Normalization could influence reported PFAS and PPCP concentrations but would be unlikely to

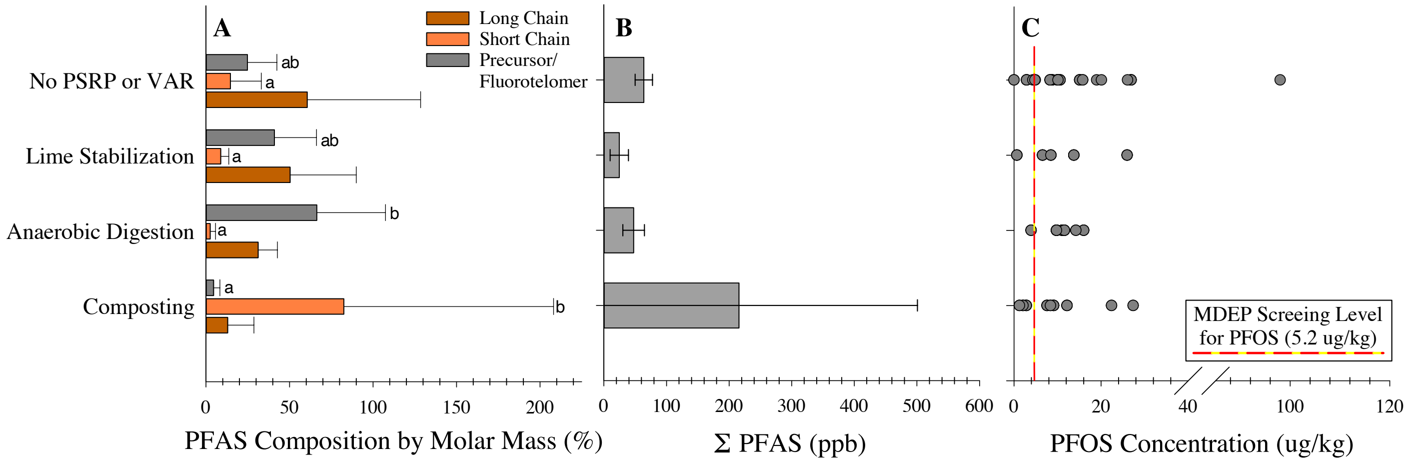


Figure 6. A) Relative abundance of long-chain, short-chain, and precursor/fluorotelomer PFAS, B) average ΣPFAS, and C) PFOS concentrations at each sampling location for different biosolid treatment, including processes to significantly reduce pathogens (PSRP) or vector attraction reduction (VAR) processes.

alter the trends observed and their implications for WWTFs.

IMPLICATIONS

PPCPs, including flame retardants, an anticonvulsant, and antibiotics, were commonly detected in wastewater effluent and sludge. PFAS were consistently detected in wastewater effluent, sludge, and biosolids. Short-chain PFAS were dominant in effluent, while longer-chain and precursor PFAS sequestered in sludge. In 2019, the Maine Department of Environmental Protection (MDEP) placed a moratorium on biosolids intended for land application unless samples contained less than 2.5 µg of PFOA/kg, 5.2 µg of PFOS/kg, and 1,900 µg of PFBS/kg (MDEP, 2019) to limit final soil concentrations to 200 parts per trillion. PFOS were the dominant PFAS detected in sludge samples collected, with both PFOS and PFOA frequently exceeding these screening levels in biosolids samples collected in New Hampshire and Vermont regardless of biosolids stabilization approach. If screening levels are developed for a short list of PFAS, this may bias regulations of specific treatment regimes. Among stabilized biosolids, composted products contained more short-chain PFAS, indicating that compost treatment influences PFAS composition. Oxygen, temperature, organic matter content, and bacterial diversity are likely key to controlling the oxidation of undegraded PFAS precursors into smaller/terminal products in these media. The use of multiple stabilization processes may confound these results (e.g., anaerobic digestion and composting). The diversity of physicochemical properties within the broad PFAS classification and corresponding environmental behaviors influencing their fate are an ongoing challenge for regulators seeking to limit human and environmental health impacts due to exposure to these "forever" chemicals.

Following land application of biosolids, uptake by agricultural products for human or animal consumption, and percolation or runoff into groundwater and surface waters serving as drinking water sources are important human and aquatic exposure pathways for both PFAS and PPCPs. Considering the preferential uptake of PFAS by vegetation (Costello & Lee, 2020) and the increased leachability of short-chain PFAS compared to their long-chain and precursor counterparts, consideration must be given to PFAS composition beyond the handful of analytes currently regulated and the potential for their transport from applied lands.

Similarly, PPCPs have been detected in biosolids-amended agricultural soils (Ben Mordechay et al., 2018; Wu et al., 2013), and numerous plants have been shown to uptake PPCPs while some accumulate in plant tissues (Al-Farsi et al., 2017; Carter et al., 2014; Dodgen et al., 2013; Shenker et al., 2011). The frequent detection of antibiotics, their preferential distribution to sludge, and the potential impact to soil health from antibiotic residuals (McClellan & Halden, 2010) warrants an expanded analysis of PPCPs in wastewater effluent, sludge, and stabilized biosolids. While compounds expected to be persistent, bioaccumulative, and toxic are of particular concern, PPCPs not meeting this threshold are still important to consider as synergistic toxicities have been observed even at low concentrations (Fent et al., 2006; Prichard & Granek, 2016).

Beneficial reuse of wastewater biosolids provides essential nutrients for agricultural lands globally and is preferential to the environmentally costly alternatives of landfill disposal or incineration. However, recycled nutrients should not compromise soil, water, and food quality for the applied area. While managing every known PFAS and PPCP is unrealistic, quantifying a range of compounds in biosolids and tracking how wastewater treatment and biosolids stabilization approaches alter compound degradation and distribution in final products are important. To support safe biosolids use and avoid compromising human and environmental health, a subset of PFAS and PPCP analytes representing a range of environmental fates should be identified for expanded effluent, sludge, and biosolids monitoring before surface water and biosolids regulations are promulgated.

Research on this pressing topic in our region has been constrained by a lack of federal and state investment in the analytical tools, expertise, and models for characterizing samples, loads, and fate of these constituents. Municipalities and the private sector bear the financial burden for sample analysis—costs that will ultimately be passed to the public. Although a handful of research labs at academic institutions in upper New England states can measure these constituents in wastewater media and biosolids, dedicated instrumentation is not broadly available across university or state analytical labs. Investment in analytical instrumentation, personnel (e.g., environmental chemists and engineers), and research funding for both the public and private sector is needed for states to address this issue. Such investment could significantly expand the following: 1) characterization of wastewater samples, including known and unknown congeners in these media; 2) lab- and field-based studies evaluating factors influencing compound fate within facilities; 3) models predicting sources and sinks within facilities; and 4) leaching studies combined with fate and transport models for lands receiving biosolids. This field is ripe for public–private–academic partnerships and sorely needs research to inform the scope of the problem and regulatory action. Such an investment would enable our region to lead knowledge development on this timely topic, as other states and nations grapple with emerging constituents such as PFAS and PPCPs in their own biosolids.

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This article condenses an extensive data collection and scientific research project; supplemental information, including more comprehensive treatment of data and illustrative tables, is available free of charge by contacting the corresponding author at Paula.Mouser@unh.edu.

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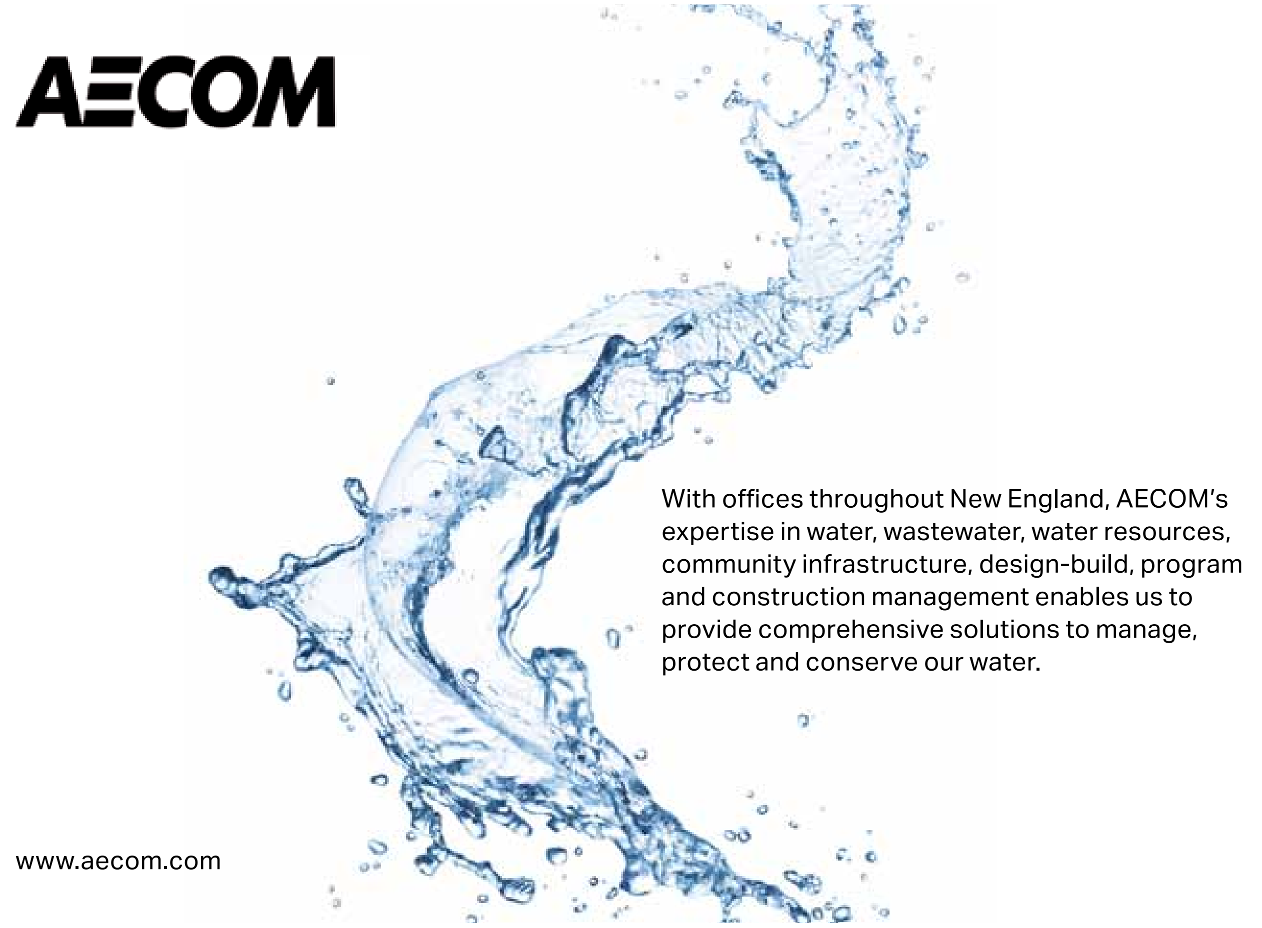

Impacts of PFAS on biosolids management costs

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ABSTRACT | The presence of per- and polyfluoroalkyl substances (PFAS) in water resource recovery facilities (WRRFs) has been widely reported. This article aims to inform about the cost impacts and unintended consequences of PFAS regulations on biosolids programs. It expands the set of data and results from the study funded by the Water Environment Federation (WEF), National Association of Clean Water Agencies (NACWA), and the North East Biosolids & Residuals Association (NEBRA) to determine the cost impact of PFAS on biosolids.

The article also discusses biosolids end use costs for entities before and after the onset of PFAS regulations. End use costs increased on average approximately 72 percent, but in some cases this change was more than 300 percent. The impact PFAS has had on those surveyed entities is also looked at, as is the cost and non-cost impact that regulations have had on utilities. The hope is to educate the public and regulators and encourage them to use the appropriate science when establishing regulations. Data from the completed study illustrate the importance of considering the risk to human health as well as the potential detriment to the environmental benefits offered by these biosolids programs.

KEYWORDS | Biosolids, residuals, PFAS, cost, end-use, disposal, economic impact, NEBRA, WEF, NACWA

INTRODUCTION

Wastewater treatment facilities (WWTFs) perform two primary functions: (1) they treat water to a level that allows its reintroduction to surface and/or groundwater, and (2) they treat the solids produced in this process to a level where they can be either recycled or disposed of properly. Both are done to ensure public safety and environmental protection. Traditionally, the suspended and dissolved solids in wastewater treatment have been called "sludge" or "sewage sludge." Most often, sludge is treated in either an aerobic or anaerobic digester (maintained for set intervals within given temperature ranges). This stabilizes the material and reduces pathogens (disease-causing organisms). Many other treatment options exist to render sludge suitable to meet federal and state requirements for beneficial use. When the sludge satisfies these requirements, it is called "biosolids."

Biosolids are the nutrient-rich, organic byproducts of wastewater treatment. Biosolids have been treated and tested and meet strict federal and state or provincial standards for use as fertilizers and soil amendments. They provide plant nutrients and organic matter to soils. They can also produce renewable energy through digestion and production of methane (biogas) or by drying and thermal processing. A 2004 national survey of biosolids use and disposal (NEBRA et al., 2007) found that about 55 percent of the wastewater solids (sewage sludge) produced in the United States are treated and recycled to soils as biosolids. About 30 percent are landfilled and 15 percent are incinerated. Of the total beneficially used on soils, three-quarters is applied to agricultural land, 22 percent is distributed as Class A products, and 3 percent is used in land reclamation. Northern New England (Maine, New Hampshire, and Vermont) is responsible for most of the biosolids beneficially reused in New England.

PFAS

Per- and polyfluoroalkyl substances (PFAS) have recently 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 has raised concerns about adverse health impacts that have led to many ongoing toxicological studies. The PFAS family constitutes roughly 8,900 known chemical varieties that have been in production and in the environment for nearly eight decades. These chemicals have recently 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 used specifically for their strong carbon–fluorine bonds, which resist heat, water, and oil effectively. As such, PFAS are commonly found in everyday consumer products, including fast-food containers, non-stick cookware, stain-resistant coatings, water-resistant clothing, and personal care products. Owing to their chemical structure, commercial value, and use, PFAS are ubiquitous. They also persist, bioaccumulate, and do not readily degrade.

In 2016, following a comprehensive toxicology study, EPA published perfluorooctanoic acid (PFOA) and perfluorooctane sulfonate (PFOS) drinking water health advisories at individual or combined concentrations of these PFAS of 70 parts per trillion (ppt). In February 2019, EPA issued its PFAS Action Plan. The plan aims to move forward with a regulatory determination for PFOA and PFOS. Meanwhile, many states have implemented their own limits and regulations, with many well below the EPA's 70 ppt health advisory. Many of these limits prevent biosolids beneficial use programs from continuing to land apply their biosolids, reversing the sustainable and environmentally friendly actions of these programs. Regulators must provide communities with the tools to limit the release of these substances at their sources and to educate the public on the impact many consumer products have on the environment.

The National Association of Clean Water Agencies (NACWA) and the Water Environment Federation (WEF) submitted comments to EPA in 2018 urging it to develop a federal response that appropriately reflects the risks posed by PFAS, closes the unresolved scientific gaps (including fate, transport, and toxicity of PFAS using a science-based approach), and evaluates how best to target the sources of PFAS and responsible disposal techniques.

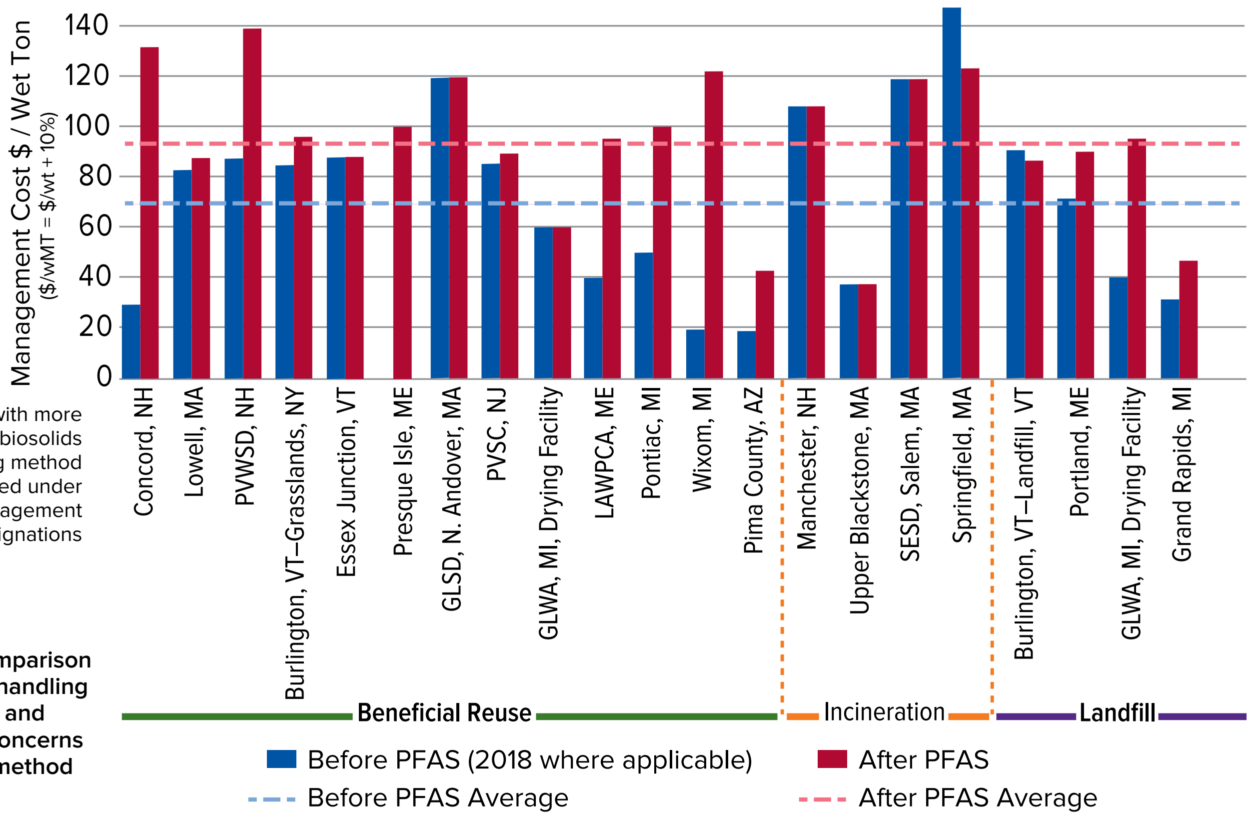
EVALUATING PFAS IMPACTS IN BIOSOLIDS

An evaluation to determine the actual costs to wastewater and biosolids management programs from PFAS was initiated to better understand the potential financial impacts on municipal wastewater and biosolids agencies. This evaluation identified facilities across the country that have been affected by PFAS and used the results from an online survey by the North East Biosolids & Residuals Association (NEBRA) to develop and implement an in-depth evaluation of the affected facilities. The evaluation team contacted the parties affected—such as water resource recovery facilities (WRRFs), residuals haulers, biosolids land appliers, and facilities dedicated to end use (incineration, compost, landfill, farms, etc.)—and requested information about the cost and operational impacts from the growing variety of state and federal PFAS policies and regulations.

An electronic survey was issued consisting of seven questions, which included yes or no, open-ended, and multiple-choice types. Responses were collected from 54 respondents and used to develop the expanded survey, targeted at potentially impacted facilities as potential participants. The team spoke with staff at 30 solids management facilities or operations; the responses 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.

For this study and the outreach with each entity, the metric used when discussing end-use cost was dollar per wet ton, $/wt (dollar per wet metric ton, $/wMT). This was the most common unit among those interviewed and includes the entire product being handled (wastewater sludge or biosolids and the interstitial water). This is most relevant when the travel or hauling costs are included, where a significant percentage of the overall end use expense may be from travel to the end-use site. It is also a consistent metric that allows all these entities to be compared to one another. The responses were compiled, and the response pool evaluated for trends related to PFAS costs, concerns, and impacts.

Results showed similar trends across participants of all management methods and facility types. Many of these outlets clearly have already seen a significant cost impact from addressing PFAS. Managing these costs can be contentious in many of these situations, with WRRFs concerned about how they will pay for PFAS treatment. WRRFs are, by design, receivers of wastes that have been introduced into clean water. Further complicating this argument, however, is whether it is reasonable for WRRFs to receive and treat something "new," such as PFAS, or whether that will be too costly and that other ways—such as source control and/or pretreatment—are more rational and cost-effective. Facilities continue to face these questions as policies and regulations are enforced.



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

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

QUANTITATIVE MANAGEMENT COSTS

While many of the questions and subsequent responses were more qualitative than quantitative, most of the facilities provided some quantitative management costs before and after the emergence of PFAS concerns. The cost information allows the impacts of PFAS regulations on the market so far to be evaluated and aids as a forecast tool for anticipated future costs if regulations proceed as proposed. The management costs from survey respondents were converted, for consistency, into terms of cost per wet ton of solids or biosolids leaving the WRRF property (Figure 1). The facilities are grouped based on their management method.

Based on the data provided, in response to PFAS regulations the management cost per facility surveyed increased by an average of around 72 percent. When this study was published in October 2020, the average increase was much lower. Since then, costs at several of the surveyed facilities have increased, driving up the average. The pertinent regulations varied from those directly affecting biosolids to others regulating groundwater and inadvertently affecting biosolids land application programs. Some facilities have seen an increase of greater than 72 percent. In the solids management market over the past couple of decades, no such dramatic cost increases have occurred. The closest comparison was in New England in 2016 when the sewage sludge incinerator (SSI) air regulations took effect, forcing incinerators to shut down temporarily for upgrades. This created a lack of sludge capacity in the region and drove up sludge end-use costs.

For example, a facility in Wixom, Michigan, is among the most heavily affected, showing an increase in management cost per wet ton to 6 times what the facility paid prior to the PFAS concerns. This cost increase was from $20/wt ($22/wMT) in 2018 to $120/wt ($132/wMT) after PFAS regulations. This facility is on the upper end of the spectrum; a few other facilities in states on the forefront of PFAS policy and regulation, such as Michigan, have seen management cost increases of 2 times or more.

Alternatively, other facilities interviewed for this study reported minimal to no impacts to management costs. These facilities generally manage their own biosolids, using methods other than beneficial reuse and/or operating in states that do not yet have quantifiable PFAS regulations. In the case of Springfield, Massachusetts, the data display a management cost decrease. The facility manages biosolids through a contract operator who must find an end-use location for the product, generally a landfill or incineration facility. The Springfield WWTF was approaching the end of contract negotiations at the time of this study. As such, Springfield's new contract restructured the 20-year-old biosolids section in response to market and regulatory changes. The previous contract and management cost had included the contractor's risk and responsibility, preventing Springfield from fully understanding the cost per ton due to the built-in service fees. The new proposed contract allows competitive bidding, while Springfield assesses the market and plans for the future, eliminating the originally built-in risk fees and allowing more long-term flexibility. As a result, the proposed corresponding management cost is anticipated to decrease. Springfield is an example of a facility that was updating its solids management contracts when PFAS regulations began being implemented, and the city moved forward amid the uncertainty of what PFAS means for wastewater solids management.

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

Figure 2 presents the same data from Figure 1 with an emphasis on state-by-state impacts. Grouping facilities by state shows that some states' PFAS responses have clearly caused significant impacts on solids management costs, while others have caused marginal impacts.

Though sample sizes were small (as little as one each in Arizona and California), Figure 2 provides a qualitative sense of the varying degrees of impact in different states that agrees with how stakeholders assess the impacts of PFAS actions. Notable conclusions from Figure 2 include Michigan and Arizona being the most-impacted states, both with an average of more than 2 times the management cost after PFAS impacts. Other significantly impacted states include New Hampshire and Maine, which have seen 69 percent and 71 percent increases in management cost, respectively.

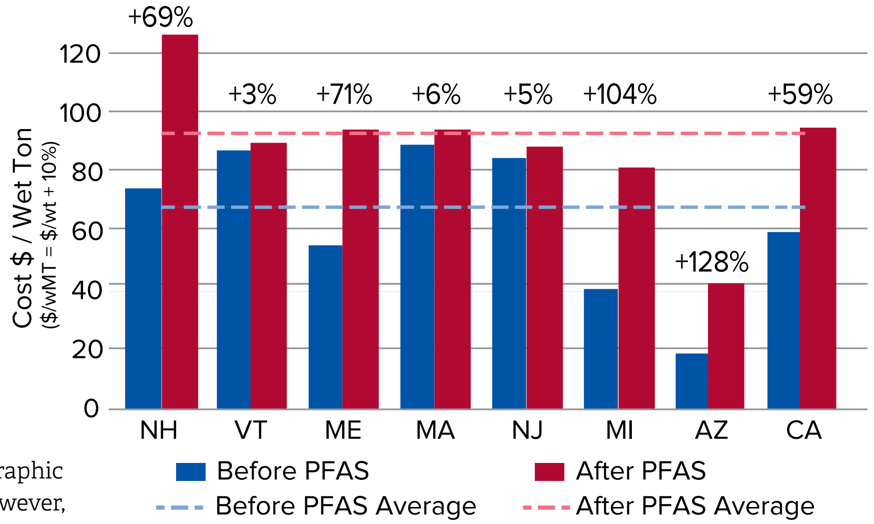


Figure 2. Comparison of average biosolids handling cost before and after PFAS concerns by state

AZ and CA are each based on one data point

QUALITATIVE MANAGEMENT COSTS

The potential consequences of regulating PFAS in biosolids before fully understanding the impacts to the market do not stop with cost implications alone. Additional concerns, as outlined by surveyed participants, include the following:

- Lack of available capacity for the sheer volume of biosolids and uncertainty about the longevity of current solids management outlets, with three options only: (1) beneficial use (e.g., land application, composting, etc.); (2) landfill disposal; and (3) incineration. All have risks and benefits
- Environmental impact of abating beneficial reuse programs and turning to disposal or incineration methods solely
- Public perception and politics driving regulations
- Inability to manage PFAS in biosolids at the source due to lack of public education and engagement
- Not making science- or knowledge-based decisions
- Lack of a universal EPA-approved testing method for PFAS in wastewater and solids (The only available EPA-approved method as of January 2021 was for drinking water specifically.)
- Very low regulatory limits for PFAS in water being adopted by some states not being achievable
- Limitations of available technology commonly used for PFAS removal in drinking water and the incompatibility with wastewater matrices—for example, no proven technology to treat PFAS in wastewater
- Liability and those who receive PFAS being responsible for removing it

PFAS COSTS FOR DRINKING WATER TREATMENT

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.

Common PFAS treatment technologies for drinking water conditions include granular activated carbon (GAC); membrane technologies, such as reverse osmosis (RO); and advanced oxidation processes (AOP). Emerging technologies to address PFAS contaminants in drinking water include sorptive removal (MIEX, PAC, other sorbents such as aerogel, silver-doped IX, organically modified silica, fluorographene, and cyclodextrin polymer), surfactant and coagulant removal, surfactant and coagulant-enhanced removal, PerfluorAd (a patented

Table 1. Construction costs for drinking water treatment of PFAS

Project location	Capacity (mgd / ML/d)	Approx. cost ($ millions)	Project-specific notes	Cost per volume treated ($/gal / $/L)
Spectacle Pond WTP Ayer, MA	2 / 7.6	5.5	• GAC pressure vessels • New building for PFAS treatment • Existing sand filters upstream of GAC	2.75 / 0.72
Grove Pond WTP Ayer, MA	2 / 7.6	3.1	• AIX pressure vessels • New building for PFAS treatment • Existing sand filters upstream of GAC.	1.55 / 0.41
Westfield, MA	4 / 15	5.6	• GAC pressure vessels • New building for PFAS treatment	1.40 / 0.37
Middlesex, NJ	12 / 45	30		2.50 / 0.67
Confidential Client in Mid-Atlantic Region (Two groundwater well sites)	2.5 / 9.5	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 / 0.57 1.96 / 0.52
	3.7 / 14	6.4 (GAC) 6.1 (AIX)		1.73 / 0.46 1.65 / 0.44
Brunswick, NC	50 / 189	120	• Reverse osmosis for PFAS and other contaminant removal • Includes in-plant improvements and expansion for PFAS • Existing upstream sand filters	2.40 / 0.64
			Average treatment cost	**2.00 / 0.53**

Table 2. O&M estimates for drinking water treatment of PFAS

Project location	Capacity (mgd / ML/d)	GAC O&M estimate	AIX O&M estimate
Confidential Client in Mid-Atlantic Region (Two groundwater well sites)	2.5 / 9.5	$113,200	$80,100
	3.7 / 14	$282,800	$211,800

ionic flocculant process), and foam fractionation. These treatment technologies could be amendable to wastewater conditions but would likely require additional study to determine the pre-treatment level required: coagulation, sand filters, membrane filters, etc. Otherwise, the PFAS-treating technologies may become prohibitively large.

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 which wastewater and biosolids treatment could be anticipated.

Table 1 presents data on completed design projects, from planning-phase facilities to those fully constructed and operational. These projects cover various capacities, from 2 to 50 mgd (7.6 to 189 ML/d), and include PFAS treatment technologies such as GAC, anion exchange (AIX), and RO. The average cost per gallon to treat drinking water for PFAS is $2.00/gal ($0.53/L), inclusive of only the capital costs of the infrastructure and not general operation and maintenance. Many of these projects include project-specific requests and considerations in the cost. These considerations could include additional chemical systems, permitting, new building requirements, and other items essential for implementation of PFAS treatment.

The cost per gallon of treatment presented and the O&M costs estimated, while representative of various PFAS treatment technologies for drinking water, would rise sharply if applied to wastewater or biosolids matrices. As mentioned, the factor by which the cost would increase is not quantifiable; the site-specific water matrix and other project requirements would need to be evaluated but the cost could be orders of magnitude larger in some cases. Important to remember is that additional treatment requirements and other considerations can greatly influence the cost to apply these PFAS treatment methods to wastewater or biosolids. For example, without pre-treatment, GAC and AIX would be challenging to implement and likely not cost-advantageous.

The costs in Tables 1 and 2 provide a reference point for the cost of treating PFAS in drinking water but should not be interpreted or applied to any other matrices.

POTENTIAL WASTEWATER TREATMENT COST 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 compared to typical groundwater or surface water sources used for drinking water. Implementing any of these technologies thus may require additional treatment: coagulation, sand filters, membrane filters, etc. Otherwise, the PFAS treating technologies may become prohibitively large. For example, the Brunswick County RO improvements shown in Table 1 and totaling $120 million to treat 50 mgd (189 ML/d) results in a cost to treat of $2.40/gpd ($0.64/Lpd) (CAPEX), in addition to the facility's normal operating costs and any operating expenses for those new facilities. A wastewater treatment facility's cost per volume treated may be 2 or 3 times that due to the wastewater matrix, increased TOC concentration, and other wastewater effluent components that would be removed upstream of the RO membranes before PFAS are removed to the ppt level.

As an example, the Lewiston-Auburn Water Pollution Control Authority (LAWPCA) facility has an average daily design capacity of 14.2 mgd (54 ML/d). If LAWPCA were to implement RO treatment at an assumed cost of $2.00/gpd ($0.53/Lpd), the resulting capital cost would be $57 million to $85 million to treat the plant's liquid side to meet drinking water standards for PFAS. The debt service on this capital expenditure would be $2.9 million to $4.3 million per year at 3 percent over a 30-year term, doubling LAWPCA's 2019/2020 annual operating budget of $3.4 million. This does not include operating costs for the new facilities or any increase in sludge disposal costs or brine treatment and disposal costs. LAWPCA's sludge disposal costs have already increased 153 percent from 2017/2018 (pre-PFAS) to their 2019/2020 budget (post-PFAS). As a result, its community fees would have to increase accordingly, in turn increasing homeowner sewer bills to between 2 and 3 times the current fees.

Agencies participating in this study reported annual sludge end-use costs of 8 to 17 percent of total annual operating budget. For entities in states where PFAS were regulated below the EPA health advisory level of 70 ppt, facilities that rely on off-site sludge outlets saw sludge end-use cost jump by 80 to 350 percent. The PFAS that partition to the solids phase and remain in the sludge would still require disposal alternatives, or if practical, one of the treatment technologies discussed herein.

ASSOCIATED TRENDS

Final federal regulations have not been promulgated for PFAS in biosolids. State-specific regulations and guidelines that have been proposed or enacted include various concentration limits of different PFAS compounds in drinking water, groundwater, and, in a few cases, surface water. Only Maine has imposed a screening limit on three PFAS compounds in biosolids. Other states, such as Massachusetts, have implemented monitoring requirements, while in some states with surface water limits, such as Michigan, those limits have directly affected wastewater effluent. Nonetheless, the very low regulatory standards for drinking water that several states have adopted are significantly increasing the cost of wastewater and biosolids management programs.

In the absence of national regulatory standards, individual states are acting, and the future of PFAS standards is unclear and varied. WRRFs and biosolids management programs are being forced to consider current and/or anticipated state PFAS regulations, explaining why some states have already seen rising costs. The unintended consequences of proactively addressing PFAS with water quality standards include these increases in wastewater solids management costs. 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—even within waters—has consequences. Doing so will continue to disrupt markets if WRRFs and other receivers of PFAS are not provided additional management, compliance, or treatment options and funding for transitioning to managing PFAS.

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Thermal drying for cost and risk control

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NATALIE SIERRA, Brown and Caldwell, Andover, Massachusetts

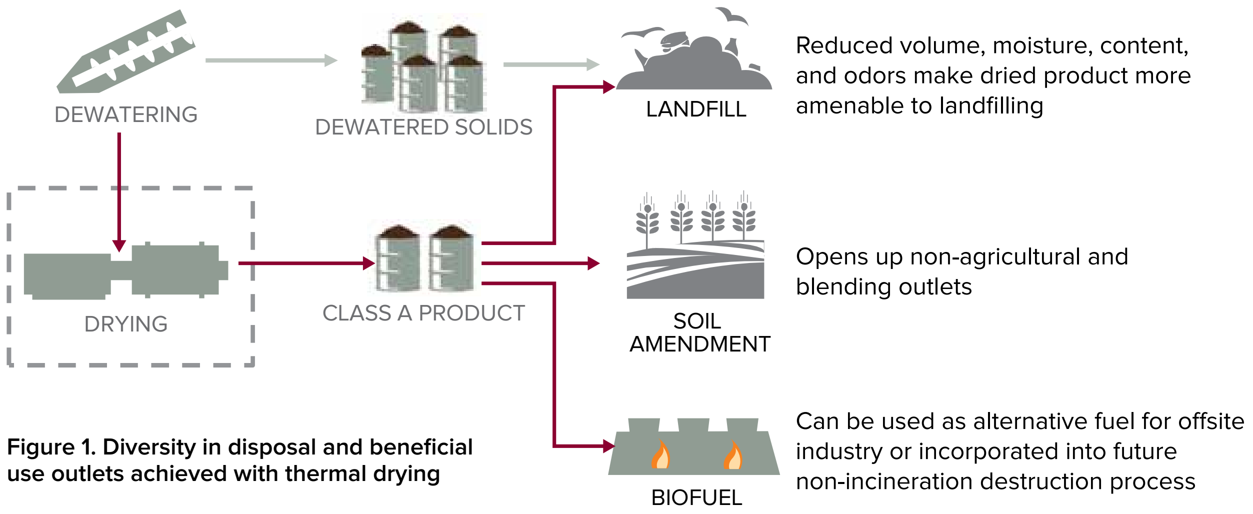
ABSTRACT | Articles from this issue and past ones of the *Journal* point toward the continuing decline in availability and reliability of disposal or beneficial reuse markets for wastewater solids in the region. Increased pressure from shrinking or limited incinerator and landfill capacity was previously documented by North East Biosolids and Residuals Association Special Projects Director Ned Beecher in 2016. The predictions that disposal costs would continue to increase have become a reality for many municipalities. Biosolids market constrictions are now compounded by increased regulatory uncertainty and public attention regarding the presence of per- and polyfluoroalkyl substances (PFAS) in solids, although the ubiquitous presence of PFAS throughout the natural and built environment has been well established at levels comparable to typical wastewater solids (Brusseau, Anderson, & Guo, 2020; Kim Lazcano et al., 2019). Municipalities face increasingly difficult questions around how to address these solids management issues considering cost and risk to ratepayers, as well as the carbon footprint and resource recovery implications of these decisions.

KEYWORDS | Thermal drying, solids management, feasibility studies, plant operations

BENEFITS OF THERMAL DRYING

Thermal drying is one strategy gaining attention throughout the region to provide cost and risk control from recent trends in the solids management market. Thermal dryers apply heat to dewatered solids to remove most of the water content and produce a value-added product. Compared to dewatering solids, thermal drying can reduce the total mass of solids by 4 to 5 times and generate a product meeting EPA Class A pathogen-reduction requirements for beneficial reuse. Thermal drying as a means of mass reduction and stabilization is a demonstrated technology in the United States with nearly 60 operational facilities identified in a 2016 survey (WEF, 2017). Concerning the current Northeast market, thermal drying offers the following benefits:

- **Mass reduction**. Less mass means less hauling and reduced tipping fees. Landfills are also under growing pressure to reduce wet waste received given recent slope failures throughout the country (WW TCC, 2019) and the potential for odor generation during transit and receiving. Moisture reduction and stabilization from thermal drying can address both these issues, providing future security if municipalities are required to landfill their solids.
- **Diversity in beneficial use opportunities**. Perhaps the most promising aspect of thermal drying is its ability to access a variety of beneficial use outlets. While there is regulatory uncertainty around the future of beneficial use in the region, biosolids land application still occurs in Maine where screening standards are being implemented, including dried product from out of state (Hopkins, 2021). Thermally dried product, when meeting low-pollutant and Class A pathogen-reduction requirements, can achieve EPA Exceptional Quality (EQ) designation, which EPA defines as being "virtually unregulated" regarding distribution (1994). This produces dried EQ product suitable as a soil amendment in various non-agricultural applications, broadening the scope of beneficial reuse opportunities to buffer future application rate restrictions or market limitations.
- **Staged thermal destruction adoption**. Interest is growing in non-incineration, thermal-destruction technologies for further mass reduction and potential per- and polyfluoroalkyl substances (PFAS) control. These technologies have yet to be demonstrated at scale with wastewater solids, and peer-reviewed PFAS fate studies are still in early stages. However, these technologies (i.e., pyrolysis, gasification, or torrefaction) require an upfront drying step; and thermal dryer facilities can be installed now with a footprint set aside to incorporate thermal destruction in the future. Options also exist for offsite use of dried product as an alternative fuel in combustion-based industrial processes, such as cement and lime kilns and energy generation facilities.



Reduced volume, moisture, content, and odors make dried product more amenable to landfilling

Opens up non-agricultural and blending outlets

Can be used as alternative fuel for offsite industry or incorporated into future non-incineration destruction process

Figure 1. Diversity in disposal and beneficial use outlets achieved with thermal drying

Figure 1 summarizes these potential benefits, which together can support each other in controlling both short- and long-term risks. They also provide a buffer from market forces projected to continue regardless of the outcome or severity of potential PFAS regulatory action.

While thermal drying can provide various programmatic benefits, it requires a large investment in capital and annual operating expenses and adds mechanical complexity to a municipality's solids handling facility. These life-cycle costs are critical to consider for a dryer project's economic feasibility and, when not properly measured alongside site-specific considerations, can lead to lasting operational issues. The technologies used for wastewater solids drying, their application, and key considerations for successful deployment are discussed below. A case study from a recent thermal dryer feasibility study in the Northeast illustrates how these elements come together to identify project viability and develop a path forward for implementing a dryer project.

TYPES OF THERMAL DRYERS

Three primary types of thermal dryers are used for wastewater solids applications in the United States: belt, paddle, and rotary drum. Belt and rotary drum technologies advance product through the dryer vessel using a rotating belt or drum, respectively, while hot gases are passed through the product to facilitate evaporation. Paddle dryers use metal discs or paddles to advance product, while transferring heat to the product through the surface of the paddles and dryer vessel casing via thermal oil or steam. Table 1 (next page) provides an overview of the primary characteristics of the main dryer types and their operational characteristics. Photos 1 through 4 (page 41) show recent installations.

As noted in Table 1, drum dryers historically have a higher loading requirement for continuous operation, which can be attributed to their higher operating temperatures. However, recent market entrants to the United States now offer drum dryers at smaller sizes. The drum drying process produces the most uniform, dense pellet and is typically employed at larger, urban facilities (for example, the Massachusetts Water Resources Authority). Belt and paddle dryers can be supplied in smaller sizes, are operationally less complex, and are more commonly employed at small-to-medium-sized municipalities. A primary advantage of the paddle dryer is its small footprint, allowing it to fit into existing spaces. Conversely, a belt dryer requires a greater footprint but can operate at temperatures below the minimum ignition temperature of standard wastewater solids dust (329°F [165°C] per NFPA 654, 2020), which poses the greatest safety risk within the dryer vessel itself. This also allows belt dryers to use waste heat from various sources including combined heat and power systems. Each technology has operated successfully in the United States, with several commercial offerings available.

KEY IMPLEMENTATION CONSIDERATIONS

A thermal dryer's ability to provide long-term, reliable operation is predicated on both appropriate technology selection and careful consideration of site-specific factors. Recent history of thermal dryers in the United States makes it clear that if these factors are not accounted for, dryers can cause

Table 1. High-level dryer-type comparison

	Belt	Paddle	Drum
Heating medium	Water (185–284°F / 85–140°C), thermal oil (430°F / 221°C), or flue gas (250–330°F / 121–166°C)	Thermal oil (385°F / 196°C) or steam (<290 psi / 2,000 kPa)	Flue gas (650–1,100°F / 343–593°C)
Material conveyance	Metal or plastic belt	Rotating (heated) discs or paddles	Rotating drum
Typical thermal efficiency	1,100–1,600 BTU/lb-H_2O evap. (2,580–3,750 kJ/kg- H_2O evap.)	1,400–1,500 BTU/lb-H_2O evap. (3,280–3,520 kJ/kg- H_2O evap.)	1,400–1,500 BTU/lb-H_2O evap. (3,280–3,520 kJ/kg- H_2O evap.)
Typical minimum machine capacity at 24/7 cycle, 24%TS feed	1,000 lb-H_2O/hr / 450 kg-H2O/hr (4 dry tons per day or dtpd / 3.6 MT per day)	700 lb-H2O/hr / 315 kg-H2O/hr (3 dtpd / 2.7 MT per day)	4,000 lb-H_2O/hr / 1,800 kg-H_2O/hr (15 dtpd / 13.6 MT per day)
Typical product	Cylindrical granule (0.04–0.3 in. / 1–8 mm)	Irregular, dusty granule (0–0.6 in. / 0–15 mm)	Dense pellet (0.08–0.16 in. / 2–4 mm)
Comparative assessment			
Footprint requirements	High	Lower	Moderate (lower at large facilities)
Energy recovery flexibility	High	Moderate	Moderate
Safety concerns	Lower	Moderate	High

significant operational problems or failures. Three municipalities in the Northeast and Mid-Atlantic region recently conducted studies assessing whether potential improvements or upgrades could allow them to regain effective use of their operationally challenging or disused thermal dryers. Consistent themes emerge from each assessment and point to three considerations when defining a thermal-drying project:

- **Upstream solids handling**. Successful thermal dryer operation requires a steady, consistent supply of solids. Facilities without sufficient wide spots or operational flexibility at upstream solids handling processes can become limited in providing load leveling to the dryer.
- **Solids characteristics**. High levels of debris and fiber, grit and abrasive material, high volatile content solids or imported wastes, and corrosive chemical constituents each have a unique effect on dryer operations and can reduce the dryer's useful life if not appropriately handled.
- **Technology readiness**. Each time a new thermal-drying concept or technology is introduced, several iterations are required to achieve long-term operational success. Understanding and planning for this cycle can support early adopters of new dryer technologies.

While these considerations represent historical challenges, they also provide an opportunity to incorporate knowledge sharing and lessons learned throughout the industry. Municipalities operating thermal dryers throughout the United States share knowledge in local and national professional organizations and have contributed to adopting thermal drying at more recent installations. The following case study demonstrates how the inclusion of these lessons learned into early stages of project planning builds consensus and aids in the development and advancement of a thermal dryer project.

CASE STUDY: CITY OF AUBURN, NEW YORK

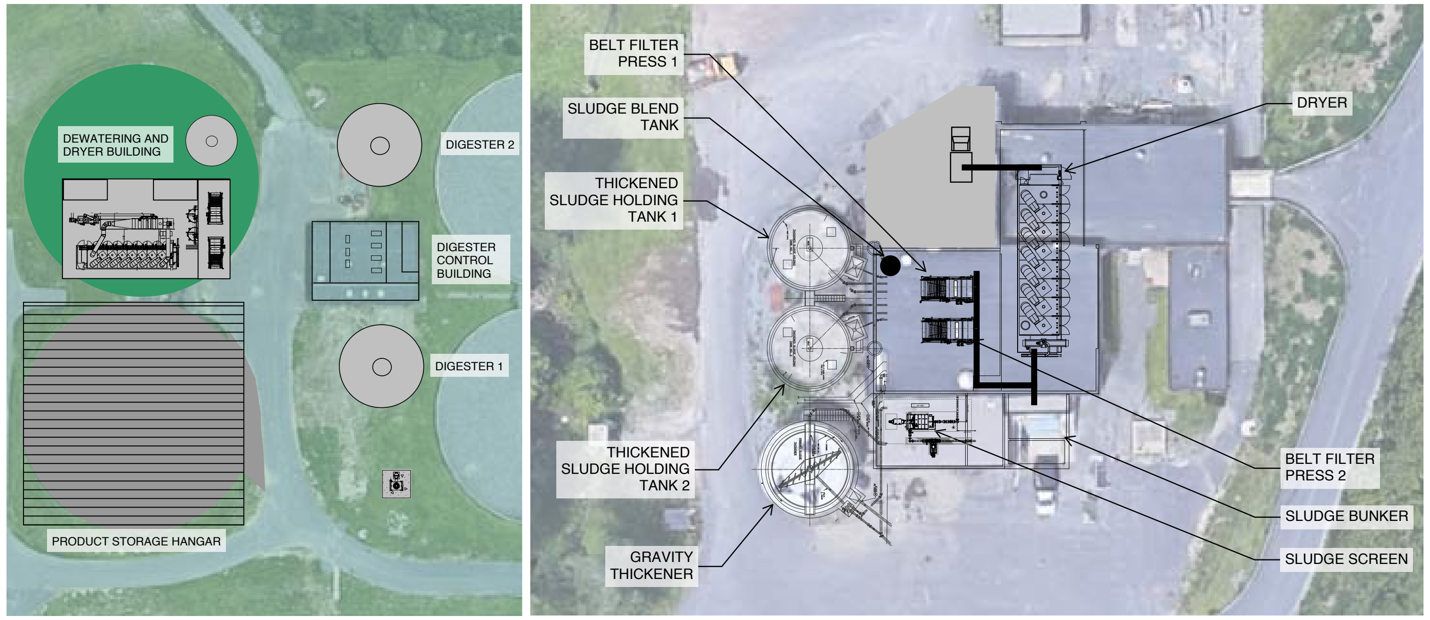
The City of Auburn owns and operates a 12 mgd (45 mL/d) average flow wastewater treatment plant (WWTP) in central New York. The City operated an onsite incinerator for solids disposal up to 2009 when it was abandoned due to operational issues and impending permit restrictions. It has since disposed of dewatered solids from its conventional primary and secondary treatment processes at a City-owned landfill; however, the landfill recently reached capacity and was shut down. Like many other facilities in the Northeast, Auburn received solids hauling and disposal cost proposals 50 percent to 150 percent higher than what they had previously paid and, as a result, initiated a thermal dryer feasibility study in the summer of 2019.

1. Belt dryer installed at the Western Wake Regional Water Reclamation Facility in New Hill, NC 2. Drum dryer installed at the Massachusetts Water Resources Authority Residuals Pellet Plant in Quincy, MA 3. Paddle dryer installed at the Derry Township Municipal Authority Clearwater Road Wastewater Treatment Facility in Hershey, PA 4. Belt dryer installed at the Chalfont-New Britain Township Joint Sewage Authority's Advanced Wastewater Treatment Facility in Doylestown, PA

Early in the study, the project team identified process bottlenecks within the solids handling system that would affect the technical feasibility of a thermal dryer project. Primary sludge and waste active sludge (WAS) are combined in a gravity thickener, from which solids are fed directly to a dewatering belt filter press and pumped via an old incinerator feed cake pump to loadout. While plant operators developed resourceful strategies to address variability in solids loading, such as changing process conditions and the characteristics of influent from a combined sewer system, dry solids content off the belt filter press could still vary substantially from day to day. To address the variability inherent in the existing system, alternatives were developed to de-bottleneck the solids handling operations. These included separate WAS mechanical thickening, elutriation water and added coagulant to primary sludge gravity thickening, and refurbishment of the intermediate holding tanks. A cost-benefit analysis compared screening upgrades at the headworks to installation of an inline sludge screen to address debris and fiber observed in the solids. The inline sludge screen met the project needs at a much-reduced cost and was included in the project definition.

Four dryer alternatives considering the solids handling train were then developed for comparison on a net present value (NPV) basis to status quo solids disposal. The alternatives were developed to compare installation of a thermal dryer in the solids handling building to a newly constructed dewatering and drying facility as well as installation with upstream anaerobic digesters and a post-drying pyrolysis step. Figures 2 and 3 (next page) show conceptual sketches for dryer installation in the existing and proposed new building. Figure 4 (page 43) presents the NPV of each alternative's 30-year life-cycle cost, considering dryer installation along with related solids handling upgrade and state-of-good-repair projects.

Figure 4 shows that with current solids management trends each dryer alternative offers major life cycle savings compared to the status quo scenario. Costs to rehabilitate a building to current dryer safety design codes and standards were similar to construction of a new solids handling building. Also, the added capital outlay for anaerobic digesters was nearly offset by the cost reduction they provide from upstream solids reduction and reduced dryer facility size, in addition to their providing a source of fuel for the dryer. As City staff became more familiar with



Figures 2 and 3. Conceptual sketches for dryer installation in the existing and proposed new building for 12 mgd (45 mL/d) average flow wastewater treatment plant, City of Auburn, New York

the drying process and historical installations, use of anaerobic digestion to provide a backup stabilization method and improve the quality and consistency of solids to the drying process was critical. Opportunities identified for dried product beneficial reuse and disposal meant that the pyrolysis system did not provide a cost advantage. However, the project advanced with a pre-defined location for its potential installation if market conditions later allow.

Following the feasibility study, the City has completed a more-detailed technology assessment phase with support from the New York State Energy Research and Development Authority. This study further familiarized plant staff with equipment operation, assessed opportunities for energy recovery with digestion with modern dryer technologies, and identified opportunities for cost and energy savings through innovative approaches to anaerobic digestion tank construction and heating. The project team plans to issue competitive bidding documents to dryer manufacturers for pre-purchase of the dryer system this spring. Bidding documents will be based on a best-value bid comparison considering life-cycle costs, service and spare parts availability, and desired features to incorporate lessons learned from past dryer installations. Detailed design is scheduled to be completed later this year to coincide with dryer delivery and fast-track installation.

CONCLUSIONS

Recent regional solids management trends can make thermal drying favorable for both cost and risk control. Thermal drying can reduce solids mass by 4 to 5 times that of dewatered solids and produce a Class A biosolids product with potential to diversify disposal and beneficial reuse outlets. If beneficial reuse is a goal, understanding your local solids market and planning accordingly for market demand and potential shifts, as well as keeping up with PFAS regulatory action, are even more important. When considering thermal drying at your facility, incorporating lessons learned from past dryer installations and site-specific factors will help accurately assess its technical and financial feasibility and develop a project concept that will deliver long-term, successful operation.

ACKNOWLEDGMENTS

The authors thank City of Auburn staff for their contributions to this article and successful project outcomes. We also thank all those in the Northeast biosolids community who provided information for this article. These groups include facilities operating thermal dryers, state regulators, and technology vendors.

ABOUT THE AUTHORS

- John Ross is a biosolids-focused engineer in Brown and Caldwell's (BC's) Andover, Massachusetts office. Mr. Ross gained experience with dryer operations early in his career working onsite at the Milorganite Facility in Milwaukee, Wisconsin, and has since worked closely with BC's subject matter experts on dryer projects across the country. He also conducted research on the fate of micropollutants in biosolids pyrolysis and will support an upcoming Water Research Foundation full-scale PFAS fate study in sewage sludge incinerators.

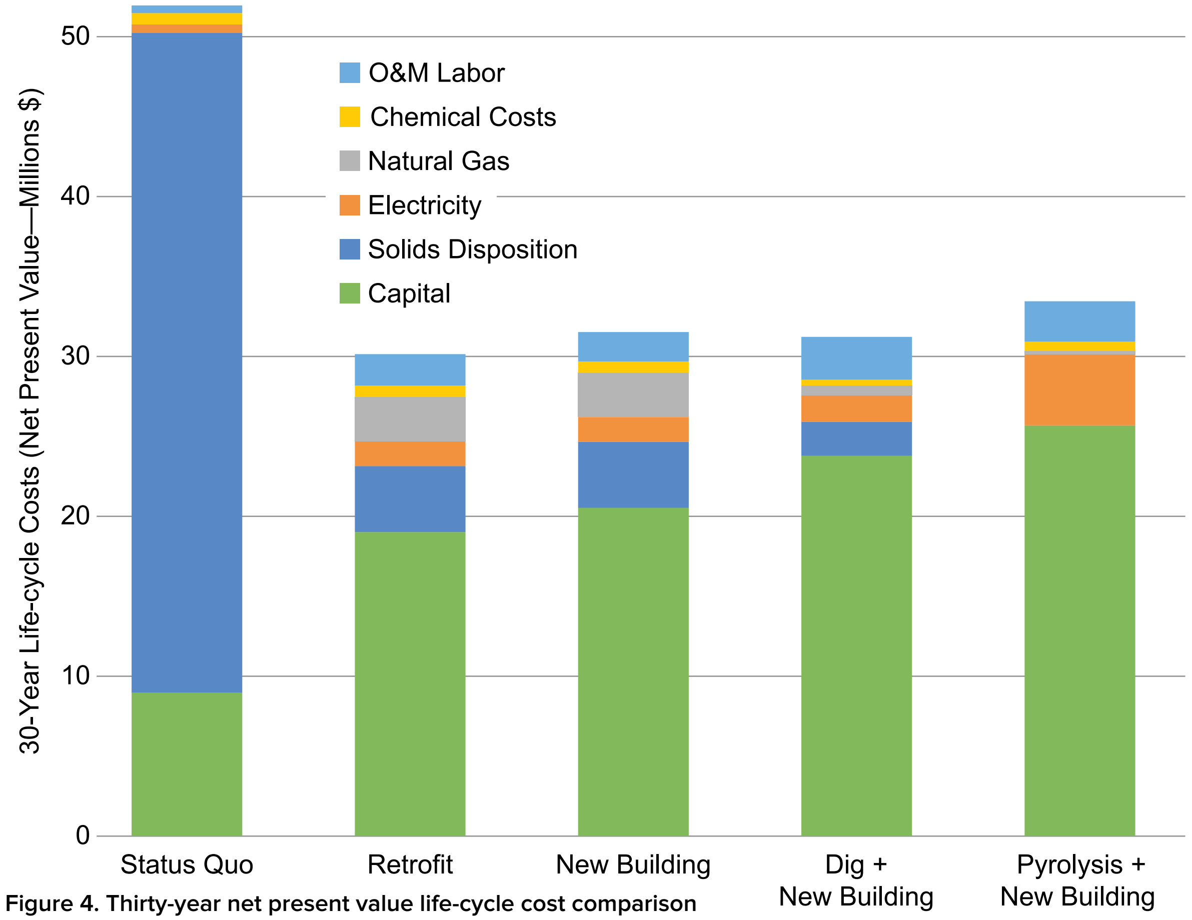


Figure 4. Thirty-year net present value life-cycle cost comparison

- Natalie Sierra supervises BC's national biosolids and energy practice and is also out of the Andover office. Ms. Sierra's specialties include biosolids master planning, biosolids regulations, and end use. She has been engaged on PFAS regulatory developments and public outreach with both North East Biosolids & Residuals Association (NEBRA) and NEWEA and supports municipal biosolids programs nationwide in their response to PFAS challenges.

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Adaptive biosolids master planning to manage PFAS in biosolids

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ABSTRACT | Biosolids master plans have historically focused on wastewater service area growth and upgrades to aging biosolids infrastructure. Master planning can no longer present technical solutions that only address capacity projections. Adaptive plans must allow for process enhancements that address changing rules and regulations, especially related to compounds of emerging concern such as per- and polyfluoroalkyl substances (PFAS). Markets for resulting biosolids products must also be evaluated. New master planning methods are needed to ensure viable, long-term end-product markets.

This article helps utility planners, operators, and engineers understand PFAS planning challenges, the changing regulatory landscape, and technologies being used or developed to eliminate PFAS from biosolids. Technical solutions to be discussed include globally implemented full-scale thermal processing applications such as thermal drying followed by pyrolysis or gasification. Pilot-scale technologies discussed include hydrothermal liquefaction, which could turn residual solids into marketable oil products.

KEYWORDS | Biosolids, master planning, PFAS, compounds of emerging concern, thermal drying, hydrothermal liquefaction

INTRODUCTION

Biosolids master planning has been practiced for decades to help wastewater utilities make informed decisions about solids management practices and the costs to build and operate needed facilities. Since solids management operations typically amount to 50 percent or more of a wastewater facility's operating costs, careful planning is required to ensure cost-effective solutions are chosen that provide long-term solids processing capabilities. Review of regulatory requirements is needed so that chosen solutions are permittable and produce end products that comply with regulations. In recent years, a shift has occurred; this shift requires utilities not only to plan for meeting capacity needs but to consider more carefully how, through various methods, to best use the energy content locked up in solids. Coupled with that is the need to address public concern regarding the presence of emerging contaminants such as per- and polyfluoroalkyl substances (PFAS) in biosolids products.

Because of the ubiquitous use of PFAS in our modern society, these compounds are present in most if not all forms of biosolids produced for land application. Various PFAS compounds are measurable in biosolids at single digits in parts per billion (ppb) on a dry weight basis. EPA has not determined the appropriate concentration of PFAS compounds suitable for land application of biosolids. Determining the risk and potential regulation (development of numeric limits) of these compounds in biosolids, however, is the top priority of EPA's biosolids group under the Health and Ecological Criteria Division, Office of Science and Technology of the Office of Water. Any EPA standard is likely two to three years away from being promulgated. In the absence of EPA rules, many states are developing interim guidelines or advisory levels of PFAS in biosolids for land application. Regulatory agencies across the United States, including in New England, are focused on understanding this issue and instituting regulations to protect public and private water supplies from these compounds. For example, Maine has promulgated concentration limits for the beneficial use of products destined for land application (including biosolids) that are highly restrictive for biosolids (Maine DEP, *Maine Solid Waste Management Rules: Beneficial Use of Solid Wastes*, 06-096 C.M.R. ch. 418, Appendix A, last amended July 8, 2018). The potential for regulatory changes to emerge after a biosolids master plan is completed and new facilities and processes are procured and built is of great concern to engineers, administrators, and operators of wastewater utilities. For these reasons, emerging technologies that can be used to eliminate PFAS from biosolids are being developed to meet the potential future needs of utilities.

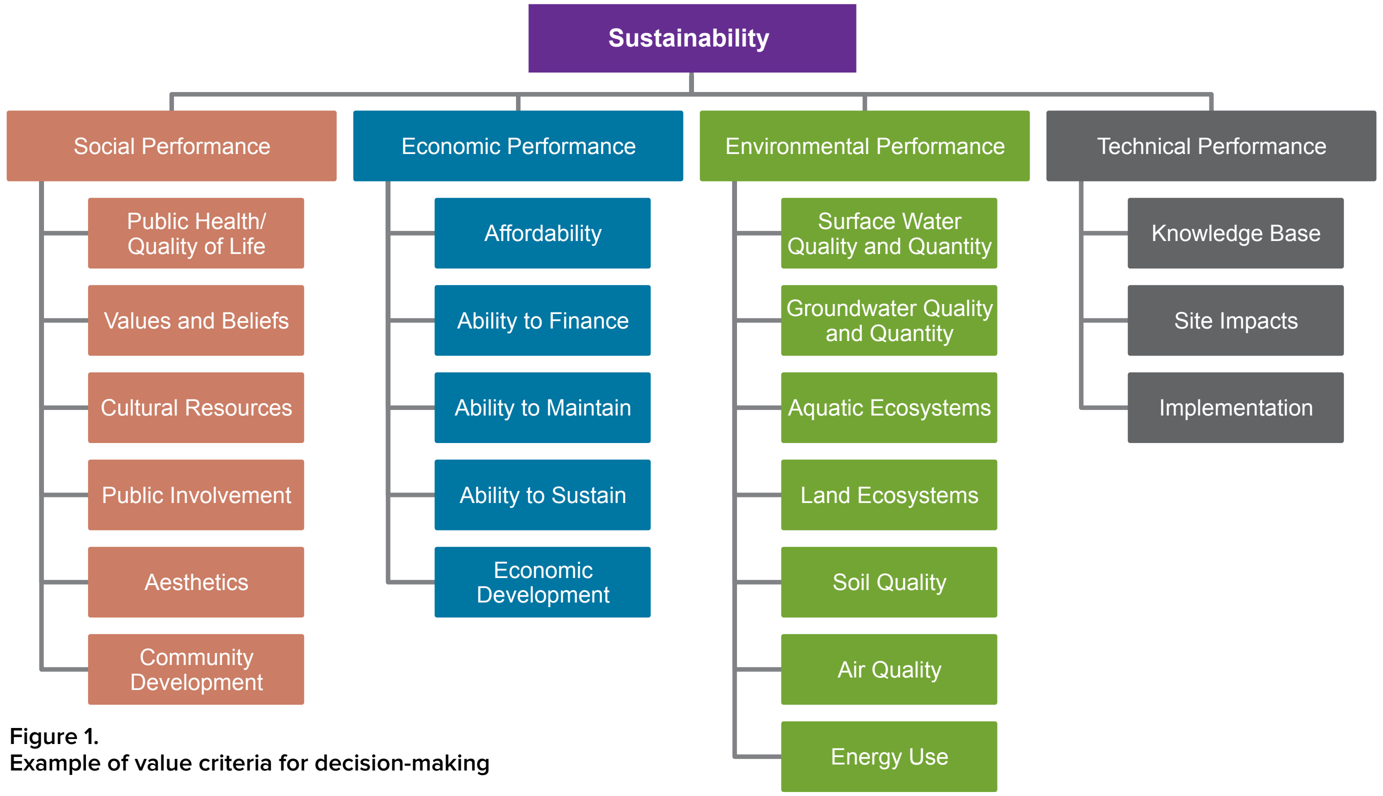


Figure 1.
Example of value criteria for decision-making

BIOSOLIDS MASTER PLANNING

Biosolids master planning projects aim at developing a road map for the future—with and sometimes without the capital funding needed for new facilities, but always with a sense of urgency given that solids processing operations can be half the operating budget of a treatment works. Engineering consultants have developed biosolids master planning tools to help utilities navigate the evaluation and selection process to develop robust, sustainable plans. By following a defensible process, the preferred long-term biosolids management strategy can be identified and an implementation plan developed. Robust biosolids master planning should be based on the multi-attribute utility analysis (MUA) approach, which incorporates client values, goals, and overall objectives to arrive at a preferred solution.

Figure 1 shows program sustainability criteria that should be considered for biosolids planning options. The criteria shown define each consideration that must be identified so that specific, quantifiable definitions are developed. The results can be displayed as a value hierarchy. This figure illustrates a sustainable development value hierarchy along with definitions for supporting criteria. Taken together they define sustainability. In developing utility-specific criteria, each criterion must be measurable and should be independent. If they are not independent, the interdependent criteria will receive a higher consideration and value-weighting than intended. Values drive decision-making when different concerns (such as environmental versus economic versus social) are considered.

Relative values of individuals or stakeholders can be surveyed, quantified, and transformed into relative weights for the individual criteria within the value hierarchy. This set of weights can be used to evaluate alternatives based on individual or stakeholder group values. Different sets of weights, representing the relative importance of various individuals or stakeholders, can be used subsequently to assess preferences for the identified alternatives.

The next step is usually to develop measures—called utility scales—for the individual criteria within the value hierarchy. These scales can initially be semi-quantitative. Generally, a 1 to 10 scale is used

Table 1. Utility scales for developing weighting for various non-monetary criteria

Utility scales	Utility score 1–10
Cannot Meet Current or Future	0
Meets Current Not Future	4
Meets Current/Modified for Future	7
Meets Current and Future	9
Exceeds Current and Future	10

for each, with the rating associated with a quantitative or semi-quantitative measure. Developing the quantitative measures is an objective technical activity, while associating that measure with a utility scale (score) requires subjective input from the stakeholders. Beginning this exercise as a general overview to capture the concept is often helpful, and then more quantitative rigor can be added as the decision process proceeds. Table 1 shows general utility scales to illustrate both the starting point and what is meant by a utility scale. For example, the utility scale referred to as "standards" could apply to most of the environmental performance and public health criteria; "institutional needs" could apply to many economic performance criteria; "community issues" could apply to many social performance criteria. Alternatives are then developed and evaluated relative to the utility scales. The utility scales can also help to establish minimum levels for each criterion, providing the basis for a "fatal flaw" analysis. A composite score is calculated for each by multiplying the utility score for each criterion by the value-based weighting and summing the result to obtain a total score that represents the relative sustainability for each alternative.

The next step is usually to apply weighted criteria to the management alternatives. Output from a recent biosolids management planning study is shown in Figure 2.

Finally, cost comparisons can be developed using capital, operating, and life-cycle analyses of each potential option. The relative costs can then be applied to non-monetary rankings in a combined cost–benefit scoring step. Carrying the example from Figure 2 to the next level, a cost–benefit score using equal weighting for life-cycle cost to non-monetary criteria is shown in Figure 3. The highest-scored option can be scored 100 percent and the other options normalized against that option to demonstrate how closely or how separated varying options result. This process provides a defensible summary of options considered and ultimately chosen.

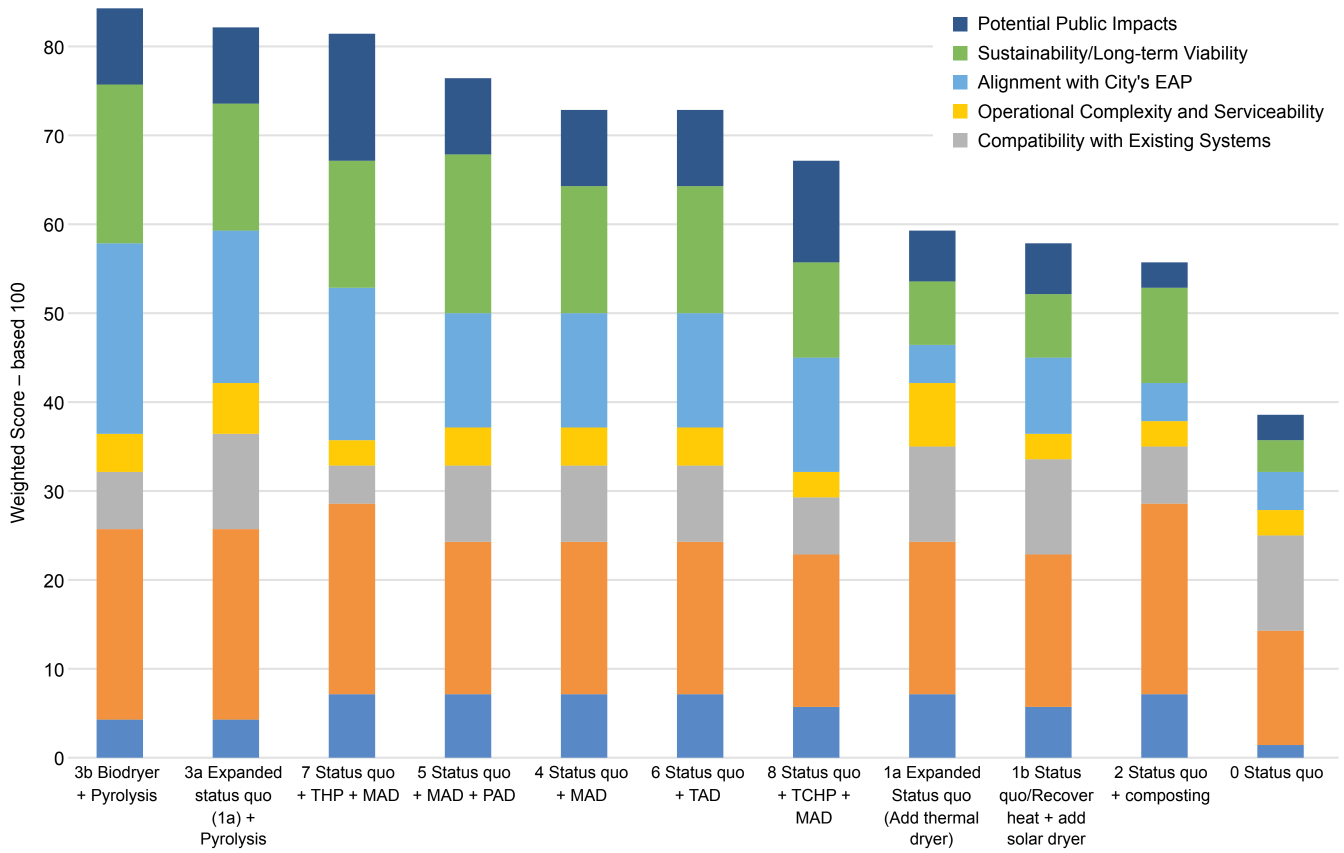


Figure 2. Results of the scoring of potential solutions using the non-monetary criteria developed

Planners must also consider how to phase portions of a recommended plan so that capital costs can be staggered over time and triggers can be identified where steps in a process can be added. In this example project, drying has been recommended initially to provide needed capacity over the planning period, but carbonization or pyrolysis would be added if regulatory limits on PFAS in biosolids emerge or energy optimization requirements or other drivers change. Below are examples of emerging technologies that show promise to address PFAS in biosolids should changing regulations require it.

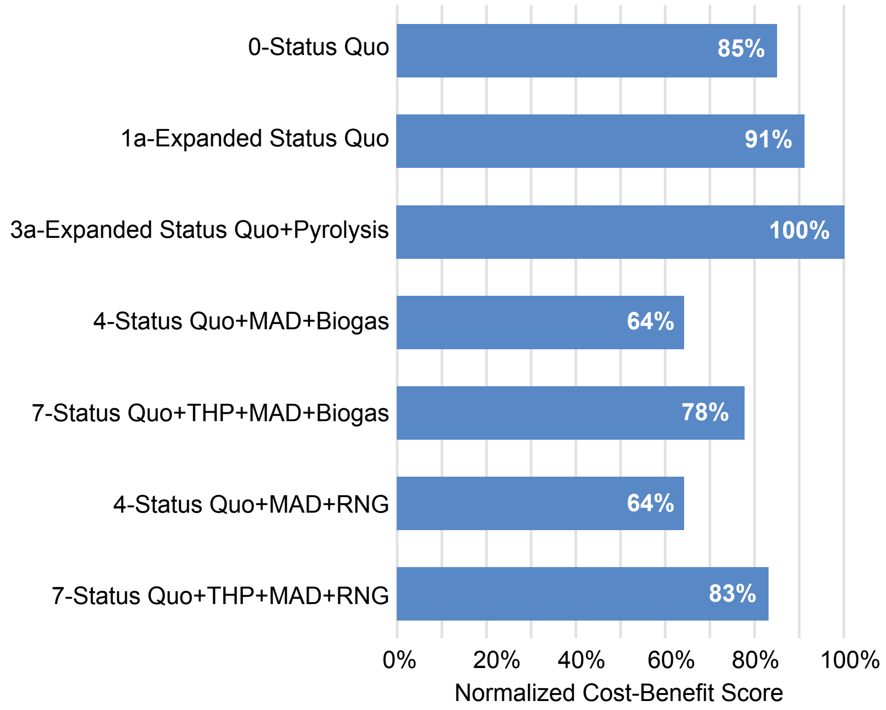


Figure 3. Cost–benefit scores for biosolids management alternatives using life-cycle cost and non-monetary criteria (higher is better)

EMERGING TECHNOLOGIES FOR ELIMINATING PFAS IN BIOSOLIDS

Incineration at high enough temperatures (>2,192°F [>1,200°C]) with sufficient residence time is believed to destroy PFAS compounds. However, more testing and research are being conducted to better understand the fate of these compounds through incineration. Recent work is considering alternatives to incineration that show potential to also eliminate these compounds from biosolids under other conditions. High-temperature (typically 932°F to 1,652°F [500°C to 900°C]) conversion of biosolids using carbonization (pyrolysis or gasification) can be achieved using dried (greater than 80 to 90 percent total solids) biosolids as a feedstock to produce an energy-laden pyrogas and a charcoal-like material referred to as char in a non-combustion process without oxygen. Carbonization converts or cracks biomass or biosolids at high temperatures in the absence of oxygen. As most organics are thermally unstable, they can be split in a carbonization process by combining thermal cracking and condensation reactions into gaseous (pyrogas), liquid (bio-oil), and solid (biochar) fractions. One benefit of these high-temperature-conversion alternatives is that they ultimately produce an energy-laden pyrogas that can run the conversion system and dry dewatered sludge fed to these systems. The char produced reportedly has significant market value in agriculture and other applications, such as a supplemental fuel in cement kilns. Recent testing by at least two system suppliers determined another benefit: high-temperature-conversion processes such as pyrolysis have been found to eliminate measurable PFAS from the dried biosolids so that the char produced is PFAS-free.

One example is a demonstration project that investigated the application of high-temperature pyrolysis technology for biosolids management and its efficacy in eliminating PFAS from the solid fraction. In addition, the transformation or elimination of PFAS compounds by measuring concentrations in the resultant bio-oil and pyrogas produced was evaluated. This is one of the first analyses using dried biosolids that captured PFAS data from all the carbonization output matrices, including the resultant char, bio-oil, and pyrogas fractions. Bench-scale testing in a continuously fed pyrolysis unit compared the measurable PFAS removal performance at 932°F and 1,292°F (500°C and 700°C) pyrolysis temperatures.

Dried biosolids tested in the bench-scale test were derived from unstable waste activated sludge. The solids were previously dewatered with belt filter presses to approximately 20 percent solids and subsequently dried in a batch thermal dryer fired with natural gas to evaporate water, resulting in a biosolids product of approximately 93 percent solids. The dried biosolids material previously met Class A Exceptional Quality biosolids status by achieving all pathogen and vector-attraction reduction requirements as well as meeting the concentration limits of heavy metals according to the US EPA 40 Code of Federal Regulations (CFR) Part 503 Rule.

Twenty-eight of the most commonly measured PFAS compounds were analyzed in the feed biosolids, biochar, and bio-oil, and 31 PFAS compounds were analyzed in the pyrogas. Three PFAS compounds were detected in the biochar at the 932°F (500°C) pyrolysis temperature, all at less than 0.5 ppb (dry weight). No PFAS compounds were detected in the biochar at the 1,292°F (700°C)

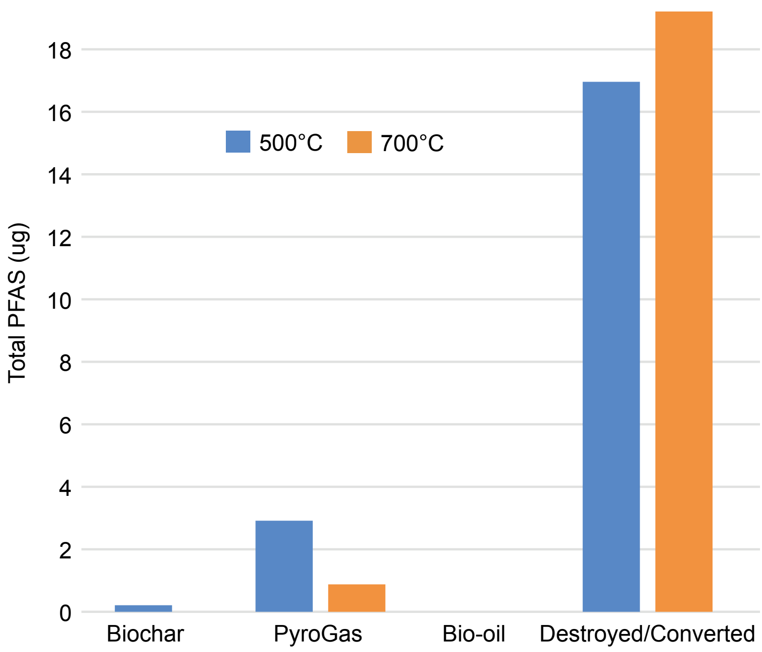


Figure 4. Total measured PFAS mass outputs from 20 μg of PFAS input at 932°F and 1,292°F (500°C and 700°C)

pyrolysis temperature. PFOS was measured at 26.6 ppb in the feed biosolids but not detected in the biochar, bio-oil, or pyrogas at either pyrolysis temperature. Although not detected in the dried biosolids, PFOA was detected at very low concentrations in the biochar and pyrogas, indicating a lack of complete destruction and/or transformation of precursor compounds during pyrolysis. A mass balance analysis on the biochar, bio-oil, and pyrogas streams was conducted, and removals of PFAS were estimated. The result of mass balance analysis based on the input weight of 20 μg of measured PFAS is summarized in Figure 4. The results indicate a total measured PFAS mass removal of 84.4 percent and 95.6 percent for 932°F and 1,292°F (500°C and 700°C) operating temperatures, respectively, for all the PFAS tested as shown. Based on this bench testing, higher temperatures of the pyrolysis process effectively removed or converted more of the PFAS compounds measured.

This analysis demonstrates that high-temperature conversion can be considered as part of planned upgrades by adding to biosolids drying operations later in response to any future regulatory requirement to reduce or remove PFAS or potentially other contaminants of emerging concern (CECs) from the biosolids produced. With at least two full-scale biosolids carbonization plants operating in the United States and several more in various stages of construction or design, this technology option has potential to address PFAS in biosolids should regulations require.

Another thermal treatment technology being evaluated by several utilities at pilot scale is the hydrothermal liquefaction process (HTP). At least two pilots in North America are exploring this technology on biosolids. This process has been demonstrated in laboratory scale on various organic waste materials. It uses high temperatures and pressures operating just below the thermodynamic critical point for water. The demonstration HTP system will heat and pump dewatered sludge cake (20 percent total solids) to 2,900 psi (200 bar), 662°F (350°C), which then will pass through a plug-flow reactor for 10 to 30 minutes. The process does not require drying the dewatered biosolids, an advantage over carbonization. Without added air or oxygen, biomass feed is converted to a mixture of slightly oxygenated liquid hydrocarbon products, referred to collectively as biocrude or biocrude oil. Other outputs from the reaction include precipitants, water effluent, and renewable natural gas. The biocrude can be upgraded to a hydrocarbon product similar to fossil crude oil through the catalytic addition of hydrogen and then marketed as an oil. Because of the high temperatures and pressures, vendors claim solids and microconstituents are effectively converted to fuel products. Several utilities, departments of energy, consultants, and researchers are partnering in this demonstration project to determine not only the viability of the process but the ability of the process to eliminate PFAS and other CECs from biosolids.

ABOUT THE AUTHOR

Todd Williams, PE, BCEE, is the past chair of the Water Environment Federation's Residuals and Biosolids Committee and is the residuals resource recovery practice leader at Jacobs. Mr. Williams has 40 years of experience assisting wastewater utilities, agencies, and communities throughout North America in developing sustainable biosolids management programs.

For additional information, Mr. Williams can be reached at todd.williams3@jacobs.com.

Committee Focus

Residuals Management

Managing residuals from water resource recovery facility (WRRF) treatment processes is important to the clean water business. Not only is it a large part of a utility's operating budget, it also poses the most significant operating risk. Only three management methods exist: thermal treatment (e.g., incineration), landfilling, and beneficial reuse. Utility managers must be aware of and plan for impacts on operating costs in case of a loss of outlets or end uses for its biosolids. NEWEA's Residuals Management Committee (RMC) is committed to educating NEWEA members about all technical and regulatory aspects of biosolids management.

If you care about residuals and biosolids issues and want to share your knowledge, network with leaders in the residuals industry, or learn from others how to do a better job managing your solids, this is the committee for you! Through various activities throughout the year, the RMC updates NEWEA members on the latest methods, research, technologies, and information about residuals and biosolids. Committee members manage the content of the annual specialty conference and technical sessions at NEWEA's annual conference.

If you care about residuals and biosolids issues and want to share your knowledge, network with leaders in the residuals industry, or learn from others how to do a better job managing your solids, this is the committee for you!

For the annual residuals conference and throughout the year, the RMC collaborates with the North East Biosolids & Residuals Association (NEBRA). NEBRA, a small non-profit focused exclusively on biosolids and residuals in this region, is plugged into residuals issues nationally and also serves members from the Atlantic provinces of Canada including Nova Scotia, Prince Edward Island, and Quebec. Examples of collaboration with NEBRA include the public information campaign around PFAS in wastewater and biosolids and a cost impacts study, which also included the Water Environment Federation (WEF) and the National Association of Clean Water Agencies (NACWA). The RMC and NEBRA are also working on a video about PFAS in biosolids for state legislative events.

The RMC is chaired by Eric Spargimino (CDM Smith). The current vice chair is Justin Motta (Stantec). The RMC participates in various related WEF committees and is responsible for sharing information with and supporting WEF and its Member Association Biosolids Committee counterparts across the country.

In 2020, the RMC participated in the Massachusetts Department of Environmental Protection (MassDEP) Stakeholder Meeting No. 1, representing its membership as MassDEP considers rules and regulations for PFAS that could affect the beneficial reuse of biosolids. The RMC will also participate in Stakeholder Meeting No. 2 in 2021.

The RMC regularly collaborates with NEWEA's Contaminants of Emerging Concern and Government Affairs committees on biosolids and wastewater-related issues. As part of that coordination the RMC planned to participate in NEWEA's Washington, D.C. Fly-in to educate regulators on PFAS and biosolids and present the concerns of our membership; however, the fly-in was canceled in 2020 due to Covid-19.

As Covid-19 forced quarantine orders through the country, NEBRA saw the need to form a biosolids contingency planning task force consisting of NEWEA leadership, the RMC, and a small group of representatives from each major residuals handling entity in New England. This task force identified and prioritized the current stressors and concerns to the biosolids market and collaborated on short- and long-term mitigation strategies.

The RMC's "parent" is WEF's Residuals and Biosolids Committee (RBC). The RBC develops, recommends, and assists with informational programs on management options, regulatory compliance, and current residuals and biosolids practices. The RBC is WEF's largest committee and sponsors a national technical conference and exhibit every year. As one of WEF's biggest events, the RBC annual conference reflects the importance of solids management and the dedication of resources toward these issues.

On January 21, the RBC held a virtual open house to showcase committee activities and goals and to strengthen connections with WEF Member Associations. The open house was hosted by the incoming vice chair, Dru Whitlock (Stantec). The current vice chair, Karri Ving (San Francisco Public Utilities Commission), will take over the chair position from John Willis (Brown & Caldwell). The RBC intends to enhance connections with Member Associations such as NEWEA and help all WEF members improve communications about the benefits of biosolids recycling. It also aims to increase membership of utility-based professionals as well as regulatory and academic affiliates.

The RBC falls under WEF's Resource Recovery Community of Practice with Jay Swift as director. It administers the National Biosolids Partnership (NBP) program, which the current committee leadership is updating with the assistance of Patrick Dube of WEF. NEWEA's RMC participates in WEF's National Biosolids Partnership Advisory Committee, administering a certification program for exceptional quality biosolids.

WEF'S RBC HAS SEVEN SUBCOMMITTEES:

1. The Bioenergy Technology subcommittee is chaired by Sarah Deslauriers (Carollo Engineers) with Vice Chair Dave Baran (Energy Power Partners). This subcommittee promotes biosolids and energy technologies associated with municipal, agricultural, and industrial wastewater residuals. It is interested in everything from co-digestion and biofuels to project funding. The subcommittee recently published a guide, "Introduction to Bioenergy Funding through Public Private Partnerships." It can be found at WEF's website (wef.org).
2. The Biosolids Product Use and Communications (BPUC) subcommittee promotes the beneficial reuse of animal, municipal, and industrial residuals through scientifically and environmentally sound management. This subcommittee fosters relationships with various players in the reuse market. It also facilitates workshops and conferences that promote beneficial reuse of residuals and identify financial resources for these methods. The BPUC subcommittee is chaired by Jody Barksdale (Carollo Engineers) with assistance from Vice Chair Dominic Brose (Metropolitan Water Reclamation District of Greater Chicago).
3. The Green House Gas (GHG) subcommittee is chaired by Christine Polo (Carollo Engineers) with assistance from Vice Chair Manon Fisher (San Francisco Public Utilities Commission). The GHG subcommittee is a clearing house throughout WEF for information on carbon emission, and its mission includes tracking industry research needs. The subcommittee coordinates with the WEF Sustainability Community of Practice and the NACWA Biosolids Management and Climate and Energy Committee. The GHG subcommittee published a guide in 2020, "How are WRRFs Inventorying Greenhouse Gas Emissions?" It can be found on WEF's website.
4. The Solids Separation subcommittee is new and focuses on solids thickening and dewatering knowledge transfer through collaboration between the industry and academia. One goal of it is to strengthen synergies between academia and the solids handling industry to develop technologies for biosolids handling facilities. Rashi Gupta (Carollo Engineers) chairs this subcommittee along with Vice Chair Ed Fritz (Huber Technology). The group developed a series of dewatering fact sheets in 2019, and the RMC contributed by helping review the factsheets.
5. WEF has an RBC Specialty Conference subcommittee chaired by Richard Tsang (CDM Smith). Like NEWEA's RMC, the RBC hosts a technical conference and exhibit each year.
6. The newest RBC subcommittee is for Young Professionals (YP), who can become lost or overwhelmed in a committee the size of the RBC. Teigan Gulliver (HDR Inc.) chairs the YP Subcommittee. This subcommittee will be the liaison with the student community and is developing a mentor program.
7. Finally, ABBA, the "association of biosolids and by-products associations" subcommittee, is not so much a subcommittee as a loose association of practitioners of beneficial reuse. ABBA provides a network for biosolids groups and committees, including NEWEA's RMC. Ned Beecher (NEBRA) was the long-time chair, but recently Ryan Batjiaka (San Francisco Public Utilities Commission) has led ABBA.

The RBC Biosolids Communications Toolkit can be dowloaded from the WEF website

WEF's RBC plans to focus in the upcoming years on the weather impacts on land applications of residuals and biosolids and public acceptance of land application—a hot topic, since PFAS has scared many utilities about relying on this management option. To learn more about the RBC, go to the WEF website.

In 2021, the RBC developed the Biosolids Communications Toolkit. This toolkit is a resource for communicating about biosolids in ways that are factual, science-based, and easily understandable by those hearing about biosolids for the first time. NEWEA's RMC will work with its membership to spread the word about these tools and the benefits of recycling biosolids, including materials created by the RMC and NEBRA for their public information campaign.

NEBRA Highlights

WEF Creates a Director Position for Residuals and Biosolids

The Water Environment Federation (WEF) announced in late January it is hiring Maile Lono-Batura as the director for sustainable biosolids programs. This new position was approved by the WEF Board of Trustees in December. WEF will also hire a coordinator for the biosolids program. This reinvestment in biosolids programs was urged by members of WEF's Residuals & Biosolids Committee (RBC) and welcomed by member associations such as NEWEA and all the regional biosolids associations and advocates that make up the RBC subcommittee known as ABBA (Association of Biosolids and Byproducts Associations).

Water Environment Federation
the water quality people

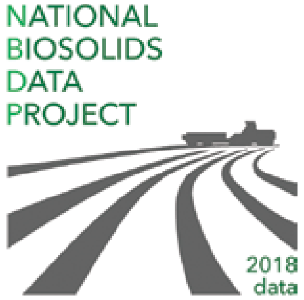
Following WEF's Biosolids Convening in October 2019, the RBC began its campaign for WEF to put more resources into biosolids. The RBC's annual specialty conference is one of WEF's largest. This reflects biosolids/residuals management representing a significant portion (generally 20 to 50 percent) of the operations budgets at water resource recovery facilities (WRRFs). The solids are also where all the resource recovery potential is with respect to energy and nutrients. Managing the solids, however, is one of the riskiest aspects of any operation. The per- and polyfluoroalkyl substances (PFAS) issue has underscored the need for an advocate at the WEF director level.


Maile Lono-Batura, WEF director for sustainable biosolids programs

The new director is charged with being a biosolids champion and proactively working with WEF utilities members but reaching beyond the usual stakeholders to realize smart policies across the country in managing biosolids and residuals, especially in this age of PFAS. Although NEBRA advocates mainly for beneficial reuse, biosolids managers agree on the importance of maintaining all practical options for wastewater solids management and supporting them in practice, research, regulation, and legislation.

Howard Carter, superintendent of the Saco, Maine Water Resource Recovery Department, said at the time WEF created the new position, "As a member of the WEF Board of Trustees and a long-time NEBRA member, I am thrilled that WEF has decided once again to take a prominent leadership role regarding the proactive advancement of biosolids priorities."

National Biosolids Data Project Update



"Where have all the biosolids gone, long time passing? Where have all the biosolids gone, long time ago?" (nod to Pete Seeger: youtube.com/watch?v=1y2SIleqy34)

That is the question being answered by the second National Biosolids Data Project. In 2007, NEBRA, *BioCycle*, North West Biosolids, and Greg Kester of the Wisconsin Department of Natural Resources (now with the California Association of Sanitation Agencies) completed the first comprehensive collection of data on biosolids use and disposal in the United States, publishing state-by-state reports and a national summary. The same team is at it again, with the addition of the Mid-Atlantic Biosolids Association (MABA) and help from other biosolids groups and state committees. The "long time ago" is 2018—the data year for this second major national survey.

The goal is to provide a robust set of data from one year—a snapshot of how wastewater solids and sewage sludges are treated, regulated, beneficially used, and/or disposed of in every state and territory of the United States. NEBRA is coordinating its efforts with NEIWPCC, which is leading the data collection for the six New England states and New York.

Preparations for the current survey began more than a year ago, with a literature review and methods report completed in May 2020, with support from a cooperative agreement provided through EPA Region 4. Data collection began in the fall of 2020, using two survey tools painstakingly developed, reviewed, and tested. Many nuances exist in how data are to be interpreted. Also, integrating various solids treatment and management practices into consistent, comparable data sets has its challenges.

As in the 2007 survey, the project team is relying on the expertise of state biosolids coordinators to provide most of the data on the regulation, quality, and end use or disposal of biosolids in their states. These state coordinators tend to have many responsibilities in addition to biosolids, and the past year has been especially trying, with stretched budgets and difficult conditions due to the pandemic. Despite the challenges, data collection has seen great cooperation. Project lead Ned Beecher is excited about the quality of data and the number of state summary reports that the project team has already compiled.

The second survey is online and to be completed by biosolids managers at wastewater treatment plants (WWTPs, aka WRRFs). It rolled out January 7 and can be accessed at nebiosolids.org/national-biosolids-survey-2018-data. It is for "Treatment Works Treating Domestic Sewage," as EPA calls them; they include publicly owned treatment works (POTWs), or, in general parlance, municipal (not industrial) WWTPs. The goal is to have at least 1,500 of these facilities complete the survey, with balanced representation in every state and territory. The project team is aiming to collect and compile data representing 70 percent of the domestic wastewater flow in every state and territory of the United States.

This second National Biosolids Data Project is funded by the National Association of Clean Water Agencies (NACWA) and WEF. Other sponsors include large public WRRF biosolids programs, private biosolids management companies, consulting engineering firms, and non-profit associations.

The project team has a stand-alone website on which the compiled data will be made available free to the biosolids profession and the public. State-by-state summary reports, spreadsheets of data, and interactive visualization graphics will provide insights into the information collected. The intention is a sustainable repository of biosolids data for the professions to access and build on in the future. The data can be used to support smart biosolids management planning, policies, and practices and facilitate resource recovery efforts. Donations are still being accepted.

For more information, visit nebiosolids.org/national-biosolids-survey-2018-data.

EPA Refocused and Reinvesting in Biosolids

EPA is re-engaged and heavily supporting biosolids management programs, with much activity and new resources being invested in biosolids management issues. Following the November 2018 Office of Inspector General (OIG) report, which was critical of EPA's biosolids program, and after hearing from stakeholders at the October 2019 Biosolids Convening, EPA is moving forward. The Biosolids Program at EPA Headquarters in Washington, D.C., has hired additional staff to manage some long-overdue initiatives and wants to engage with states, tribes, practitioners, researchers, and others to improve biosolids management.

EPA has been addressing the PFAS issue for biosolids programs on several fronts. In November 2020, EPA presented its risk assessment model for PFAS in biosolids (two in particular: perfluorooctanoic acid and perfluorooctane sulfonate [PFOA and PFOS]). EPA's biosolids program hopes to present the methodology and get approval from its science advisory board in early spring. EPA is proposing a deterministic risk assessment as a screening tool to determine those PFAS chemicals that require further evaluation using a probabilistic risk assessment framework. It will base its risk assessment on publicly available, previously peer-reviewed models for leaching, runoff, erosion, air dispersal, and plant uptake. EPA was also seeking all available data on PFAS in biosolids, soils, groundwater, etc. The methodology approved for PFOA and PFOS will be applied to the rest of the PFAS class, with the screening tool used to prioritize the full risk assessments.

In December 2020, EPA hosted a three-day virtual stakeholder meeting that included more than 150 participants, mainly state and tribal biosolids program managers but also various wastewater utilities and all the regional biosolids associations. The meetings were structured to maximize the feedback for EPA as it reinvests in its biosolids program.

On the first day of the meeting, NEBRA presented along with EPA's Office of Research and Development, the Water Research Foundation, and W-4170, a research arm of the U.S. Department of Agriculture, as part of the plenary session, "Upcoming Research Snapshots." Later in the day, biosolids coordinators from Michigan and Maine highlighted their recent experience with biosolids and PFAS.

The second day held breakout sessions on various topics that EPA sought input on as well as actions for EPA to work on alongside the biosolids community. Topics included the following:

- Chemical and Microbial Methods for Meeting Part 503 Requirements
- Considerations for Resource Recovery
- Experiences in Risk Communications
- Thermal Technologies: Incineration, Pyrolysis and Gasification
- Surface Disposal and Storage Approaches, Planning, and Challenges
- Continuity and Institutional Knowledge Transfer within Biosolids Programs

- (Non-PFAS!) Current Challenges for State and Tribal Biosolids Programs

A poll at the beginning of the meeting revealed that most participants have worked with biosolids for fewer than five years. On the meeting's final day, EPA invited experienced biosolids practitioners to provide insights into the field. Speakers included Kyle Dorsey, Washington Department of Ecology; Lauren Fondahl, EPA Region 9; Greg Kester, California Association of Sanitation Agencies; Cynthia Sans, EPA Region 7; Frederick J. Hegeman, Wisconsin Department of Natural Resources; John Dunn, EPA Region 7; and Bob Bastian, retired EPA senior environmental scientist.

EPA has published a summary of the meeting at https://www.epa.gov/sites/production/files/2021-02/documents/national-biosolids-meeting-summary-12-2020.pdf. Another stakeholder meeting is planned for the fall of 2021.

NEBRA Writes Letters in Support of EPA Biosolids Research Grants

In November, EPA published a Request for Applications (epa.gov/research-grants/national-priorities-evaluation-pollutants-biosolids) for biosolids research grant proposals to identify, characterize, and manage risks of known and emerging chemical pollutants found in biosolids. EPA is making nearly $6 million available to private non-profit institutions and public and private universities and colleges within the United States doing this kind of research. The grant solicitation opened on October 13 and closed on January 5.

NEBRA was asked and signed on in support of several of the research proposals, including the Water Research Foundation's project, "Unregulated Chemicals in Biosolids: Chemical Prioritization, Fate and Risk Evaluation for Land Applications." NEBRA also wrote in support of the University of Buffalo's project, "Prioritization of Pollutants in Land-Applied Biosolids Based on Occurrence, Fate, and Risks." North Carolina State University (NC State) hopes for funding to work on "Identification of 'At Risk' Organic Chemicals of Concern for Class A Biosolids and Exceptional Quality Products across the United States and Major Soil Regimes." If successful, NEBRA will support this NC State project by helping to collect biosolids samples from members. The fourth research project of interest to NEBRA was from the University of Albany, which plans to develop a tool for biosolid risk assessment using site-specific information. Best of luck to all the biosolids researchers!

NEBRA to Update Strategic Plan

The NEBRA Board of Directors, led by President Tom Schwartz—former chair of NEWEA's Residuals Committee—has begun updating NEBRA's strategic plan. The board will create a plan for NEBRA to, as Mr. Schwartz described it to members at the 2020 annual meeting, "ensure a relevant and sustainable NEBRA" into the future. The plan will set out the board's vision for the 2022–2027 period.

NEBRA will celebrate its 25th anniversary in 2022! In addition to looking forward, NEBRA hopes to celebrate this milestone with a look back at its history of advocating for the beneficial reuse of residuals and biosolids in the Northeast. Please email NEBRA (info@nebiosolids.org) if you have any old photos, memorabilia, stories of your involvement with NEBRA over the years, or anything to help with the commemorations.

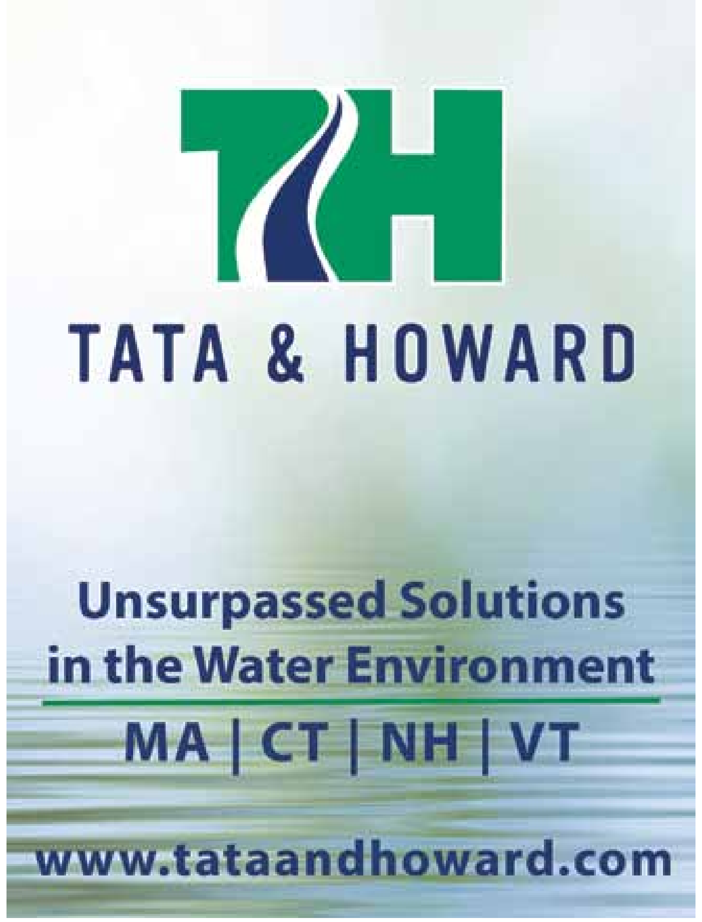
Upcoming Events

- **North East Digestion Roundtable**, April 9—Co-Digestion with Food Waste, the Greater Lawrence Sanitary District's Start-Up Experience (nebiosolids.org/ne-digestion-roundtable)
- **WEF Residuals and Biosolids Conference**, May 11–13 (wef.org/events/conferences/upcoming-conferences/ResidualsBiosolids/)

Janine Burke-Wells, Executive Director
603-323-7654 / info@nebiosolids.org

For additional news or to subscribe to NEBRAMail, NEBRA's email newsletter, visit nebiosolids.org

nebra
North East Biosolids & Residuals Association



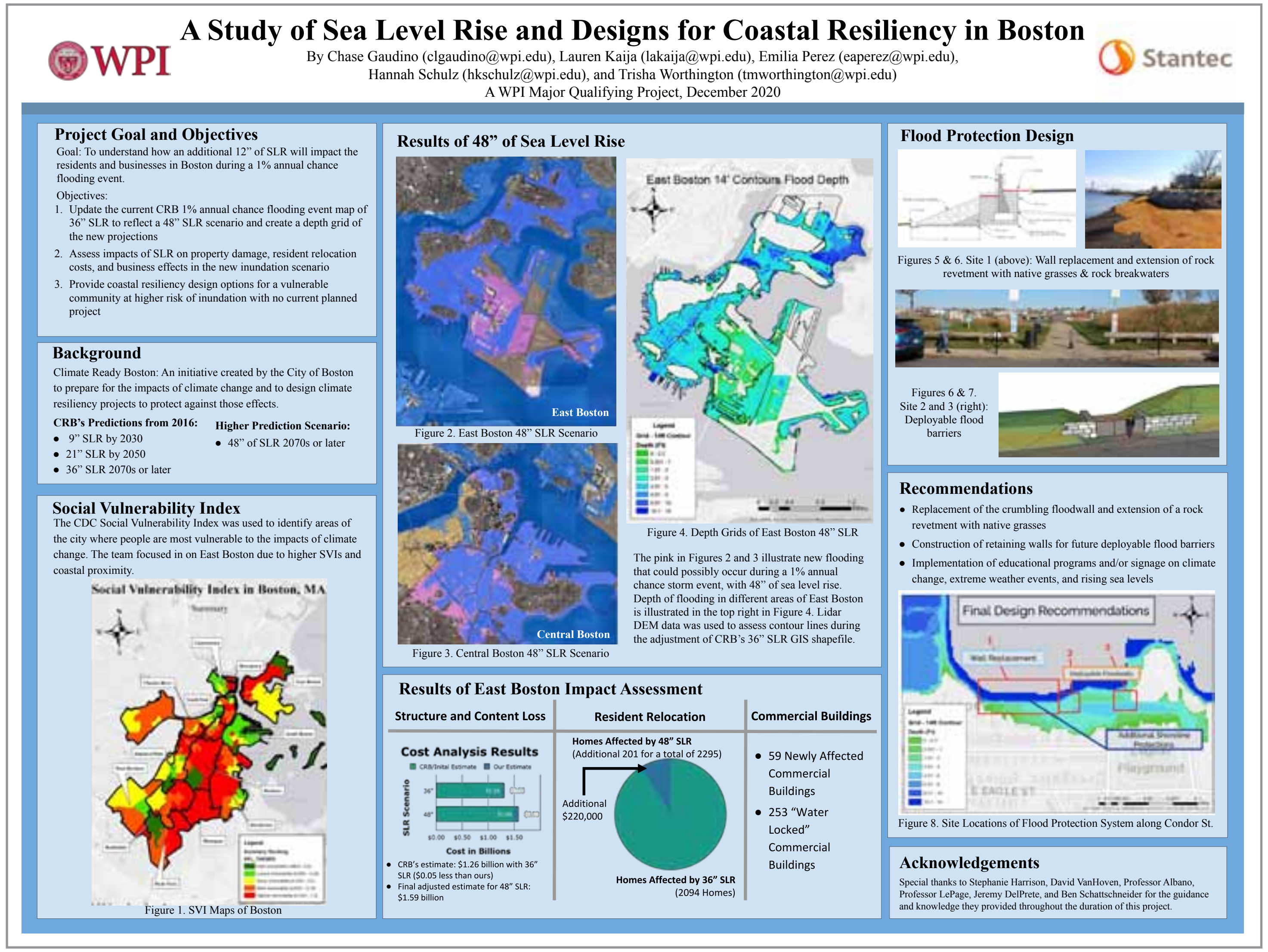
2021 Student Poster Board Competition

The NEWEA Student Activities Committee hosted a virtual version of the annual student poster competition during this year's Annual Conference. Students from six universities participated: Northeastern University, University of Massachusetts Amherst, University of Massachusetts Lowell, University of New Hampshire, University of Vermont, and Worcester Polytechnic Institute. Five undergraduate and two graduate poster entries were presented during the session and judged by a panel of industry professionals. The virtual session enabled judges and attendees to move between breakout rooms to engage with each poster session participant.

The winning posters were presented by undergraduates Hannah Schulz, Lauren Kaija, Trisha Worthington, Chase Guadino, and Emilia Perez of Worcester Polytechnic Institute for their project, "A Study of Sea Level Rise and Designs for Coastal Resiliency in Boston," and by graduate student Bridgette Charlebois of the University of Massachusetts Amherst for her project, "Rain Rain Flush Away: Evaluating Rainwater Catchment First Flush Volumes." The winning posters are included here.

The Student Activities Committee thanks all the student teams for their hard work and enthusiasm. We also extend our gratitude to all the professionals who volunteered their time to judge the competition. As always, the quality of the student posters was impressive, and we highly recommend stopping by the session at the 2022 Annual Conference if you missed it this year.

If your organization would like to support future student poster sessions and the student engineers and scientists who present their work, please reach out to the Student Activities Committee chair for more information about sponsoring this event.



A Study of Sea Level Rise and Designs for Coastal Resiliency in Boston

By Chase Gaudino (clgaudino@wpi.edu), Lauren Kaija (lakaija@wpi.edu), Emilia Perez (eaperez@wpi.edu),
Hannah Schulz (hkschulz@wpi.edu), and Trisha Worthington (tmworthington@wpi.edu)
A WPI Major Qualifying Project, December 2020

Project Goal and Objectives

Goal: To understand how an additional 12" of SLR will impact the residents and businesses in Boston during a 1% annual chance flooding event.

Objectives:

1. Update the current CRB 1% annual chance flooding event map of 36" SLR to reflect a 48" SLR scenario and create a depth grid of the new projections
2. Assess impacts of SLR on property damage, resident relocation costs, and business effects in the new inundation scenario
3. Provide coastal resiliency design options for a vulnerable community at higher risk of inundation with no current planned project

Background

Climate Ready Boston: An initiative created by the City of Boston to prepare for the impacts of climate change and to design climate resiliency projects to protect against those effects.

CRB's Predictions from 2016:

- 9" SLR by 2030
- 21" SLR by 2050
- 36" SLR 2070s or later

Higher Prediction Scenario:

- 48" of SLR 2070s or later

Social Vulnerability Index

The CDC Social Vulnerability Index was used to identify areas of the city where people are most vulnerable to the impacts of climate change. The team focused in on East Boston due to higher SVIs and coastal proximity.

Social Vulnerability Index in Boston, MA

Figure 1. SVI Maps of Boston

Results of 48" of Sea Level Rise

East Boston

Figure 2. East Boston 48" SLR Scenario

Central Boston

Figure 3. Central Boston 48" SLR Scenario

East Boston 14' Contours Flood Depth

Figure 4. Depth Grids of East Boston 48" SLR

The pink in Figures 2 and 3 illustrate new flooding that could possibly occur during a 1% annual chance storm event, with 48" of sea level rise. Depth of flooding in different areas of East Boston is illustrated in the top right in Figure 4. Lidar DEM data was used to assess contour lines during the adjustment of CRB's 36" SLR GIS shapefile.

Results of East Boston Impact Assessment

Structure and Content Loss

Cost Analysis Results

- CRB's estimate: $1.26 billion with 36" SLR ($0.05 less than ours)
- Final adjusted estimate for 48" SLR: $1.59 billion

Resident Relocation

Homes Affected by 48" SLR
(Additional 201 for a total of 2295)

Additional $220,000

Homes Affected by 36" SLR
(2094 Homes)

Commercial Buildings

- 59 Newly Affected Commercial Buildings
- 253 "Water Locked" Commercial Buildings

Flood Protection Design

Figures 5 & 6. Site 1 (above): Wall replacement and extension of rock revetment with native grasses & rock breakwaters

Figures 6 & 7. Site 2 and 3 (right): Deployable flood barriers

Recommendations

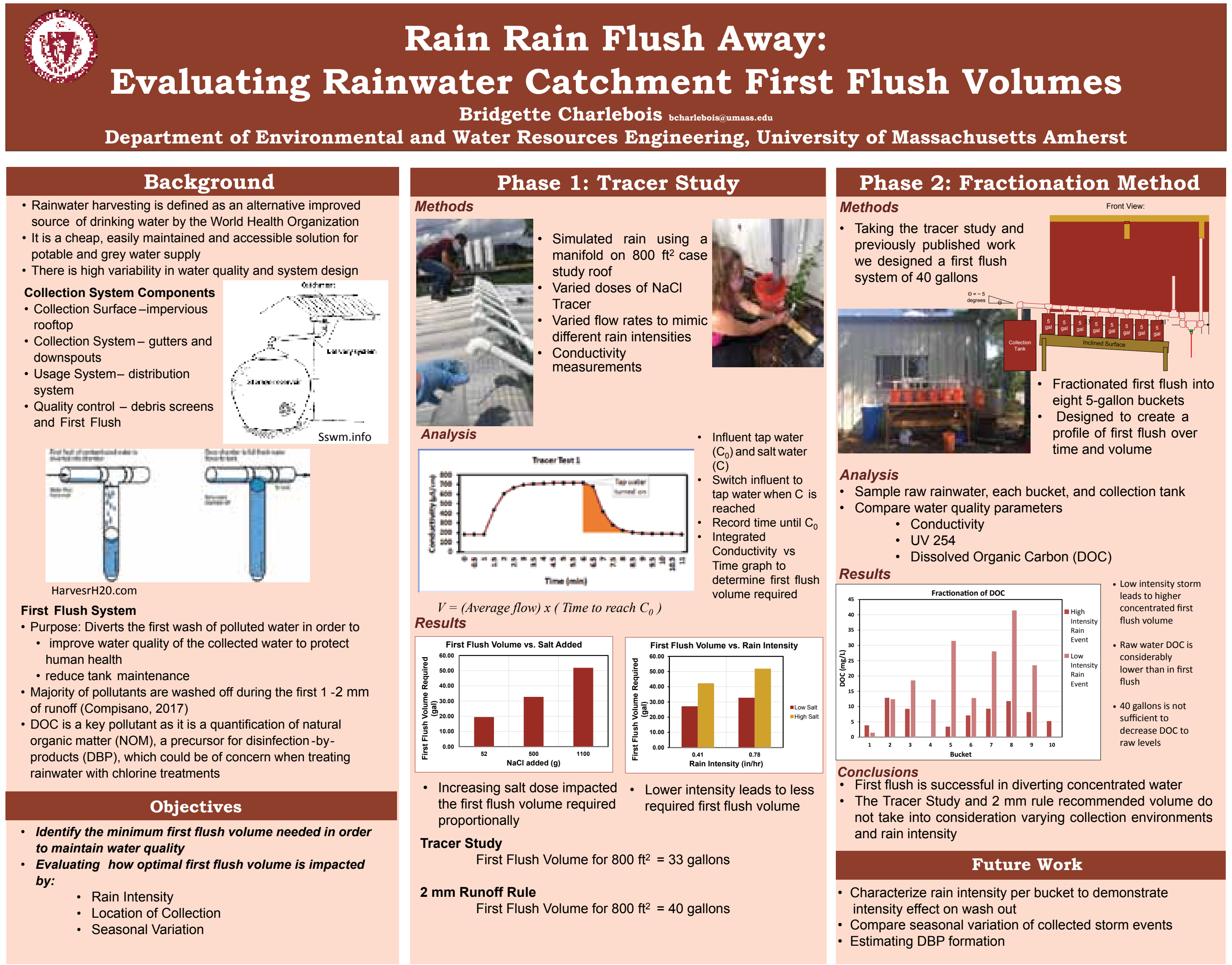
- Replacement of the crumbling floodwall and extension of a rock revetment with native grasses
- Construction of retaining walls for future deployable flood barriers
- Implementation of educational programs and/or signage on climate change, extreme weather events, and rising sea levels

Final Design Recommendations

Figure 8. Site Locations of Flood Protection System along Condor St.

Acknowledgements

Special thanks to Stephanie Harrison, David VanHoven, Professor Albano, Professor LePage, Jeremy DelPrete, and Ben Schattschneider for the guidance and knowledge they provided throughout the duration of this project.



Rain Rain Flush Away:
Evaluating Rainwater Catchment First Flush Volumes

Bridgette Charlebois bcharlebois@umass.edu
Department of Environmental and Water Resources Engineering, University of Massachusetts Amherst

Background

- Rainwater harvesting is defined as an alternative improved source of drinking water by the World Health Organization
- It is a cheap, easily maintained and accessible solution for potable and grey water supply
- There is high variability in water quality and system design

Collection System Components

- Collection Surface – impervious rooftop
- Collection System – gutters and downspouts
- Usage System – distribution system
- Quality control – debris screens and First Flush

Sswm.info

HarvesrH20.com

First Flush System

- Purpose: Diverts the first wash of polluted water in order to
  - improve water quality of the collected water to protect human health
  - reduce tank maintenance
- Majority of pollutants are washed off during the first 1 -2 mm of runoff (Compisano, 2017)
- DOC is a key pollutant as it is a quantification of natural organic matter (NOM), a precursor for disinfection-by-products (DBP), which could be of concern when treating rainwater with chlorine treatments

Objectives

- ***Identify the minimum first flush volume needed in order to maintain water quality***
- ***Evaluating how optimal first flush volume is impacted by:***
  - Rain Intensity
  - Location of Collection
  - Seasonal Variation

Phase 1: Tracer Study

Methods

- Simulated rain using a manifold on 800 ft² case study roof
- Varied doses of NaCl Tracer
- Varied flow rates to mimic different rain intensities
- Conductivity measurements

Analysis

- Influent tap water (C_0) and salt water (C)
- Switch influent to tap water when C is reached
- Record time until C_0
- Integrated Conductivity vs Time graph to determine first flush volume required

$$V = (Average\ flow)\ x\ (\ Time\ to\ reach\ C_0\ )$$

Results

- Increasing salt dose impacted the first flush volume required proportionally
- Lower intensity leads to less required first flush volume

Tracer Study

First Flush Volume for 800 ft² = 33 gallons

2 mm Runoff Rule

First Flush Volume for 800 ft² = 40 gallons

Phase 2: Fractionation Method

Methods

- Taking the tracer study and previously published work we designed a first flush system of 40 gallons
- Fractionated first flush into eight 5-gallon buckets
- Designed to create a profile of first flush over time and volume

Analysis

- Sample raw rainwater, each bucket, and collection tank
- Compare water quality parameters
  - Conductivity
  - UV 254
  - Dissolved Organic Carbon (DOC)

Results

- Low intensity storm leads to higher concentrated first flush volume
- Raw water DOC is considerably lower than in first flush
- 40 gallons is not sufficient to decrease DOC to raw levels

Conclusions

- First flush is successful in diverting concentrated water
- The Tracer Study and 2 mm rule recommended volume do not take into consideration varying collection environments and rain intensity

Future Work

- Characterize rain intensity per bucket to demonstrate intensity effect on wash out
- Compare seasonal variation of collected storm events
- Estimating DBP formation

UNDERGRADUATE WINNERS
Hannah Schulz, Lauren Kaija, Emilia Perez,
Trisha Worthington, and Chase Gaudino
Worcester Polytechnic Institute

GRADUATE STUDENT WINNER
Bridgette Charlebois, University of Massachusetts Amherst

Connecticut State Director Report

by Bill Norton
WNorton@fairfieldct.org

info at ctwpaa.org

Zoom, zoom, zoom with a little Webex and Microsoft Teams thrown in for good measure; just some words reflecting the way we are all meeting these days. The Covid-19 Pandemic has created the need and required our resolve to overcome and prosper using modern technologies to accomplish our goals. The NEWEA family has used these resources for Executive Committee meetings, specialty conferences, and even our Annual Conference. I am not alone in hoping that we can all be together at the Spring Meeting. Connecticut is no different, as we continue to do our business using these formats, and here is my update on our (mostly virtual) activities.

Covid-19 Pandemic

Governor Ned Lamont continues to provide daily press briefings, reassuring the state regarding Covid-19 protocols and statistics, and mapping out a plan to administer the vaccine, while urging the public to take all necessary precautions to prevent the spread of the virus. He has described the completion of phase 1A of the vaccine roll out and the start of phase 1B, which lists wastewater operators as intended recipients. Connecticut Department of Energy and Environmental Protection (CT DEEP) continues to support municipalities by conducting its business, programs, and meetings virtually, by phone, or electronically as statewide most spend no time in their offices. Locally, mayors and first selectpersons are keeping their respective communities aware of the protocols, prevention details, and upcoming vaccine events at this level. In Fairfield, our first selectperson and the fire chief inform the community daily through a website and weekly by press release of current Covid-19 data for the town, county, and state, and globally, while also reinforcing all the Covid-19 risks and recommended safety protocols.

CTWEA

President Ray Weaver and his team of the Connecticut Water Environment Association (CTWEA) have been meeting monthly via conference call over the last year to accomplish CTWEA's business and goals. Achievements include the following:

- CTWEA and the Connecticut Association of Water Pollution Control Authorities (CAWPCA) co-signed and sent a letter to the state legislature successfully encouraging the inclusion of wastewater workers as essential employees to be included in Phase IB of the state's vaccine rollouts.
- CT DEEP has structured a procedure for online certification testing via the Association of Boards of Certification. An additional fee of $112 is required for site and administration costs, above the state's fee of $240. CTWEA is working with the state to reduce these costs.
- CTWEA is also working with CT DEEP to enable an operator to retain his or her license after leaving the field by earning additional training contact hours (TCHs) in the field. Currently, if an operator leaves the field for two years, the license lapses. Another issue being addressed is for an operator to obtain a Class IV operator-in-training (OIT) license. The OIT designation is currently available only for Class I, II, and III levels.
- CT DEEP has moved to virtual inspection of facilities during the pandemic.
- CTWEA held its Annual Managers Forum in December as a virtual event. Our gratitude and appreciation to Jennifer Lichtensteiger and her staff at NEIWPCC for coordinating this event.
- CTWEA and CAWPCA continue to work on a merger. Once consolidated, the new association would be called CTWEA.
- Owing to the Pandemic, our Legislative Day at the state capitol, Annual Trade Show, and fishing outing for 2020 all had to be canceled.

CAWPCA

CAWPCA, led by President Tom Sgroi, held its first virtual workshop to accommodate Covid-19 safety protocols limiting public gatherings. Although many were disappointed we could not meet at the Aqua Turf this fall and network with our favorite colleagues, the virtual workshop was well attended. The workshop was held on two consecutive Fridays in November from 12:30pm to 2:00pm.

The first session, on November 6, featured a CT DEEP update from George Hicks and a technical presentation by Carina Hart of JK Muir on Connecticut energy efficiency programs for wastewater utilities. Brian Armet was presented with a CAWPCA Presidential Excellence award in recognition of his long-term dedication and exemplary service to the water pollution control profession.

The second session, on November 13, included a government affairs update from lobbyist Melissa Biggs, who highlighted the upcoming legislative session and shared insight on how the legislature plans to operate using webcast technology for public hearings. Mike Schrader of Tighe and Bond presented information on how municipalities set sewer user rates, balancing long-term financial planning with affordability and equity among ratepayers. Robbie Marshal of Old Saybrook Water Pollution Control Authority (WPCA) received a Presidential Excellence award.

Both sessions concluded with results of a Covid-19 survey issued though CAWPCA membership and summarized by Ted Donoghue of Litchfield WPCA. Survey results along with video replay of each session can be accessed at cawpca.org.

Progress continues toward an eventual merger of the CAWPCA and CTWEA into one water environment association. We are gradually increasing our collaboration, currently focusing on legislative outreach using our shared lobby firm DePino, Nunez, and Biggs. Merger committees from both organizations meet monthly and are creating other joint wastewater committees to help with issues such as education and workforce development. The cooperative efforts emphasize the benefits of the potential merger.

DEEP MIU and SIU Permitting

Sally Keating of the Hartford Metropolitan District and the General Permit from Miscellaneous Industrial Users Committee have worked closely with the CT DEEP to develop a new plan for this permit, unveiled this past fall. The CT DEEP commissioner has extended the notification and registration process to April 29, 2021. Ms. Keating's and her committee's highlights follow:

- The CT DEEP's General Permit for Discharges from Miscellaneous Industrial Users (MIU GP) was reissued and effective October 31, 2020. At the same time, the Significant Industrial User GP (SIU GP) was also reissued and effective October 31, 2020.
- On December 23, 2020, Commissioner Katie Dykes extended the deadlines for the notification required by the MIU GP and registration required by the SIU GP for past registrants to April 29, 2021. Notifications for the MIU GP will be submitted to the publicly owned treatment works (POTWs) only. POTWs are encouraged to provide information on their websites regarding where the permitted entity should email or send MIU GP notifications. If a wastewater is discharged to a sewer pipe managed by one POTW and the wastewater flows to a treatment plant managed by a second POTW, both POTWs should receive a copy of the notification.
- The general permits, fact sheets, forms, and frequently asked questions are available on CT DEEP's website.

NEWEA and WEF Award Recipients

- CT Operator of the Year—Mark Bukowski, East Windsor Water Pollution Control Facility
- CT Alfred E. Peloquin Award—Gary Zrelak, Greater New Haven Regional WPCA
- Founders Award—Jeanette Brown, Manhattan College
- Arthur SIdney Bedell Award—Dennis Palumbo

Congratulations to Jennifer Kelly Lachmayr for a NEWEA presidency like no other! With the Covid-19 pandemic, nothing was normal or could be expected. However, even given these challenges Ms. Lachmayr led us through these times, meeting all NEWEA goals and moving our organization forward. Great job! Now we have an incoming president who is a past state director and Connecticut Alfred E. Peloquin Award recipient. I know all my fellow Nutmeggers and NEWEA members are proud to welcome in Virgil Lloyd.

Upcoming Events

- Ray Bahr remains optimistic he will soon announce his **CTWEA Ski Day**
- **CTWEA Product Show**, which is normally held in April, is tentatively planned for late summer or early fall
- **CAWPCA Spring Meeting** is expected to be virtual once again
- **CTWEA Sewer Open**—This popular golfing event has always been held on the third Friday in June. With the pandemic, however, for the first time in over 25 years, the tournament was moved. It took place last August, enabling more time to plan with clarity on all the social distancing and safety protocols involved. The Sewer Open is expected to be held on its normal date in June this year, but that plan may change depending on the pandemic. Feel free to reach out to Ray Bahr at Green Mountain Pipe as we get closer to June at ray@greenmountainpipe.com, or check the website ctwpaa.org for updates this spring.

Vermont
State Director Report

by Michael A. Smith
smithm@wseinc.com

I am Michael Smith, the new state director for Vermont and member of the Green Mountain Water Environment Association (GMWEA). I am a team leader and senior wastewater process designer for Weston & Sampson and have worked in Vermont and throughout New York and New England for the past 33 years on municipal and industrial wastewater treatment design and construction projects as well as agricultural bio-energy projects.

Most recently, I worked with craft breweries throughout New England on high-strength wastewater planning and pre-treatment. I have been an active member of GMWEA and NEWEA for more than 20 years, probably most familiar to the Collection Systems and Operations Challenge committees. I am also volunteering on a technical advisory committee with other environmental consultants and members of the Vermont Department of Environmental Conservation (VTDEC) to update Vermont's indirect discharge rules.

I will start my first report by acknowledging my NEWEA predecessor, Chris Robinson, who completed his term as Vermont state director at the 2021 NEWEA Annual Conference. Thanks, Chris for your years of service, and for your assistance with this, my first *Journal* article!

This has been a very unusual year in the industry due to the coronavirus pandemic. GMWEA canceled the spring and fall conferences, and our monthly meetings have been remote. However, the association has remained active under the leadership of President Mike Barsotti and part-time Executive Director Daniel Hecht. A huge thank you to the volunteer committees and board of GMWEA for their dedication and commitment in making GMWEA such a great organization. And thanks also to NEWEA for an outstanding job at adapting to the pandemic and continuing to advocate for our industry. Below is a summary of how the GMWEA handled some of our normal activities during 2020.

The **Vermont Science, Technology, Engineering, and Mathematics Fair** is normally hosted each year by Norwich University, and features exhibits by about 200 middle school and high school students from throughout the state, all of them winners of their schools' project competitions. This event was canceled last year due to the pandemic, but we look forward to attending and judging this event in the future.

GMWEA 2020 Spring Meeting

This was also canceled due to the pandemic. However, our Awards Committee continued its work and bestowed the annual awards to the following deserving individuals:

- Michael J. Garofano Water Operator Excellence Award to Villas Gentes of the Champlain Water District
- Two Wastewater Operator Excellence Awards to Peter Laramie of Fair Haven and Robert Wheeler, Chief Operator of Bellows Falls
- Water Facility Excellence Award to Randolph Water District #1 (Vermont Technical College)
- Wastewater Facility Excellence Award to Newport Wastewater Treatment Facility
- Andrew D. Fish Laboratory Excellence Award to Endyne Labs, Inc.
- Bob Wood Young Professional Award to Cody Grimm, Simon Operation Services
- Stormwater Award to Dave Wheeler, South Burlington
- Elizabeth A. Walker Meritorious Service Award to Liz Royer, Executive Director of Vermont Rural Water Association
- President's Award to Daniel Hecht, Executive Director of GMWEA

GMWEA Fall Trade and Technical Conference

Though the event was canceled due to the pandemic, GMWEA and the Doubletree by Hilton Hotel have agreed to use the $3,000 deposit toward a donation of food to the local food shelf Feeding Chittenden.

VTWARN is an emergency mutual aid system that was set up years ago but has lacked strong long-term organization. Owing to the pandemic, GMWEA, VTDEC, and Vermont Rural Water Association (VRWA) collaborated to update and reactivate the system. With the renewed urgency of these times, VTDEC is now overseeing the program to keep it effective.

NEWEA Award Winners

The following Vermont individuals were recognized with NEWEA awards this year:

- Operator Award winner—Marty Frizzell, chief operator Brighton Water and Wastewater, Piscataqua Environmental Services
- Alfred E. Peloquin Award winner—Margaret Dwyer, water and wastewater senior manager/chief operator, Winhall-Stratton Fire District #1

Congratulations to both winners on this recognition of your years of excellent work!

Operator Exchange

Though this event was canceled due to the pandemic, GMWEA looks forward to attempting to participate in our planned exchange with Massachusetts in 2021.

Regulators Meetings

GMWEA's Government Affairs Committee continued its third year of quarterly stakeholder meetings (this year in virtual mode) with staff from Vermont's Agency of Natural Resources water quality divisions. The meetings allow for sharing of concerns and crucial information, and for brainstorming sessions and potential solutions to problems. They foster a sense of community among people working across sectors in water-related fields while aiming for smarter water policy and more collaborative, effective water quality policy implementation.

GMWEA-sponsored virtual training is underway, having hosted a successful basic wastewater course that started in late January with 25 operators registered.

Thanks to our current GMWEA Board for keeping the association on track and relevant during this difficult year: President Mike Barsotti, First Vice-President Eileen Toomey, Second Vice-President Wayne Elliott, Treasurer Rick Kenney, Secretary Amy Macrellis, Past-President Tom DiPietro, Directors Christine Dougherty, Joe Duncan, Bob Fischer, Brian Ovitt, Ryan Peebles, and Chris Robinson, and Executive Director Daniel Hecht. Thank you all for your leadership and enthusiasm.

UPCOMING EVENTS

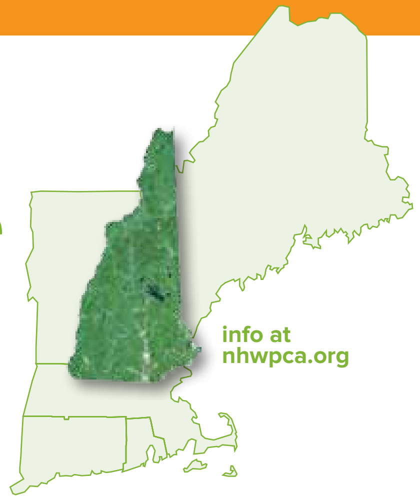
- GMWEA Spring Meeting and Conference is scheduled for May 21, 2021. The event will be a virtual event that will include training, business meeting, and awards.
- The George Dow Golf Tournament, which was not held in 2020 for the first time in 20 years, is scheduled for August at the Cedar Knoll Country Club in Hinesburg. Details will be posted soon.

For further information about GMWEA/NEWEA activities and events, contact Vermont Director Mike Smith (Smitty) at smithm@wseinc.com, or visit gmwea.org.

Measurement unit conversions and (abbreviations) used in the *Journal*

U.S.	International System of Units (SI)	U.S.	International System of Units (SI)
Liquid volume		**Length**	
gallon (gal)	liter (L)	inches (in.)	centimeters (cm)
cubic feet (ft^3)	cubic meters (m^3)	feet (ft)	meters (m)
cubic yards (yd^3)	cubic meters (m^3)	miles (mi)	kilometers (km)
acre-feet (ac ft)	cubic meters (m^3)	**Area**	
Flow		square feet (ft^2) or yards (yd^2)	square meters (m^2)
million gallons per day (mgd)	million liters per day (ML/d)	acre (ac)	hectare (ha)
for larger flows (over 264 mgd)	cubic meters per day (m^3/d)	square miles (mi^2)	square kilometers (km^2)
gallons per minute (gpm)	liters per minute (L/min)	**Weight**	
Power		pounds (lb)	kilograms (kg)
horsepower (hp)	kilowatts (kW)	pounds per day (lb/d)	kilograms per day (kg/d)
British Thermal Units (BTUs)	kilojoules (kJ) / watt-hours (Wh)	ton – aka short ton (tn)	metric ton or tonne (MT)
Velocity		**Pressure**	
feet per second (fps)	meters per second (m/s)	pounds/square inch (psi)	kiloPascals (kPa)
miles per hour (mph)	kilometers per hour (km/h)	Inches water column (in wc)	kiloPascals (kPa)
Gas		**Head**	
cubic feet per minute (ft^3/min)	cubic meters per minute (m^3/min)	feet of head (ft of head)	meters of head (m of head)

New Hampshire State Director Report



by Steve Clifton
sclifton@underwoodengineers.com

This past year was challenging for everyone. The political turmoil, pandemic, and swift changes to work and play kept us all on edge. When history looks back on 2020, it will find an abundance of sacrifice, unselfish help and caring, and pockets of heroes in all corners of society that will ultimately define this era. First responders include our water and sewer workers who kept vital infrastructure functioning without impact as we switched from a social gathering society to one of isolation and remote communications.

To those who lost loved ones, you have my deepest sympathy. To those who had unique changes because of the pandemic, your story should be told. In the context of our profession, what you have had to do to keep the plumbing of our nation functioning deserves to be documented and preserved for future generations that may face similar crisis. Please share your story through the association newsletters and meetings to preserve that unique knowledge only you can provide.

NHWPCA Year-End Summary and Passing of the Guard

As reported throughout the past year, our normal routine was muted by pandemic protocols, government edicts, and general overall concern for public health. Instead of reporting what we did not do because of the pandemic limitations, I choose to put things in a positive light by highlighting the events that were held during 2020.

On March 4, 2020, the New Hampshire Water Pollution Control Association (NHWPCA) held the annual Legislative Breakfast at the Holiday Inn in Concord. Speakers included Sean McDonald, co-host of *New Hampshire Chronicle* and WMUR morning anchor, and Tom O'Donovan, director of New Hampshire Department of Environmental Services (NHDES) Water Division. Attendance was low (20 legislators) as expected due to concerns about the virus working its way from China to the United States.

On August 5, 2020, NHWPCA held the 31st annual golf tournament at Beaver Meadow Golf Course in Concord. This annual event led by Fred McNeill was a welcome relief to the stress of self-isolation affecting the masses. Attendance was high with 85 attendees and 21 teams. All that attended had a great time.

On September 25, 2020, NHWPCA held the annual Trade Fair at the Nashua Radisson Hotel. About 20 vendors (of a normal 60 to 70) attended, tables were spaced at least 20 feet apart, masks were worn, and people maintained a healthy distance from each other. Ray Vermette, NEWEA past president, attended and presented the 2020 NEWEA awards to New Hampshire members.

On December 11, 2020, while the scheduled Winter Meeting and plant tour in Portsmouth was canceled, NHWPCA held its annual Business Meeting by Zoom, capping a year of remote meetings on screen rather than face to face. At the business meeting, the annual election was tallied based on mailed-in ballots, and outgoing President Ken Conaty of Hooksett passed the gavel to Mike Carle of Hampton. Mr. Conaty must be acknowledged for his leadership throughout the year in keeping the association together while operating under lockdown protocols. He led strong support for the newsletter to keep members informed and focused on important events.

The Trade Fair was delayed until the time was right, keeping the association budget above water at a time of decreased membership when revenue could not be generated as normal. We should all thank Mr. Conaty and the 2020 NHWPCA Board of Directors for showing leadership in the face of adversity.

The NHWPCA officers for 2021 are as follows:

- President Mike Carle of Hampton
- Vice President Rob Robinson of Manchester
- Secretary Dave Mercier of Underwood Engineers
- Treasurer Mario Leclerc of Seabrook
- 1st Director Ryan Peebles of Clean Waters, Inc.
- 2nd Director Mike Theriault of Wright Pierce
- 3rd Director Aaron Costa of Keene
- 1st Director at Large Nate Brown of Peterborough
- 2nd Director at Large Peter Conroy of Portsmouth

Great Bay General Permit for Total Nitrogen

After months of extensions and time to prepare the Response to Comments on the January 7, 2020 EPA-issued Draft NPDES Great Bay Total Nitrogen General Permit, EPA issued the Final NPDES Great Bay Total Nitrogen General Permit on November 24, 2020, and the permit became effective on February 1, 2021. Thirteen wastewater treatment facilities (WWTFs) in New Hampshire are affected by this permit. Each community must decide by March 31 whether to opt into the new General Permit or stay with the NPDES individual permit.

The General Permit has the following major components:

- April through October seasonal rolling monthly average lb/d permit limits for total nitrogen based on the seasonal historical average flow from 2015 through 2019, and a Total Nitrogen limit of 8 mg/L for WWTFs with design flows >2 mgd (7.6 ML/d) or the average historical nitrogen concentrations for WWTFs < 2 mgd (7.6 ML/d); Newmarket, Epping, Rollinsford, and Milford with slight variations are in line with this criterion
- Year-round reporting for total nitrogen
- Scientific spatial loading target of 100 kg N ha^{-1} yr^{-1} (rather than a numerical water quality value)
- Voluntary Adaptive Management Framework Submittal by July 31, 2021, with components including an approach to monitoring ambient water quality, Total Nitrogen tracking and accounting methods, an outline/plan for overall source reduction, a process to evaluate permit-related issues including the load-based threshold of 100 kg N ha^{-1} yr^{-1}, and a proposed timeline to complete a TMDL

This has been a defining moment for communities affected to address all aspects of the General Permit.

NEWEA Awards

The NEWEA Annual Conference awards ceremony was not held in January, but we recognize New Hampshire winners of these prestigious awards and anticipate upcoming notices of award ceremonies. For now, congratulations to the following:

- John Esler of Clarifiers, Inc. of Enfield, the E. Sherman Chase Award
- Ray Gordon of the Winnipesaukee River Basin Program in Franklin, the Alfred E. Peloquin Award
- Ray McNeil of Rollinsford, NEWEA New Hampshire Operator Award

Finally, we congratulate Jim Pouliot of Epping for receiving the EPA 2020 New Hampshire Operator of the Year.

Upcoming NHWPCA Events

The NHWPCA Board is in virtual mode, with the normal calendar of in-person gatherings uncertain. For now, the board intends the Trade Fair and the Winter Meeting to be a priority this year, but all events depend on the safety measures in place at the time. Be sure to check nhwpca.org for current dates of all upcoming events.

If you are not already a member of NEWEA or NHWPCA, please consider joining to enhance your growth as a professional in the industry. As the NEWEA New Hampshire state director, I can be reached at sclifton@underwoodengineers.com or 603-436-6192. Please contact me with any NEWEA questions. As I enter my third and final year as state director, I continue to look for ways to better serve the NHWPCA and NEWEA community.

Maine State Director Report

info at mewea.org

by Jeffrey McBurnie
Jeff.McBurnie@casella.com

"Pandemic" is an anagram for "camped in." Coincidence? Yeah, sure. Ironic? Absolutely! At one time or another in the past year, each of us has camped in our individual bubbles, longing for the days of personal contact and freedom to travel. It's not a surprise; we're social animals and we truly need each other. Ideally the resiliency that we have worked on and continually strive for in our profession has seeped into our personal lives, helping us cope with adversity in all facets of our lives. Nothing rings truer than "Stay positive, test negative."

Nothing can support a positive attitude more than a return to the routines that typically consume our days, especially those that so directly protect and enhance the environment to which we have committed ourselves. The Maine Water Environment Association (MEWEA) has risen to the challenge and has returned to meet the goals expressed in our mission statement: operator training, public outreach, and legislative advocacy. The tasks are mostly familiar, but the forums where they are undertaken and the mechanisms by which they are achieved have taken us to a brave, new world. Not that that world hasn't been there; we have only now come to better understand and embrace it.

> *MEWEA has returned to meet the goals expressed in our mission statement: operator training, public outreach, and legislative advocacy*

NEWEA Conference

In January, the annual pilgrimage to Boston for the NEWEA Annual Conference and Trade Show was replaced by a virtual event spanning six days over two weeks (January 26–28, February 2–4). Many excellent training sessions were offered and the virtual exhibit hall, although no match for the in-person event, was exceptional. The Awards Luncheon, the premier closing event of the Annual Conference, was not held due to pandemic concerns. Award winners will be recognized on various platforms throughout the year. Award winners from Maine included Clayton "Mac" Richardson (Peloquin); Scot Lausier (Operator of the Year), Shannon Eyler (Operator Safety), Hawk Ridge Compost Facility (Biosolids Management), and Amarachukwu Ifeji (Stockholm Junior Water Prize Maine Finalist).

Collaborative Training with Maine Water Utilities Association

MEWEA provided three days of morning training sessions (February 2–4) in collaboration with the Maine Water Utilities Association (MWUA) at its Annual Conference. This year's conference was affected but not hobbled by the Covid-19 situation. The conference and trade show were successfully held on the Whova virtual meeting platform. With hundreds of attendees and dozens of vendors, the conference provided quality technical content and virtual networking opportunities. MWUA and MEWEA provided 27 wastewater operator training contact hours (seven sponsored by MEWEA) on a range of topics, including UV disinfection, water and wastewater math, line installation, inflow and infiltration, PFAS, pipe inspection, thermal drying, phosphorus loading, healthy watersheds, industrial pretreatment programs, asset management, efficiency strategies, pressure monitoring and hydraulics, wastewater utility resiliency during the pandemic, and PFAS developments in residuals and biosolids management. The sessions were well attended. Several sessions were presented and/or moderated by MEWEA members.

Legislative Breakfast

MEWEA and MWUA held their annual Legislative Breakfast (renamed Legislative Information Session) virtually, on February 2, with the MWUA Annual Conference and Trade Show. Sponsors were MEWEA, MWUA, NEWEA, and NEIWPCC. The theme for this year's meeting was "utility efficiency and cost-effectiveness." Keynote speakers included representatives from the American Society of Civil Engineers, Portland Water District, Maine Department of Environmental…

MAINE *continued on page 67*

Massachusetts State Director Report

info at MAWEA.org

by Adam Yanulis
FAYanulis@tigheBond.com

The Massachusetts clean water community and members of the Massachusetts Water Environment Association (MAWEA) have continued to serve their customers in the difficult times of the Covid-19 pandemic. Utility managers and staff have been managing staggered schedules at wastewater treatment plants while continuing to maintain collection systems and pump stations. Massachusetts Department of Environmental Protection has been steadily supportive of utility managers and operators; Commissioner Martin Suuberg and Assistant Commissioner for Water Resources Kathleen Baskin have hosted monthly virtual, interactive meetings along with EPA Region 1 leadership. Issues related to Covid-19, PFAS, combined sewer overflow (CSO) and other reporting, staffing, training, personal protective equipment (PPE) distribution, and emergency response have been common topics presented and discussed during these meetings.

2021 NEWEA Annual Conference

MAWEA, now in the second year with its updated name, attended and participated in several of the recent virtual sessions of the 2021 NEWEA Annual Conference. While the regular awards luncheon and ceremony did not take place, NEWEA plans to present the following awards at future 2021 local events:

- Operator Award for Massachusetts
  Carl Thurston, City of Chicopee
- Alfred E. Peloquin Award for Massachusetts
  Keith Bourassa, City of Pittsfield
- Paul Keough Public Relations Award
  Bonnie Combs, Blackstone National Heritage Corridor
- Committee Service Award
  Katelyn Biedron, CDM Smith (posthumous)
- Elizabeth Cutone Executive Leadership Award
  John Sullivan, Boston Water and Sewer Commission
- Energy Management Award
  Greater Lawrence Sanitary District
- James J. Courchaine Collection Systems Award
  Don Kennedy, NEIWPCC
- Youth Educator Award
  Kerry Reed, City of Framingham
- Young Professional Award
  Kate Roosa, Kleinfelder
- WEF William D. Hatfield Award
  Jeff Gamelli, City of Westfield

Congratulations to all the award winners!

Massachusetts developed an Interagency PFAS Task Force

The House Ways and Means Committee of the commonwealth has developed an interagency PFAS task force to address the emerging crisis of contamination, permit limits, and treatment options. The task force comprises representatives of several state agencies as well as other interest groups and has met numerous times in 2020 with continuing plans for 2021 meetings. PFAS in biosolids continues to raise issues with land application and other disposal strategies in Massachusetts. The task force continues to discuss and prioritize the many issues facing the clean water community in Massachusetts.

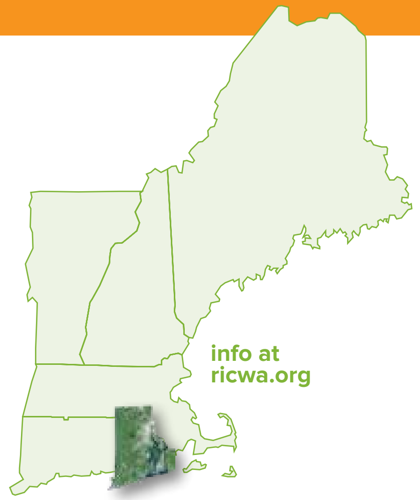
Events

- MAWEA held its spring quarterly meeting on March 18 on a virtual platform with the gracious assistance of NEIWPCC. The main topic of the well-attended meeting was PFAS and its far-reaching effects on wastewater and biosolids treatment and handling.
- MAWEA plans to hold its annual Golf Tournament on June 16 at the Heritage Country Club in Charlton. Mark your calendars and register your team or yourself at MAWEA.org.

Rhode Island State Director Report

by Eddie Davies

edavies@quonset.com



As newly-elected state director, I would first like to thank my predecessor, Scott Goodinson, for his hard work and dedication to Rhode Island Clean Water Association (RICWA) and NEWEA. No matter how big the crowd, a person like Mr. Goodinson always stands out! He has represented our associations very well over the past three years, and I can only hope to match the success he has had and his commitment to our amazing industry.

DEM Announces Grants to Help Communities Confront Climate Change

Rhode Island Department of Environmental Management (DEM) and the Rhode Island Infrastructure Bank (RIIB) awarded $4.7 million in matching grants to 15 municipalities for wastewater treatment facility resilience projects. The grants will fund 18 projects and $10.5 million of construction across the state to protect publicly owned wastewater treatment facilities from storm surge, winds, and other natural hazards expected to increase in frequency and severity. Funding was provided through the 2018 green economy and clean water bond, which Rhode Island voters approved by almost 80 percent.

Statewide, 19 wastewater treatment facilities treat some 120 mgd (450 ML/d) of sewage in Rhode Island. These highly technical and costly systems, which treat and remove pollutants from wastewater, protect our state's waters—especially important for public health, recreation, and our economy. Designed to take advantage of gravity, many wastewater facilities and associated pump stations risk inundation due to their location at low elevations, often in riverine or coastal floodplains.

NEWEA Annual Conference

Rhode Island's clean water professionals were well represented at this year's virtual NEWEA Annual Conference as vendors, committee chair, state director, state legislators, and attendees. Several RICWA members participated in the Executive Committee Meeting, Operations Challenge Committee meeting, Government Affairs New England state roundtable, and amazing technical sessions and important discussion forums.

Award Winners

The board would like to congratulate the following RICWA members on receiving awards:

- Peter Connell for joining the WEF Quarter Century Operators Club.

NEWEA awards

- Jose DaSilva—NEWEA Operator Award
- Stephen Buckley—Alfred E. Peloquin Award
- Nora Lough—Clair N. Sawyer Award

RICWA awards

- Kevin Wunschel—Robert J. Markelewicz Award
- Paul Desrosiers—Carmine J. Goneconte Operator of the Year
- Joyce Smith-Corrente—Facility Support Excellence Award

Operator Training and Development

In 2020, RICWA continued to provide high-level continuing education for operators, while offering state approved training contact hours to Connecticut, Massachusetts, and Rhode Island for two of the three virtual training classes below:

"Introduction to the Bioreactor in a Wastewater Treatment Facility"—Instructor Nora Lough (Clean Water Training & Solutions)

"Practical Methods for Operation of Analytical Measurements in a Wastewater & Drinking Water Facility"—Instructors Bob Osnoe and Tim Larsen (Pond Technical) and Nora Lough (Clean Water Training & Solutions)

"Wastewater Operator Grade 1 Exam Prep Review"— Instructor Eddie Davies (Quonset Development Corporation)

Please visit ricwa.org for upcoming training opportunities.

2020 RICWA Scholarship Recipients

RICWA provides several scholarships annually to college students sponsored by our members. Scholarships range from $500 to $1,000 depending on the number and quality of applications. Congratulations to our 2020 Scholarship recipients: (l to r) Camille Drury, Alexander Iannuzzi, Benjamin Iannuzzi, and Kevin Gardner.

New Board Members

RICWA held its first monthly meeting of 2021 on January 12 to develop committees, discuss the events calendar, and welcome its newest board members. The 2021 board members are as follows:

- President, Peter Connell (Inland Waters)
- Past President, Scott Goodinson (Town of Narragansett)
- Vice President, Nora Lough (Narragansett Bay Commission)
- Treasurer, Jeff Chapdelaine (West Warwick WPCF)
- Secretary, Kim Sandbach (Narragansett Bay Commission)

Executive Board:

- Mike Bedard (Warwick Sewer Authority)
- Vinnie Russo (West Warwick WPCF)
- Dana DiScullio (Warwick Sewer Authority)
- Steve Buckley (Fusion Environmental Services)
- Directors of Vendor/Consultant Coordination, Kelly Bailey (United Rentals, Fluid Solutions), and Chris Campo (Seacoast Supply)
- RI Board of Certifications, Paul Desrosiers (Narragansett Bay Commission)
- NEWEA State Director, Eddie Davies (Quonset Development Corporation)

Congratulations to all!

Upcoming Events

- Clean Water Legislative Luncheon (March)
- Annual Golf Classic (June)
- Annual Clambake & Exhibition (September)
- Annual Awards banquet (October)
- Annual Holiday Party, Food Drive & Elections (December)

Please check ricwa.org or our Facebook page for all association news and full event listings.

MAINE *continued from page 64*

...Protection (ME DEP), and Maine Center for Disease Control and Prevention (CDC) drinking water program. The number of legislators that signed up in advance to participate in the forum increased significantly. The only downside of the online presentation was it lacked the smell of bacon wafting through the room. Someone needs to get to work on Smell-evision!

Ongoing and Upcoming

- **MEWEA Government Affairs Committee**
  The Government Affairs Committee (GAC) is tracking and testifying on several bills being discussed in the Maine Legislature. Like many activities in which MEWEA participates, this is a fully virtual engagement, with no in-person opportunities at the state capitol. The GAC has been monitoring a broad spectrum of legislation including PFAS source reduction, remote participation in public proceedings, PFAS standards for drinking water, Superfund site cleanup, and infrastructure improvement funding. The committee has also been working with the ME DEP to facilitate science-based actions on both nutrient criteria and response to PFAS contamination.
- **MEWEA Spring Conference (April 8–9)**
  Because of the continuing concern regarding Covid-19, this event will be conducted virtually.
- **Washington, D.C. Fly-In (April 26–27)**
  MEWEA is looking forward to virtual participation in the WEF/NACWA National Water Policy Fly-In. Having learned by trial and error in last year's online event, MEWEA is anxious to engage with its national delegation. While in the planning stages, we anticipate having many of the same talking points (sustainable infrastructure funding, workforce development, PFAS) as before, but we will work more directly with our senators' and representatives' environmental policy staffs. We also plan to have a more structured and frequent engagement with them.

2021 Annual Conference & Exhibit Proceedings

VIRTUAL • January 26 – 28, February 2 – 4, 2021

Prior to the commencement of the 91st Annual NEWEA Conference, the Executive Committee and all chairs gathered for the Annual Conference meeting via virtual meeting platform on Wednesday, January 20, 2021. More than 700 attended the four-day Annual Conference virtual event, which featured over 50 exhibitors and 16 technical sessions.

The Annual Business Meeting was held on Wednesday, January 20. Nominating Committee Chair Jim Barsanti presented the slate of officers for election in 2021 as follows:

- Vice President – Robert Fischer
- Deputy Treasurer – David Van Hoven
- Council Director (Outreach) – Colin O’Brien
- Council Director (Communications) – Deborah Mahoney
- WEF Delegate – Raymond A. Vermette, Jr.
- Vermont Director – Michael Smith
- Rhode Island Director – Edward Davies

In accordance with the provisions of Article 9.3.2 of the NEWEA Constitution & Bylaws, these Officers have advanced to the following positions:

- President – Virgil J. Lloyd
- President-Elect – Frederick J. McNeill
- Past President – Jennifer Kelly Lachmayr

The remaining incumbents are fulfilling unexpired terms:

- Treasurer – Clayton “Mac” Richardson (3rd year)
- WEF Delegate – Susan Guswa (through WEFTEC 2021)
- WEF Delegate – James R. Barsanti (through WEFTEC 2022)
- WEF Delegate – Peter B. Garvey (through WEFTEC 2023)
- Council Director (Meeting Management) – Amy Anderson George (3rd year)
- Council Director (Treatment System Operations & Management) – Philip E. Forzley (3rd year)
- Council Director (Collection Systems/Water Resources) – Vonnie Reis (2nd year)
- Council Director (Innovation) – Dr. Marianne Langridge (2nd year)
- New Hampshire Director – W. Steven Clifton (3rd year)
- Maine Director – Jeffrey C. McBurnie (3rd year)
- Connecticut Director – William C. Norton (2nd year)
- Massachusetts Director – F. Adam Yanulis (2nd year)

All nominees have indicated their willingness to serve. Respectfully Submitted on January 20, 2021, by the NEWEA Nominating Committee: Jim Barsanti (Chair), Janine Burke-Wells, Ray Vermette, Jeff McBurnie, and William Norton.

16 Technical Sessions

Session 1
Collection Systems: Overcoming Operational Challenges: The Future Depends on What You Do Today

Moderators:
- Kara Johnston, CDM Smith
- Tom Loto, AECOM

Wastewater Surveillance for COVID-19 Disease in Detroit, MI
- Dr. Anna Mehrotra, CDM Smith
- Brijen Miyani, Michigan State University
- John Norton, Jr., Great Lakes Water Authority, MI
- Irene Xagoraraki, Michigan State University

Developing an Early Warning Sensor for Chemical Anomalies in Wastewater Collection Systems
- Alfred Navato, Northeastern University
- Ken Pousland, Upper Blackstone Clean Water, MA
- Dr. Edris Taher, Upper Blackstone Clean Water, MA
- Amy Mueller, Northeastern University

When an Existing Force Main Becomes a Cascading Waterfall
- John Potts, Weston & Sampson
- Michael Vosnakis, Town of Chelmsford, MA
- Gary Persechetti, Town of Chelmsford, MA
- Stephen Jahnle, Town of Chelmsford, MA

What Came First? The Pump Station or the Shopping Plaza? Major Sewer Pump Station Replacement in Fall River
- Jennica Srey, Wright-Pierce
- Paul Ferland, City of Fall River, MA
- Edward Whatley, Wright-Pierce

Session 2
Contaminants of Emerging Concern: Pandemic, PFAS and Plastics…oh my!

Moderators:
- W. Camilla Kuo-Dahab, University of Massachusetts, Amherst
- John Bergendahl, Worcester Polytechnic Institute

Influence of Sludge Management on Per- and Polyfluoroalkyl Substances (PFAS) Within and After Treatment
- Sydney Adams, University of New Hampshire
- Paula Mouser, University of New Hampshire
- James Malley, University of New Hampshire

Aclarity—Electrochemical Contaminant Destruction
- Julie Bliss Mullen, Aclarity

Spatial and Temporal Distribution of COVID-19 Biomarkers in NH Wastewater Treatment Facilities
- Dr. Fabrizio Colosimo, University of New Hampshire
- Mina Aghababaei, University of New Hampshire
- Stephen Jones, University of New Hampshire
- Paula Mouser, University of New Hampshire

Microplastics—from Sinks to Oceans, and the Water in between
- Teigan Gulliver, HDR

Session 3
Sustainability: Technologies for Sustainable Nutrient and Biosolids Management

Moderators:
- Lenna Quackenbush, GHD
- Courtney Eaton, Kleinfelder

Small Community Solutions—Packed Bed Filter Achieves Stable Nutrient Reduction
- Dennis Hallahan, Infiltrator Water Technologies

Membrane Aerated Biofilm Reactor (MABR) Technology Offers Resiliency and Sustainability to Nitrogen Removal Challenges
- Dr. Amit Kaldate, Suez

Achieving Ultra-Low Phosphorus and Metals Removal at Burrillville, RI
- Dr. Damian Kruk, Nexom

Stop Hauling Water! RMI Launches Shincci-USA Dryer Projects in New England
- Charley Hanson, Resource Management, Inc.
- April Sargent, Resource Management, Inc.

Session 4
Utility Management: What a Year!

Moderators:
- Gary Zrelak, Greater New Haven WPCA, CT
- Kevin Garvey, Wright-Pierce

Resiliency Planning—More Important than Ever
- Roger Null, HDR

Impacts of the COVID-19 Quarantine on the Water & Energy Sector
- Chelsea Conlon, JKMuir
- Megan Whitesell, JK Muir

Our New World—Digital Solutions That Effectively Optimize Your Utility
- Michael Karl, Brown and Caldwell

Technology for 2021 and Beyond
- Michael Karl, Brown and Caldwell

Session 5
Asset Management: Getting the Most Out of Your Asset Management Dollars

Moderators:
- Teresa Demers, Woodard & Curran
- Daniel Roop, Tighe & Bond

Asset Management Planning for Wastewater Systems—A Case Study in Gardner, MA
- James Hoyt, Tata and Howard
- Steven Landry, Tata and Howard

Using Asset Management Decision Trees for Sewer Rehabilitation to Mitigate CSO Events in Haverhill, MA
- Eliza Morrison, Wright-Pierce
- Matthew Corbin, Wright-Pierce

System-Wide Pump Station Assessment for Effective Prioritization and CIP Development in Newton, MA
- Nick Stevens, Brown and Caldwell
- Adrian D’Orlando, Brown and Caldwell

Milwaukee Metropolitan Sewerage District’s Asset Management Journey
- Jeff Stillman, Black & Veatch
- Greg Hottinger, Milwaukee MSD, WI
- Paul Boersma, Black & Veatch

Session 6
Plant Operations: Nutrient Removal

Moderators:
- John Adie, NHDES
- Nick Tooker, University of Massachusetts, Amherst

Optimizing Nitrogen Removal Performance from Diurnal Influent Nitrogen Loading Pattern: Operator’s First Experiences Using a Grant Funded Instrumentation Installation to Make Process Control Decisions
- Stephanie Alimena, Kleinfelder
- Matt Lapointe, Suez
- Bill Fuqua, Springfield Water and Sewer Commission, MA

The Data Management Plan Puzzle—Putting the Pieces Together
- Dr. Edris Taher, Upper Blackstone Clean Water, MA
- Karla H. Sangrey, Upper Blackstone Clean Water, MA
- Timothy Loftus, Upper Blackstone Clean Water, MA
- Mark Johnson, Upper Blackstone Clean Water, MA

Utilizing a Combination of Proven and Innovative Technologies to Achieve Stringent Nutrient Limits
- Amine Hanafi, Woodard & Curran
- Paul Dombrowski, Woodard & Curran
- Jennifer Leister, Upper Montgomery Joint Authority, PA
- Ken Kohlbrenner, Woodard & Curran

Piloting a Pre-Anoxic Fixed Film Process for Nitrogen Removal at the Poquonock WPCF
- Jeff Reade, AECOM
- Dennis Setzko, AECOM
- Carl Veilleux, Metropolitan District Commission, CT

Session 7
Small Community: Effective Wastewater Considerations and Solutions for Small Communities in New England

Moderators:
- Mary Danielson, Tighe & Bond
- Dan Ottenheimer, Oakson

Electrochemical Systems for Nitrogen Treatment in Septic Systems
- Quynh-May Dao, Aclarity

Northern Exposure: North Conway Septage Receiving and Dewatering Upgrades
- Paige Howard, Wright-Pierce
- Michael Curry, Wright-Pierce

What’s That Pipe Worth? Calculating Economic Return on Sewer Investment
- Jay Sheehan, Woodard & Curran

Partnering in Design to Optimize Nitrogen Removal to the Limit of Technology (and Beyond)
- Marc Drainville, GHD
- Richard Peter, Weston & Sampson

Session 8
Government Affairs: New England State Regulators Roundtable

Moderators:
- Scott Firmin, Portland Water District, ME
- F. Adam Yanulis, Tighe and Bond

The pandemic has certainly affected utilities and regulators. While significant resources are still dedicated towards navigating COVID-19, the regulatory process continues. This session shared common themes across our New England States and highlighted developing items in others.

Panelists:
- Connecticut: Rowland Deny, Supervising Environmental Analyst, CT DEEP
- Massachusetts: Kathleen Baskin, Assistant Commissioner, Mass DEP Bureau of Water Resources
- Maine: Gregg Wood, Director, Division of Water Quality Management, ME DEP
- New Hampshire: Thomas O’Donovan, Water Division Director, NH DES
- Rhode Island: Angelo Liberti, Administrator, Surface Water Protection, RI DEM
- Vermont: Amy Policy, Wastewater Program Director, VT DEC

Session 9
Stormwater: Municipalities in it for the Long Haul

Moderators:
- Angela Blanchette, Town of Scarborough, ME
- Kathryn Edwards, Arcadis

Ghosts of Drainage Systems Past—Restoring the Cress Brook Drainage System in Fall River
- Andrew Smith, Wright-Pierce
- Paul Ferland, City of Fall River, MA
- Edward Whatley, Wright-Pierce

Falling Back In Love with Grey Infrastructure—A New England Community's Proactive Approach to Managing Stormwater Infrastructure
- Zach Henderson, Woodard & Curran

Reinvesting in History and Place to Build Resiliency and Community in Quincy, MA
- Joseph Kirby, Woodard & Curran
- Daniel Windsor, Woodard & Curran

Inside-Out—Comprehensive Stormwater Mitigation and Lake Sediment Phosphorus Inactivation Reduce Harmful Algal Blooms
- Maria Rose, Newton, MA Public Works Department
- Dr. Ken Wagner, Water Resource Services
- Carly Quinn, Woodard & Curran

Session 10
Watershed Management: From Planning to Implementation

Moderators:
- Sara Greenberg, GHD
- Steve Wolosoff, CDM Smith

Estimating Nitrogen Loading from Onsite Wastewater Treatment Systems in Coastal Connecticut
- Constantine Karos, CDM Smith
- Zach Eichenwald, CDM Smith
- Mary Anne Taylor, CDM Smith
- Kelly Streich, CT DEEP

People, Process, and Performance—A Tailored Approach to Integrated Water Resources Planning in Portland
- Laura Nolan, Kleinfelder
- Nancy Gallinaro, City of Portland, ME
- Daniel Bisson, Tighe & Bond
- Stephanie Alimena, Kleinfelder

Setting Site-Specific Aquatic Life Use Targets in Watersheds and Estuaries—An Effective Alternative to Numeric Nutrient Criteria
- Paul Stacey, Footprints in The Water

Keeping Downtown Above Water—Urban Flood Control Strategies in Salem, Mass.
- David White, Woodard & Curran
- David Knowlton, City of Salem, MA

Session 11
Industrial Wastewater: Innovative Techniques for Treating Industrial Wastewater

Moderators:
- Sarah White, Unifirst Corporation
- Russell Parkman, Ramboll

Treatment of Wastewater from Steel Industry Using Various Types of Natural and Chemical Coagulants
- Mina Aghababaei, University of New Hampshire
- Sayed Hossein Hashemi, Shahid Beheshti University
- Naghmeh Mobarghaee, Shahid Beheshti University
- Reza Deihimfard, Shahid Beheshti University
- Tahereh Ebrahimi, Shahid Beheshti University

Treatment of Selected Pharmaceutical Drugs in a Batch Aerobic Suspended Bioreactor
- Dr. Mohamed Hamoda, Kuwait University

Temporary Treatment Facility Improves Long-term ROI for Food Manufacturer
- Joshua Jondro, Woodard & Curran

Industrial and Aviation Contamination—Looking Upstream to Prevent PFAS from Impacting Municipal Wastewater
- Patrick McKeown, ECT2

Session 12
Water Reuse: Discussion Forum

Moderators:
- David Moering, Woodard & Curran
- Anastasia Rudenko, GHD

Effective Online Microbial Monitoring for Onsite Water Reuse
- Sheng Chu, Natural Systems Utilities
- Zach Gallagher, Natural Systems Utilities
- Derek Dunn, LuminUltra Technologies
- Jonathan Clarke, LuminUltra Technologies

Well, Well—Securing Future Disposal Capacity for the West Island WWTF
- Meredith Zona, Stantec
- Linda Schick, Town of Fairhaven, MA
- Rene Robillard, Town of Fairhaven, MA
- David B. Hill, Stantec
- Richard Learned, Stantec

Session 13
CSO/Wet Weather Issues: Rise of the Machines and the Atlantic—Computer Modeling and Sea Level Rise

Moderators:
- Steve Perdios, Dewberry
- Mike Armes, ADS Environmental Services

Lights, Camera, Action! Integrating Video with Computer Model and Flow Meters to Validate and Enhance Realtime CSO Reporting Practices
- Ana Fernandes, Stantec
- Josh Schimmel, Springfield Water and Sewer Commission, MA
- Bill Fuqua, Springfield Water and Sewer Commission, MA
- Matthew Travers, Stantec

Operational Knowledge-Sharing Using 3D Depictions of Sewer Structures in Boston, MA
- Adam Horst, Boston Water and Sewer Commission, MA
- Jonnas Jacques, Kleinfelder

SWMMing with Updates: Preparing Bridgeport's Hydraulic Model for Facilities Planning
- Laurie Locke, CDM Smith
- Mitchell Heineman, CDM Smith
- Lauren McBennet Mappa, Water Pollution Control Authority of Bridgeport, CT

Adapting to the Challenges of Climate Change and Precipitation on Wastewater Infrastructure—A Wareham, MA WPCF Case Study
- Lenna Quackenbush, GHD
- Anastasia Rudenko, GHD

Session 14
Energy: Optimizing Energy Use in Wastewater Treatment

Moderators:
- Sharon Nall, NHDES
- Megan Whitesell, JK Muir

Energy Master Planning for Cost-effective Energy Management
- Dr. Tracy Chouinard, Brown and Caldwell
- Jordan Damerel, Fairfield Suisun Sewer District, CT
- Alexis Valenti, Fairfield Suisun Sewer District, CT
- Adam Ross, Brown and Caldwell

Is Ammonia-Based Aeration Control Worth the Effort?
- Susan Guswa, Woodard & Curran
- Jeff Gamelli, City of Westfield, MA
- Julia Beni, Woodard & Curran

Town of Exeter, NH WWTF Upgrade Including Cost-effective Mixing for BNR and Sludge Holding Tanks
- Tyler Kunz, EnviroMix
- Matt Berube, Town of Exeter, NH

Low and No Cost Operational Measures for Energy and Cost Savings
- Jen Muir, JKMuir

Session 15
Residuals: Residuals Handling

Moderators:
- Natalie Sierra, Brown and Caldwell
- Justin Motta, Stantec

Thermal Oxidation of Biosolids Provides a Pathway for Maximum Phosphorous Recovery—The German Approach
- Webster Hoener, Black & Veatch
- Dr. Christian Kabbe, Easy Mining

Treatment of Side-Stream Centrate at Pierce County & Bay Park WWTP Using Anammox Technology
- Chandler Johnson, World Water Works

Diversity, Equity, and Inclusion Forum Panelists: (l to r) OJ McFoy, Nikita Lingenfelter, Stephen Sanders (bottom row) Ifetayo Venner, Rachel Gilbert

Emerging Contaminants in a Circular Economy—How Biosolids Programs Have Been Disrupted by PFAS
- Eric Spargimino, CDM Smith
- Maddison Ledoux, CDM Smith
- Sarah Jakositz, CDM Smith

The Birth of a New Regional Biosolids Handling Facility
- Dr. Eric Staunton, CDM Smith
- Angelo Gaudio, Albany County Water Purification District, NY
- Dan Rourke, Saratoga County Sewer District, NY
- Robert Ostapczuk, Arcadis

Session 16
Stormwater: 2020 Stormy Awards

Moderators:
- Kerry Reed, Town of Framingham
- Zach Henderson, Woodard & Curran

City of Revere—Bringing Stormwater Education In and Out of the Classroom
- Don Ciaramella, City of Revere, MA
- Meg Tabacsko, MWRA, MA
- Danielle DiRuzza, MWRA, MA

City of Portland—India Street Green Roof Incentive
- Caitlin Camron, City of Portland, ME

Town of Lexington: Enabling Contractors to use Municipal GIS
- John Livsey, Town of Lexington, MA
- Kevin Flanders, PeopleGIS

Roundtable Discussion with Award Winners

FORUMS
Stormwater Forum

Four Years of MS4 Assistance from MassDEP
- Dr. Laura Schifman, MassDEP

"Think Blue"
- Kerry Reed, City of Framingham, MA

Panelists:
- Peter Carney on the Long Creek Watershed District
- Dr. Laura Schifman, MassDEP
- Kerry Reed, City of Framingham, MA

Diversity, Equity, and Inclusion Forum: Analyzing Racial Inequalities in the Water and Wastewater Industry

As our nation grapples with systemic racism against Black Americans, we must examine the programs, structures (e.g., academic, workplace, community, etc.), and policies of the water and sanitation industry to determine improvements that can be made for racial equality. This panel discussion fostered a thoughtful dialogue around this topic, as well as identified steps we can take in each of our respective workplaces to ensure that we are equitably serving our communities and expanding the diversity of our industry.

Moderator
- Oluwole A. (OJ) McFoy, Buffalo Sewer Authority

Panelists
- Nikita Lingenfelter, Nevada Division of Environmental Protection
- Ifetayo Venner, Arcadis
- Stephen Sanders, Morrisville State College, NY
- Rachel Gilbert, Woodard & Curran

Women in Water Forum: Commemorating the 100th Anniversary of the 19th Amendment

This moderated discussion highlighted the progress in the 100 years since passing the 19th amendment, as well as the barriers to equitable access to voting that persisted after the amendment passed, and the steps that must be taken to support women in the water industry and foster greater diversity in water industry leadership.

Moderator
- Fredie Kay, Suffrage100MA

Panelists
- Phyllis Arnold Rand, Greater Augusta Utility District
- Liz Levin, Normandeau Associates
- Elisa Speranza, Seventh Ward Strategies, LLC
- Megan Yoo Schneider, Seven Management and Consulting, Inc., Municipal Water District of Orange County

STUDENT POSTERS

The Biodegradation of Pharmaceuticals and Personal Care Products in Secondary Wastewater Treatment
- Carmela Antonellis, Paula J. Mouser
  University of New Hampshire

Rain Rain Flush Away: Evaluating Rainwater Catchment First Flush Volumes
- Bridgette Charlebois
  University of Massachusetts, Amherst

Elucidating the Potential of Waste Management Systems to Reduce Greenhouse Gas Emissions in Vermont
- Kennedy Brown, University of Vermont

UMass Amherst: Kenya Project
- Alexandra Shea, Chloe Smith, Shane Hancox
  University of Massachusetts, Amherst

Microplastics: Biodegradation, Community, and Engagement
- Greg Reimonn, Madison Reed, Demetre Fontaine
  University of Massachusetts, Lowell

A Study of Sea Level Rise and Designs for Coastal Resiliency in Boston
- Chase Gaudino, Lauren Kaija, Emilia Perez, Hannah Schulz, Trisha Worthington
  Worcester Polytechnic Institute

Impacts of Microplastic Pollution on Tidal Flow Constructed Wetland Technology for Tertiary Wastewater Treatment
- Louiza Wise, Ben Lavana
  Northeastern University

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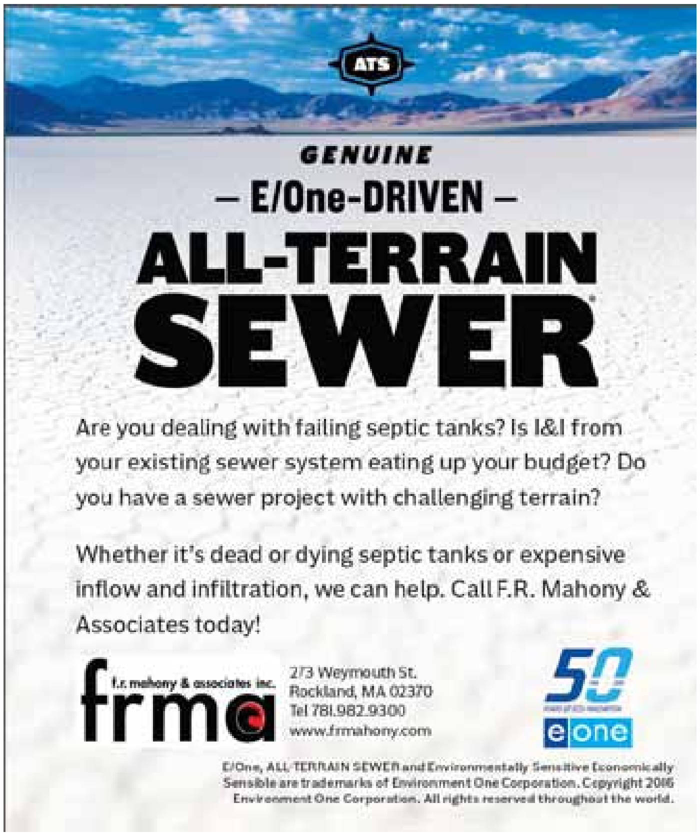

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