Barr Engineering and Hazen & Sawyer Prepare Study For Minnesota Pollution Control Agency

A report published by the **Minnesota Pollution Control Agency** (MPCA) in June 2023 found that technologies and expenses needed to remove and destroy per- and polyfluoroalkyl substances (PFAS) from certain wastewater streams across Minnesota in approximately 370 facilities would cost between $14 billion and $28 billion over 20 years. The study is described as the first of its kind and, although specific to Minnesota, the novel methods developed to estimate costs can be applied anywhere, says MPCA.

The MPCA commissioned the independent study as part of Minnesota's PFAS Blueprint, a comprehensive interagency plan to prevent, manage, and clean up PFAS pollution. The report, titled *Evaluation of Current Alternatives and Estimated Cost Curves for PFAS Removal and Destruction from Municipal Wastewater, Biosolids, Landfill Leachate, and Compost Contact Water*, was prepared by **Barr Engineering Company** and **Hazen and Sawyer** with funding from the Minnesota Environment and Natural Resources Trust Fund.

Key findings include:

- PFAS can be bought for $50 - $1,000 per pound (according to MPCA estimates), but costs between $2.7 million and $18 million per pound to remove and destroy from municipal wastewater, depending on facility size.
- Small wastewater treatment facilities would face per-pound costs over six times greater than large facilities, due to economies of scale.
- New "short-chain" types of PFAS are more difficult and up to 70% more expensive to remove and destroy compared to old "long-chain" PFAS.
- Cost estimates are based on the required upgrades to Minnesota's existing wastewater infrastructure to treat and destroy PFAS using current commercially available technologies and PFAS levels. In total, 13 PFAS removal and destruction technologies passed a screening on their real-world effectiveness and the most cost-effective technology was selected for statewide cost development.
- New technology that reduces costs to remove and destroy PFAS from wastewater is in development, but the MPCA believes that without an alternative source of funding, PFAS removal and destruction from municipal wastewater will be unaffordable for the foreseeable future. In contrast, emerging biosolids technologies, Pyrolysis and/or Gasification followed by Thermal Oxidation:; and Supercritical Water Oxidation in particular, capable of destroying PFAS can be cost-competitive with current practices.

PFAS IN WASTEWATER

PFAS can enter wastewater through industrial processes, everyday use of commercial products or when PFAS-containing products are discarded in landfills and compost sites. Even decades after they are brought to a landfill or compost site, PFAS can make their way into liquids, most frequently landfill leachate and compost contact water. These liquids are often sent to wastewater treatment facilities that are not designed to remove PFAS and ultimately released into the environment, where PFAS can contaminate surface water, groundwater, drinking water, fish, other wildlife, and the food supply. Targeting PFAS in wastewater streams, as the study assesses, would be a significant step toward protecting these resources.

Minnesota's wastewater treatment facilities recognize the need to address PFAS pollution. They have begun monitoring for PFAS and completing PFAS source identification work, but no municipal wastewater facility has the infrastructure capable of removing and destroying PFAS.

MANAGING AND PREVENTING PFAS POLLUTION

Minnesota's PFAS Blueprint prioritizes pollution prevention as the most effective way to protect health and the environment, and the new PFAS wastewater cleanup cost estimates add a greater urgency to prevention efforts in Minnesota and elsewhere. The MPCA is working to implement a new law passed by the Minnesota Legislature and signed by Gov. Tim Walz to phase out nonessential PFAS use over the coming decade. The Legislature also funded PFAS Blueprint programs to help businesses transition away from PFAS, protect drinking water supplies, and enhance monitoring systems.

Table ES-1 Select capital and O&M cost ranges for highest-ranking alternatives

Waste Stream	Facility Size	Highest-Ranking Alternatives	Capital Cost Range (by facility)	Annual O&M Cost Range (by facility)	Relative Confidence in Ability to Reliably Meet PFAS Targets[2]
Municipal WRRF effluent	10 million gallons per day (MGD) (6,940 gpm) (similar to Mankato or Moorhead with a population of 45,000)	GAC with reactivation (Alt 1a)[1]	$41M–$88M	$4.5M–$9.6M	Medium-high (breakthrough of short-chain PFAS may limit reliability)
		GAC, single-use AIX with GAC reactivation and AIX high-temperature incineration (Alt 6a)[1]	$80M–$170M	$6.1M–$13M	High (two processes provide more controlled breakthrough)
Municipal WRRF biosolids	10 dry tons per day (estimated for 10 MGD WRRF)	SCWO[3]	$40M–$85M	$0.47M–$0.99M	Medium-high (limited testing at full-scale)
		Pyrolysis or gasification with thermal oxidation of pyrogas[1,3]	$53M–$110M	$0.55M–$1.2M	Medium-high high (limited testing at full scale)
Mixed MSW landfill leachate	0.014 MGD (10 gpm)	GAC with high-temperature incineration (Alt 1a)[1]	$0.30M–$0.60M	$0.23M–$0.48M	Medium (breakthrough of short-chain PFAS may limit reliability)
		Foam fractionation with high-temperature incineration of foamate (Alt 8a)	$5.0M–$11M	$0.20M–$0.42M	Low (limited removal of short-chain PFAS)
Compost contact water	0.014 MGD (10 gpm)	GAC with high-temperature incineration (Alt 1a)[1]	$0.30M–$0.60M	$0.21M–$0.44M	Medium (breakthrough of short-chain PFAS may limit reliability)
		Foam fractionation with high-temperature incineration of foamate (Alt 8a)	$5.0M–$11M	$0.20M–$0.42M	Low (limited removal of short-chain PFAS)

1) Alternatives indicated likely need pretreatment processes to operate PFAS separation and destruction technologies. Pretreatment costs are not included in this table but are discussed in report sections for each waste stream.

2] Relative ability to reliably meet PFAS targets reflects a combination of technology performance and reliability. For example, foam fractionation alternatives receive a "low" score because they are not expected to meet short-chain PFAS treatment targets. Alternately, single-process media filtration is expected to meet targets most of the time, except when a breakthrough event occurs. Hence, it receives a "medium" to "medium-high" score for reduced reliability. Breakthrough can be monitored and managed to limit PFAS reporting to effluent; however, targeting levels below analytical reporting limits for PFBA in highconcentration waste streams like landfill leachate could require media changeout every 2–4 weeks, which is on a similar time frame as analytical turnaround time for PFAS. Thus, PFAS breakthrough may not be detected in time for changeout, resulting in a lower reliability score for single-process media filtration for high PFAS concentration waste streams. Compared to singleprocess media filtration, dual-process media filtration receives a score of "high" because it is expected to allow for more time for monitoring breakthrough and thus to more reliably meet PFAS targets.

[3] Biosolids costs are extrapolated from cost curves developed for this study.

BARR BRINGS A STRAIGHTFORWARD APPROACH TO MINNESOTA PFAS COST ESTIMATE STUDY

Barr Engineering Co. provides engineering and environmental consulting services to clients across the Midwest, throughout the Americas, and around the world with offices in seven states and Canada. Barr has been employee-owned since 1966 and trace our origins to the early 1900s. Barr's 900+ engineers, scientists, and technical specialists help clients develop, manage, and restore natural resources in industries such as power, refining, mining, and manufacturing as well as attorneys, government agencies, and natural-resource-management organizations. Project sites range from iron-ore mines in South America to wind-power farms in South Dakota, from manufacturing facilities in California to oil-sands fields in western Canada.

Don Richard, vice president and senior civil engineer, Barr Engineering Co. has three decades of experience have been focused on treating industrial wastewater and groundwater contaminated by a wide variety of substances. He has managed numerous soil, sediment, and groundwater investigation and remediation projects to enhance and restore natural environments and promote redevelopment. In addition, he has directed several projects involving petroleum-release response actions; served as a senior technical resource in evaluating, pilot-testing, designing, and installing treatment technologies at contaminated sites; and managed the investigation and remediation of contaminated sediments in lakes, rivers, and wetlands.

EBJ: How did you hear about this proposed research project and how did the firm get involved and what qualifications did you and the firm bring to bear to conduct and support this research and production of the report?

Don Richard: Barr Engineering Co. has a long record of working with the **Minnesota Pollution Control Agency** (MPCA) on complex issues related to specific compounds in the environment, including mercury, phosphorus, sulfate, and now PFAS. We have also worked with several clients to develop and implement grants using Minnesota's Legislative-Citizen Commission on Minnesota Resources (LCCMR) grant program, so we were familiar with this grant process. Based on our experience, we were alerted to the MPCA's upcoming request for professional services for this project. When developing our proposal, we were also proactive in seeking partners that could expand the qualifications of our team; for example, we engaged **Hazen and Sawyer** as a subconsultant based on their national experience with managing wastewater biosolids.

EBJ: How did the collaboration go with the state and the project partners and what were the most challenging aspects of the research and project completion?

Richard: One of the most challenging aspects of projects related to new chemicals with environmental concerns is the volume of current publications to review and assimilate. The environmental industry is very large, and many players—from researchers to equipment suppliers—are interested in developing new tools to better address these new challenges. Fortunately, Barr has a very large network, and we have a long history of working collaboratively with both public and private clients, consulting partners like Hazen, and a wide array of technology vendors.

EBJ: MPCA responses are possibly motivated by not wanting wastewater treatment plants to shoulder more than their share of the PFAS burden. Do you believe other social or political or economic issues will come into play related to the ultimate social cost of PFAS?

Richard: The cost estimates we developed for this work represent the straightforward application of costs from experience with existing technologies that are commercially available at this time for the treatment of PFAS.

EBJ: How many projects and what kind of projects has your firm been involved with with PFAS?

Richard: Barr has over 20 years of experience working with PFAS issues in air, soil, water, and sediments for a wide range of public and private clients throughout North America and Europe. We help clients assess the fate and transport of PFAS; evaluate, permit, and design PFAS treatment and disposal options; sample and characterize wastes; and identify and reduce sources. We have designed numerous water treatment systems for industrial wastewater in various industries, from emergency response systems to public drinking water.

EBJ: Do you have any expectation that the proverbial silver bullet technology will emerge or do you think engineered solutions and multiple approaches will be the vast majority of treatment systems and remedial approaches?

Richard: The current state of practice for treatment of PFAS in water and wastewater is to use conventional technologies, such as adsorption to granular activated carbon (GAC) or ion exchange (IX), followed by destruction using incineration. These are general treatment tools. They were developed decades ago for different applications, and they are used now for PFAS treatment because they are industry standards. It is reasonable to assume that, by focusing on the unique chemical characteristics of PFAS, new technologies can be developed that would specifically target

GAC or IX followed by incineration are general treatment tools developed decades ago for different applications, and they are used now for PFAS treatment because they are industry standards..... It is reasonable to assume that, by focusing on the unique chemical characteristics of PFAS, new technologies can be developed that would specifically target removal and destruction of PFAS.

removal and destruction of PFAS. However, given the broad spectrum of chemical characteristics within the PFAS family, with potentially thousands of different individual chemicals, it is likely that different approaches may be necessary for different groups of PFAS, such as long-chain or short-chain PFAS.

EBJ: Some view the PFAS market as treatment of drinking water systems then source remediation and then these downstream issues like wastewater plants and landfills. Do you have an opinion or is that unrelated to the technology cost focus of your research?

Richard: The evaluation of technologies and the costs developed during this project provide a benchmark for comparison of PFAS treatment at wastewater facilities to other potential approaches. This work did not explicitly develop costs for other approaches such as drinking water treatment, source remediation, or prevention; however, using methods similar to those developed for this study, it should be possible to develop similar costs for comparison of alternative approaches.

EBJ: How did you get involved in the environmental industry in the first place or what were some of your original inspirations to develop your career to the subject matter you have?

Richard: Barr was incorporated by Doug Barr in 1966 with a primary focus on water resources for a wide variety of public and private clients. Over the years, the management of water resources has evolved from addressing questions related to quantity to include developing solutions to address the impact of human activities on water quality for multiple sources of water, including surface and groundwater. Al Gebhard, another former president of Barr, was one of the pioneers of addressing issues related to groundwater quality in Minnesota in the late 1970s. From this early work, Barr's experience has expanded to address a wide array of water-related issues—because our scientists and engineers listen to our clients and develop innovative solutions to meet their needs. We develop solutions for complex water and wastewater issues, to benefit both our clients and the communities where we live. □

HAZEN BIOSOLIDS PRACTICE LEADER SEES POTENTIAL IN TECHNOLOGIES TO COST-EFFECTIVELY TREAT PFAS IN BIOSOLIDS

Since 1951, **Hazen and Sawyer** has focused on providing safe drinking water and controlling water pollution. Hazen's range of services encompasses the planning, design, and construction management of water and wastewater-related projects – from clean water treatment, storage, and distribution to wastewater and stormwater collection, treatment, and reuse. Hazen's focus brings us exceptional challenges – such as the largest drinking water UV disinfection installation in the world, upgrade of major wastewater treatment plants to reduce nutrient discharges to sensitive receiving waters, and recharging vital drinking water aquifers with highly-treated wastewater effluent.

National Biosolids Practice Leader Dr. Mohammad Abu-Orf aka Dr. Mo is a globally acknowledged biosolids processing expert. He serves as Hazen's Biosolids and Residuals Group Leader providing master planning, process optimization, innovative technologies evaluation, and conceptual design in the areas of sludge dewatering, thermal dryers, stabilization, and energy recovery. Mo has more than 130 peer-reviewed and conference publications to his credit and is the main inventor for five patents related to biosolids processing. Co-authored the Fifth Edition of Metcalf and Eddy Textbook "Wastewater Engineering: Treatment and Resource Recovery," published by McGraw Hill, October 2013. Previously VP of AECOM Water and North America Biosolids Practice Leader. In this role, directed biosolids master planning and management plans for various size wastewater treatment plants ranging from 5 to 350 MGD. Prior to AECOM, worked with Siemens Water Technologies as Director of Product Development and Veolia Water North America Operating Services as Director of Biosolids Technical Services and Head of Applied Research.

EBJ: How did you hear about this proposed research project and how did the firm get involved and what qualifications did you and the firm bring to bear to conduct and support this research and production of the report?

Dr. Mohammad Abu-Orf: The Minnesota Pollution Control Agency (MPCA) issued an RFP for the research project and Hazen and Sawyer teamed with Barr Engineering to prepare a proposal addressing the issues outlined in the RFP. Hazen focused on destroying PFAS in biosolids. Being a national consulting firm with a strong biosolids management resume, Hazen provided national subject matter experts to the project. Hazen National Biosolids Practice Leader Dr. Mohammad Abu-Orf directed the technical aspects of the project with Hazen Associate Anna Munson, Hazen Applied Research Director Dr. Derya Dursun and Hazen Northeast Biosolids Practice Leader Micah Blate. Prior to this project, Hazen's biosolids group had been working on research on technologies for the removal and destruction of PFAS from biosolids, with several projects supported by the Water Environment Research.

EBJ: How did the collaboration go with the state and the project partners and what were the most challenging aspects of the research and project completion?

Abu-Orf: Hazen met with Barr Engineering Co. regularly throughout the project to align research approaches and preparation of calculations and work products. We presented our work as a team to MPCA and their stakeholders. We also presented this work to professional associations as a team several times. Occasionally, each firm presented work independent of the others, but we all had the opportunity to review the materials before they were presented. The most challenging aspect of working on biosolids was preparing cost curves for the shortlisted technologies that met the criteria established by MPCA. These technologies are emerging and not well established and, thus, rely on engineering judgement, reasonable assumptions to estimate both construction, and O&M costs.