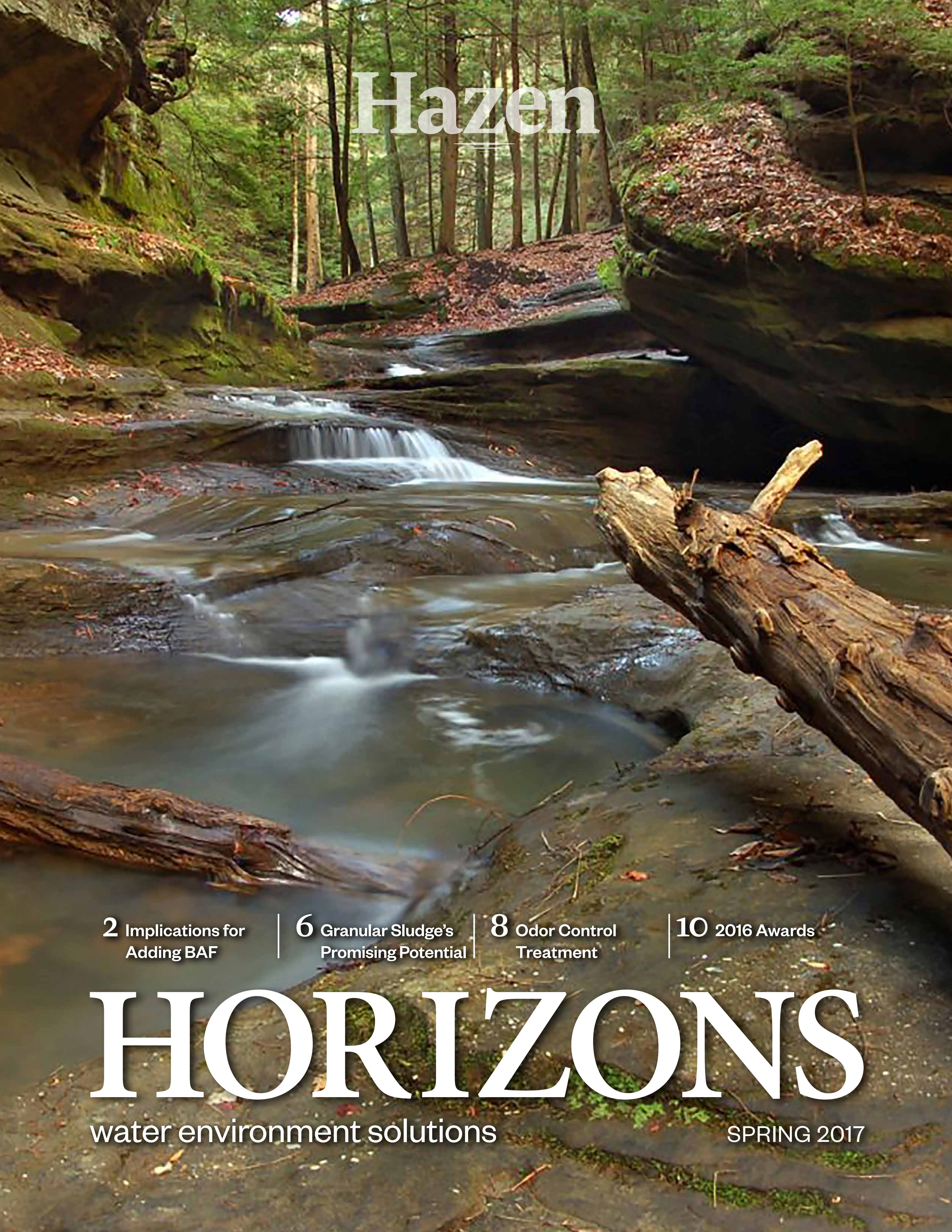


Hazen

HORIZONS

water environment solutions

SPRING 2017

Implications for Adding Biofiltration

Biologically active filtration (BAF) is a cost-effective, multi-barrier water treatment process that provides a broad foundation for controlling taste and odors, removing DBP precusors and other contaminants, and increasing water stability.

In the following pages we examine four aspects of implementing BAF:

1. Comparison to Conventional Filtration
2. Characteristics and Components
3. Challenges and Considerations
4. Considerations in Potable Reuse

The suitability of adding BAF to any given water treatment plant requires an examination of potential benefits and costs. Providers challenged by trying to control disinfection byproducts (DBPs), taste/color/odor issues, algal toxins, industrial or wastewater contaminants, or reducing assimilable organic carbon (AOC) to enhance stabilization can often achieve major improvement with the proper operation of BAF. That said, proper operation can require significant capital investment, in addition to new challenges for operators.

1 Comparison to Conventional Filtration

Six advantages of BAF over conventional filtration:

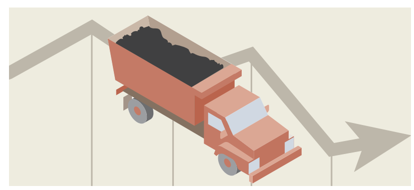
Better Contaminant Removal

BAF more readily removes microbial, organic, and inorganic contaminants than conventional filtration.

Improved Taste

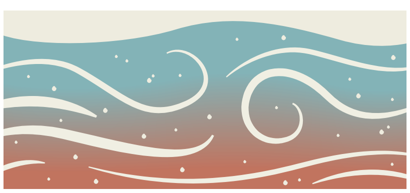
Removes difficult to treat geosmin and methyl-Isoborneol (MIB) compounds that cause earthy or musty tastes and odors.

Reduced Solids Production



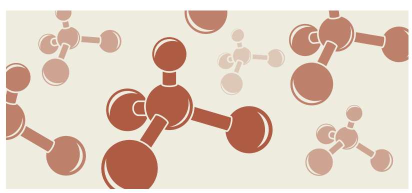
Reduces residual solids production and resulting handling costs as biofiltration can facilitate decreased coagulant and Powdered Activated Carbon use.

Increased Water Stability



Increases water stability within the distribution system due to the reduction in AOC and biodegradable dissolved organic carbon (BDOC).

Reduced DBP Formation

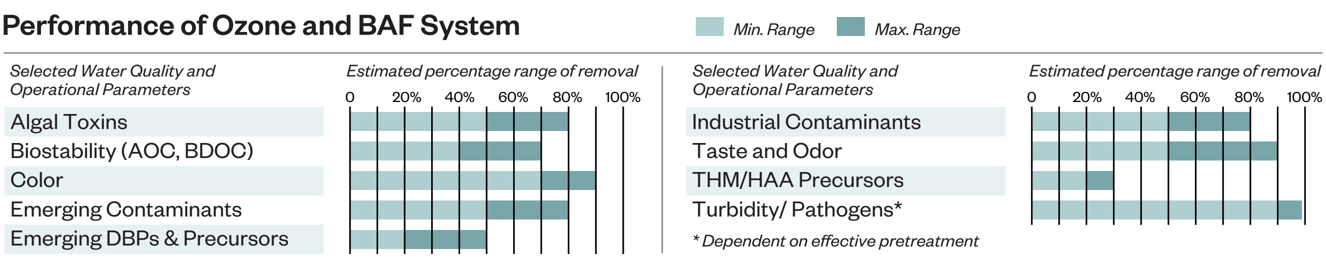


Reduction of organic carbon consequently reduces the formation potential of DBPs, such as trihalomethanes and haloacetic acids, and provides removal of NDMA.

Flexibility to Water Changes

Takes advantage of co-metabolism and organism population restructuring as the nature of constituents in source water changes over time to consume a variety of emerging contaminants.

Performance of Ozone and BAF System

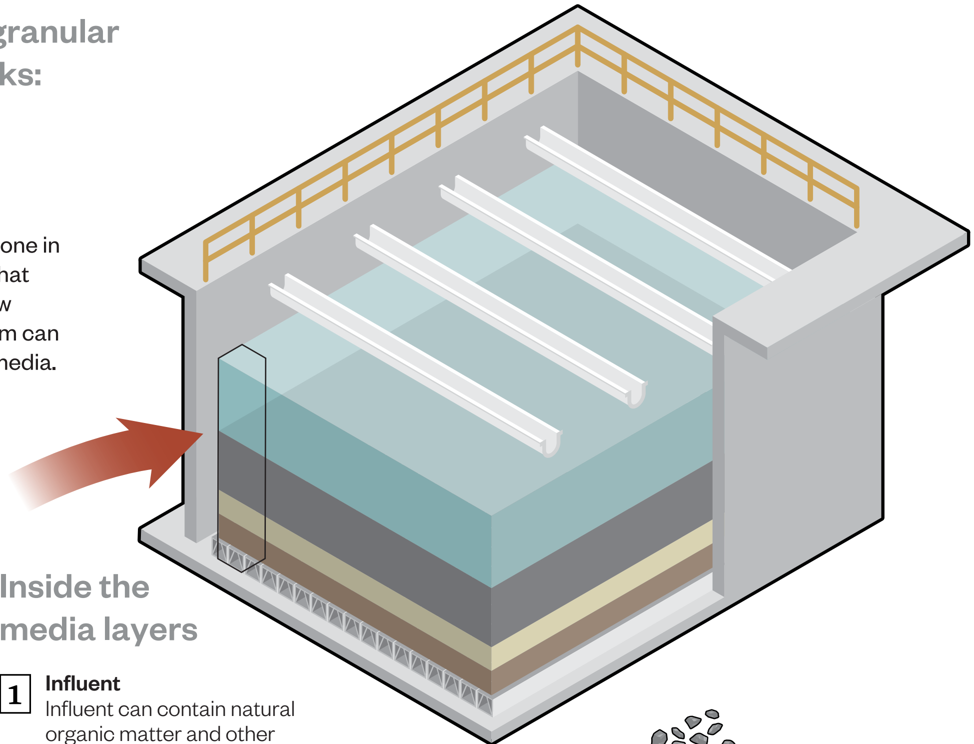


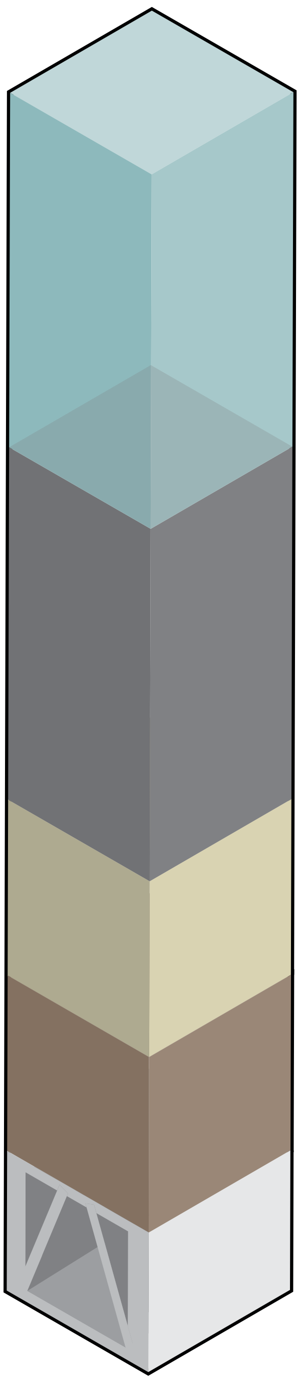
* Dependent on effective pretreatment

2 Characteristics and Components

How a biofilter using granular activated carbon works:

Biologically active filters remove problematic contaminants by biodegradation, adsorption, and filtration of solids. By adding a preoxidant such as chlorine or ozone in front of the filter, then removing that oxidant upstream or in the top few inches of the filter, a natural biofilm can develop on the surfaces of filter media.





Inside the media layers

1 Influent
Influent can contain natural organic matter and other contaminanants such as algal toxins, iron, manganese, and DBPs & their precursors.

2 Granular Activated Carbon (GAC)
As the influent travels through the media, the highly porous structure of GAC provides a large surface area for supporting the growth of microorganisms. These microorganisms form the biofilm layer that degrades and/or adsorbs organic contaminants and provides a surface for deposition and consumption of inorganic contaminants such as manganese.

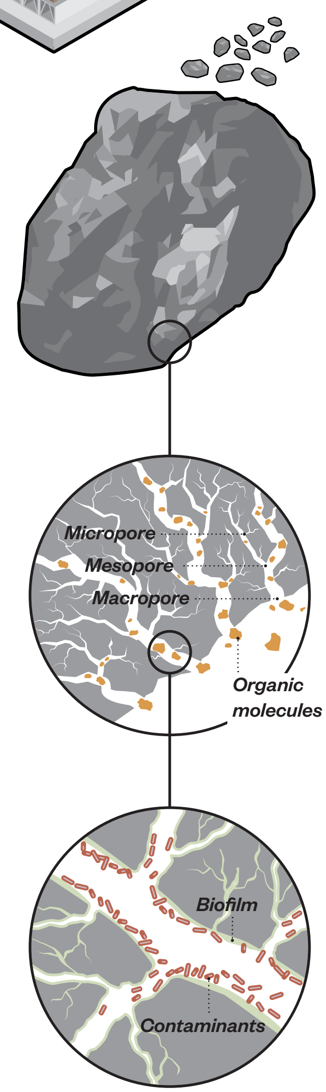
3 Sand
The underlaying sand media provides a substrate under the GAC to increase the removal of particles and micororganisms.

4 Gravel
The gravel (optional, depending on underdrain selection) serves as a support layer for the sand and GAC. It also prohibits the sand from obstructing the underdrains.

5 Underdrain
A modular underdrain system provides the final design layer of the filter and serves to collect filtered water and to distribute backwash water.

Inside GAC

Granular activated carbon is manufactured from raw organic materials such as coconut shells or coal. Heat and pressure activates and increases the surface area, creating a highly-porous structure.



The intrinsic pores act as pathways where molecules adhere and become trapped. This attachment is called adsorption.

Microbial growth on the porous surface (biofilm) breaks down contaminants and total organic carbon (TOC).

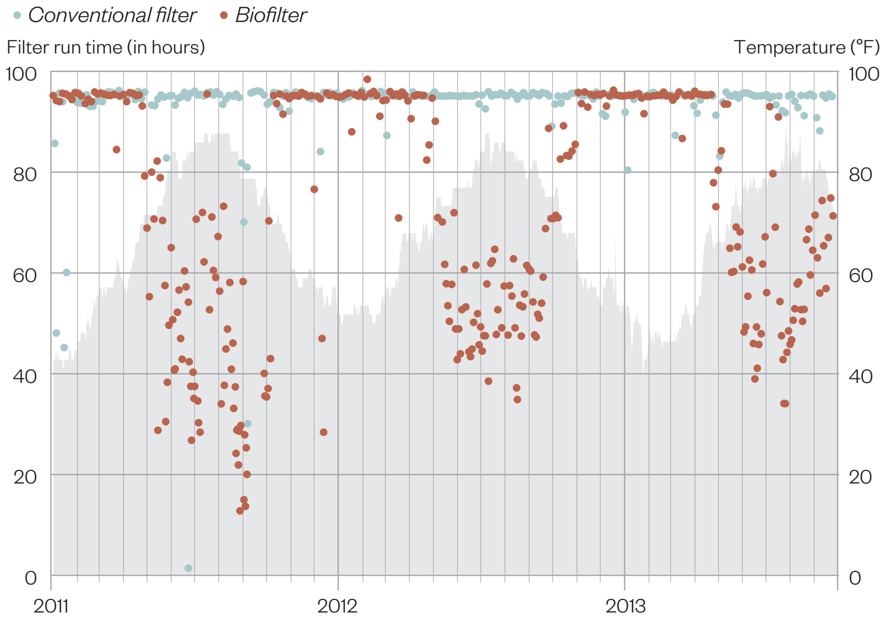
3 Challenges and Considerations

Reduced Filter Run Time

One of the more common biofiltration challenges we help clients address is that of reduced filter run times. Our consistent observation has been that warmer water temperature and/or higher nutrient concentrations will increase biological growth on the filters, producing hydraulic constraints. The chart at right displays run times observed during three years of BAF operation at one client facility, highlighting significantly reduced filter run time with increased temperature. Techniques including nutrient balancing and the addition of mild disinfectants like hydrogen peroxide can improve run times, as shown in Summer of 2012 and 2013 (compared to 2011), but better filter design or additional filters are needed to account for biological growth during warmer weather.

BAF reduces filter run time

Warmer water fosters increased biological growth on the filters, resulting in excessive headloss and reduced filter runtimes during the high-demand summer season.

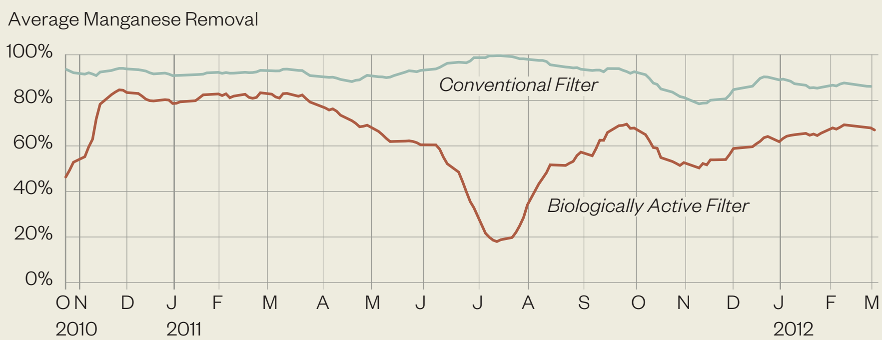


Negative Impact on Manganese Removal

Other common challenges of BAF include "sloughing" of surplus biological material (after it grows very thick) from the filters and occasional periods of low-efficiency maganese removal. Each of these problems can be overcome with sound design and deliberate operation.

Manganese removal

Over the second half of 2011, our team observed significant differences in manganese removal efficiency between conventional and biological filters at the same facility. On several occasions, manganese removal of the biofilters dropped to critically low efficiency (less than 30%), while conventional filtration was always capable of removing greater than 80% manganese.



Design and Operations Considerations

While biofiltration has many benefits and often produces a finished water that is safer and more aesthetically pleasing, there are some limitations that must be addressed by proper design and operations.

The keyword in biofiltration is filtration. The primary purpose is to remove particles and microbial contaminates such as *Giardia, Cryptosporidium,* and viruses. It is extremely important to maintain filtered water turbidity values less than 0.1 NTU.

Biofiltration requires greater operator attention. Adequate backwashing and filter maintenance and condition assessment is key to the reliable production of finished water. In addition, the system must be operated such that excessive AOC does not leave the plant.

Excessive headloss development and short filter runs need to be addressed during design. Selection of media with the optimal depth, effective size, and uniformity coefficient is key to meeting production goals at all times.

Catastrophic underdrain failure – some utilities have experienced catastrophic underdrain failure due to biological fouling. This can be avoided through sound underdrain design.

4 Considerations in Potable Reuse

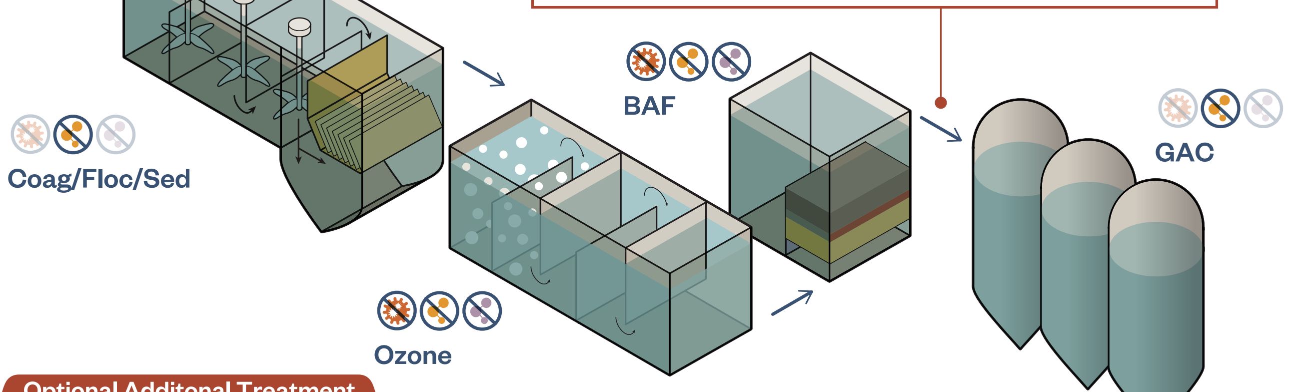
Treating reclaimed water effluent to drinking water standards requires integration of treatment goals, design, and operation.

BAF is an integral component to non-reverse osmosis membrane based DPR treatment systems. Biofiltration in conjunction with coagulation/flocculation/ sedimentation serves as a combined barrier to pathogen removal, and stabilizes water chemistry by removing readily biodegradable organic matter that is produced during ozonation. BAF also removes disinfection byproducts (DBPs) such as NDMA that are formed during ozonation, and provides a low turbidity water for subsequent GAC treatment. Sound design practices ensure that there are no unintended consequences such as underdrain plugging or excessively short filter runs. The design and operation of BAF systems for potable reuse vary depending on treatment goals and overall risk mitigation strategies. For example, in some cases BAF may be sized and operated primarily for nitrification or denitrification purposes rather than as a primary mechanism of turbidity removal. In other cases, BAF in conjunction with upstream coag/floc/sed may be a major part of overall pathogen reduction objectives. These goals must be clearly defined to ensure BAF meets the desired water quality goals.

Contaminants: *Microbial* *Chemical (organic)* *Chemical (inorganic)*

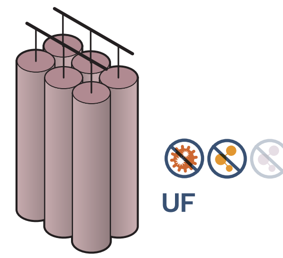
Example IPR Scheme

Advanced purification for groundwater injection to mitigate climate change impacts, sea level rise, and saltwater intrusion.



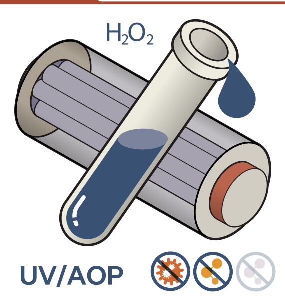
Optional Additonal Treatment

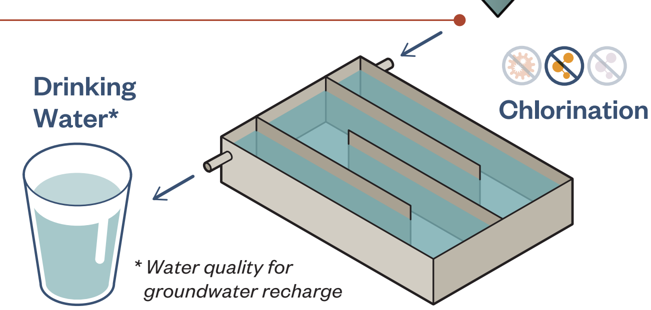
Ultrafiltration
provides an opportunity to gain additional pathogen removal performance in DPR and provide the ability to have more flexibility in biofilter operation to focus on chemistry and biology.



Optional Additonal Treatment

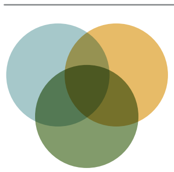
Advanced Oxidation
provides additional chemical and microbial risk mitigation. However, water chemistry in DPR must be carefully considered to determine if AOP provides a cost-effective solution.





BAF Science

Biology *Physics* *Chemistry*



Microbial communities can be developed to enhance nitrification or denitrification with additional trace organic contaminant removal and DBP mitigation.

Filters need to have proper media size, shape, and stratification to function properly in a biological mode. In addition, biology and filter operations must be controlled to avoid compromising filter performance.

Chemical additives (e.g., phosphate, peroxide) may change microbial dynamics but can also impact the operation of the filter in positive and negative ways.

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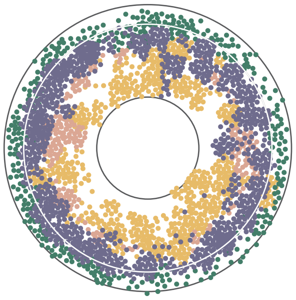
GRAPHICS BY TROY OXFORD & WM PITZER/HAZEN

Granular Sludge: A Promising Inno

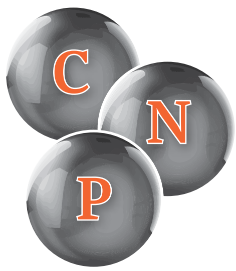
As the water industry increasingly transitions to a resource recovery paradigm, the int
more with less. Here's a closer look at one such promising technology alternative tha

What is Aerobic Granular Sludge?

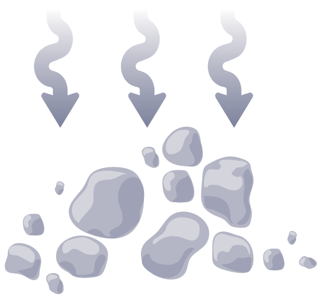
Aerobic granular sludge represents an emerging approach for intensifying biological treatment at WRRFs in order to do more with less.



At the heart of the process is the development of fast settling aggregates of bacterial communities (granules).



These granules allow for simultaneous removal of carbon, nitrogen, and phosphorus.

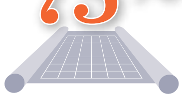


Fast settling granules also allow WRRFs to separate the solids and liquids more effectively than with conventional activated sludge. Improvements to settling associated with granular sludge are generally reflected in low sludge volume index measurements (SVI).

State of the Industry

Early adopters are already seeing these substantial benefits over an activated sludge process:

75%



Smaller footprint when compared with activated sludge

Lower construction and operational costs

25 to 35%

Energy savings

Characteristics

The development of granules for use in WRRFs for facilitating intensified organic and nutrient removal is being studied since granular sludge has several advantages over conventional activated sludge.

Dense compact biofilm allows for multiple redox conditions to exist.

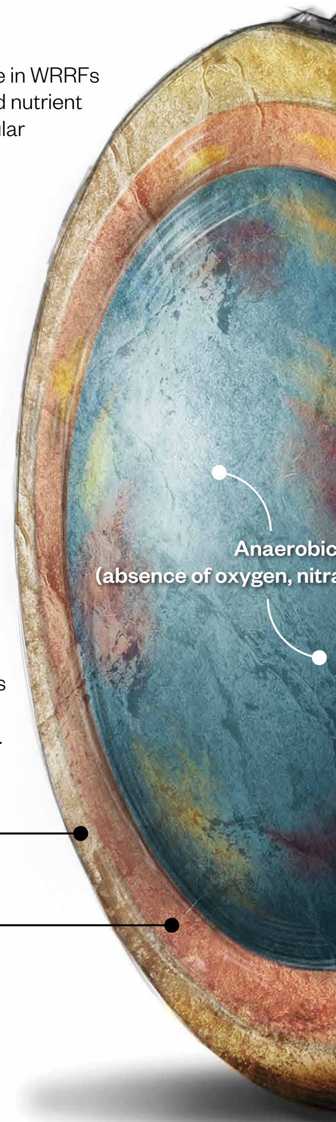
High mechanical strength promotes resistance to shear.

High settling velocity results in very low SVI.

Combination of fast settling sludge, multiple redox conditions and differential penetration of substrates allow for multiple microbial processes (nitrification, denitrification, biological phosphorus removal, anaerobic ammonia oxidation) to occur in small footprint.

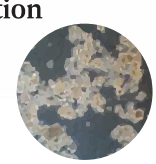
Aerobic
(presence of oxygen)

Anoxic
(presence of nitrate/nitrite)



Stages of Granulation

1. Bacteria convert soluble substrates to internal storage products.



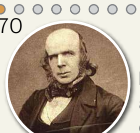
2. Bacteria use internal storage products to facilitate granule formation and to powe nutrient removal and recovery.

1870s to 1910s

During early years of process development researchers find extended aeration of sewage transforms ammonium to nitrate; however, the process of nitrification is largely unexploited.

1919 – Jones & Attwood patent the concept of "Activated Sludge" in UK

1870 1880 1890 1900 1910 1920 1930 1940

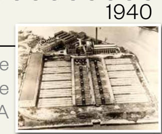


Early 1880's – Dr. Angus Smith aerated WW to accelerate oxidation of organic matter (UK)

1910 – Black & Phelps reported reduced putrescibility by forcing air through WW (NYC)

1914 – E. Ardern & W. T. Lockett discovered the activated sludge process

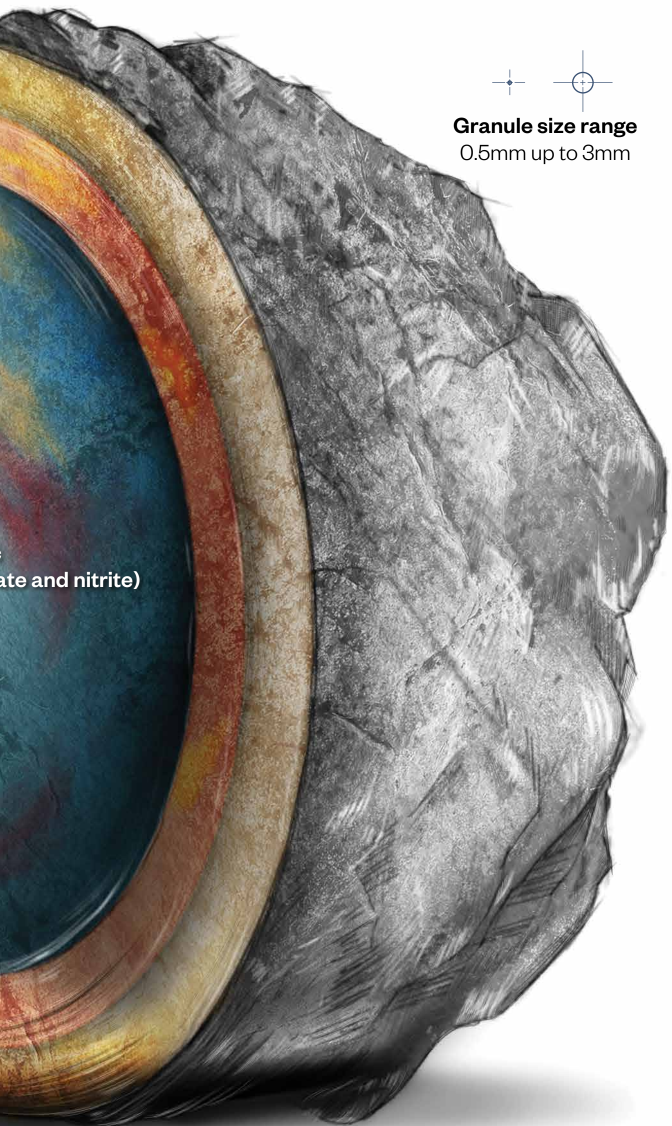
1925 – Milwaukee First Large Scale AS Plant in the USA

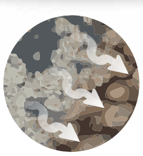


AUTHORS: WENDELL KHUNJAR, PE, PHD | MARK STRAHOTA, PE | PAUL PITT, PE, PHD | RON LATIMER, PE | KEVIN GILMORE, PHD - BUCKNELL UNI

vation for More Efficient Settling

ensification of biological processes within existing infrastructure often means doing
t could be coming soon to a water resource reclamation facility (WRRF) near you.





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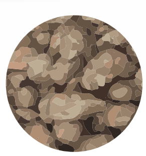
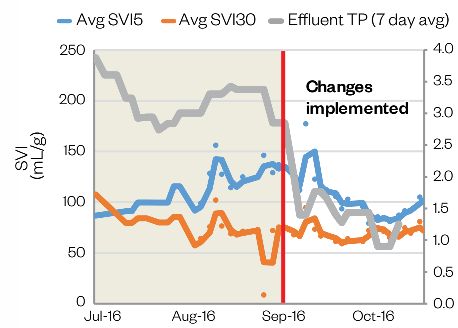


3. Fast settling bacteria are retained and flocs are converted to granules.

Gregg Township Municipal Authority

Hazen is working with Gregg Township Municipal Authority (GTMA) on a strategy to intensify nutrient removal capability. The current work is focused on promoting enrichment of biological phosphorus removal organisms as a means for enhancing settling properties and potentially stimulating granule formation.

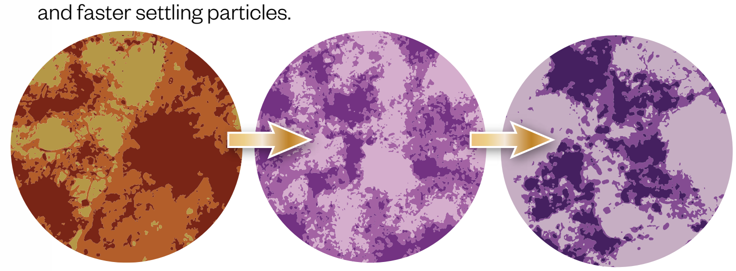
Initial changes, including improvements to mixing and cycle time operation, were implemented in September 2016.



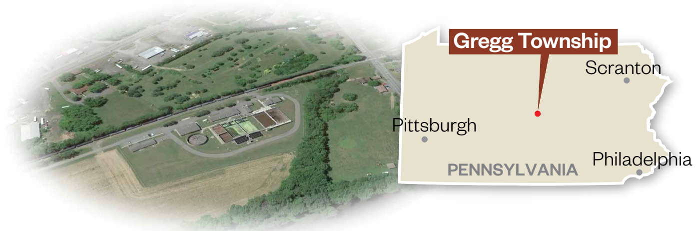
5 minute sludge volume index decreased by 25% in October 2016 versus September 2016

Enrichment of Biological Phosphorus Removal at GTMA

Improvement in P removal and sludge settleability coincided with enrichment of phosphorus accumulating organisms (PAOs) and development of larger and faster settling particles.



June 2016 **August** 2016 **October** 2016



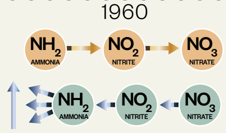
Efforts to further improve sludge settleability and nutrient removal capacity (both N and P) is underway at the GTMA facility.

Mid 20th Century

Research leads to the development of a 2- step N removal processes that combine denitrification and nitrification.These findings are further refined to create multi-stage processes that utilize alternating redox conditions to facilitate carbon, N and P removal from the mainstream flow.

Struvite recovered from WRRF

1950 1960 1970 1980 1990 2000 2010 2016



2000s

Advancement of treatment technologies to remove nutrients to limits of technology using nitrification, denitrification, anaerobic ammonia oxidation.

2010s

Emerging resource recovery paradigm promotes AGS development and commercialization.

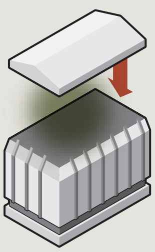
VERSITY

GRAPHIC BY FRED MATAMOROS/HAZEN

ODOR CONTROL
Treatment Technologies

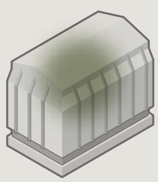
Cost-effective treatment technology plays a key role when implementing a successful odor control strategy. Activated carbon, biofilters and bio-trickling are three technologies that Hazen employs in its odor control projects.

FIVE KEY ELEMENTS
REQUIRED FOR A SUCCESSFUL ODOR CONTROL SYSTEM



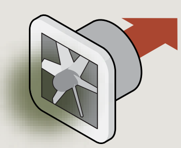
COVER

Place a cover or enclosure over the odor source to restrict it from fouling the air around it.



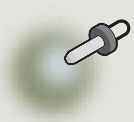
CONTAIN

Create a negative air pressure within the covered or enclosed air space to prevent any fugitive leaks of foul odors.



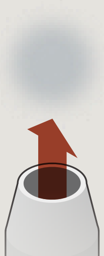
CONVEY

Direct the foul odors contained under negative air pressure through a conduit or duct to the odor control technology.



TREAT

Install a cost-effective odor control technology that is capable of performing under the design diurnal odor load patterns and will mitigate any off-site nuisance odors.



DISCHARGE

Optimize the location, height, and shape of the exhaust stack to take advantage of additional entrainment, dilution, and dispersion characteristics to further reduce any potential off-site odor impacts.

THREE TREATMENT TECHNOLOGIES

Selection of cost-effective technology is dependent upon a characterization of the influent odor load, which can be determined by sampling and data analysis. If implementing a new technology while leaving the current technology in service, it is important to develop a maintenance of plant operations plan and schedule that allows the current technology to continue operating until the new technology is in place, and transition from the old to the new seamlessly without the loss of odor control.

Once a technology is selected, the number of vessels and the location of the technology must be determined. There are several potential treatment technologies available to operators:

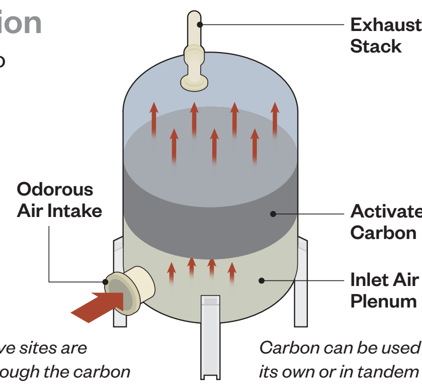
Activated Carbon Absorption

In this process, contaminants adsorb onto active sites on the surface of the carbon, which has a high surface-to-volume ratio.

1 Odorous air is pumped into air plenum chamber.

2 Carbon absorbs odor compounds.

3 Cleansed air is released through exhaust stack.



Carbon will continue to adsorb compounds until active sites are occupied; once that occurs, compounds will pass through the carbon and be present in exhaust air (also known as breakthrough).

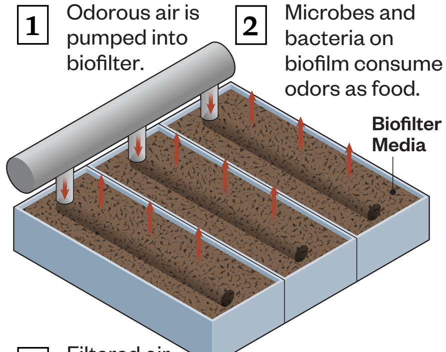
Carbon can be used on its own or in tandem with a biofilter system.

Biofilters

Biofilters rely on the ability of odorous compounds to be absorbed into the liquid film that coats biofilter media, comprised of organic materials such as wood chips or compost, or an inorganic material provided by a third party vendor.

1 Odorous air is pumped into biofilter.

2 Microbes and bacteria on biofilm consume odors as food.

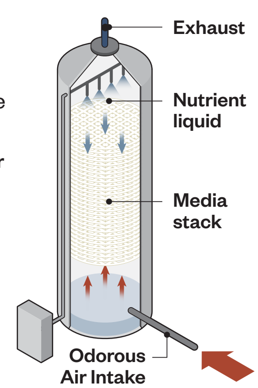


3 Filtered air exits with water vapor.

Biofilters avoid hazardous chemicals, saving money, reducing maintenance, and protecting environment.

Bio-trickling

Bio-trickling filters combine the relatively low maintenance and operating cost principles of biofilter systems with the smaller footprint and reduced residence time associated with wet scrubbers.



1 Air is passed upward though a column containing a host material, while a liquid stream of nutrients passes downward.

2 Odors are filtered out as they move upward to exhaust stack.

Best suited for high concentrations of hydrogen sulfide; may need to add nutrients to wetting source if effluent lacks sufficient nutrients or odors are too concentrated.

SELECTED HAZEN ODOR CONTROL PROJECTS

1 The south battery of the Newtown Creek Wastewater Treatment Plant consists of eight grit tanks, four aeration tanks, and eight sedimentation tanks, all of which are hydraulically separated and contain covered weirs for odor control. The 310-mgd plant mitigates all odor using only activated carbon.

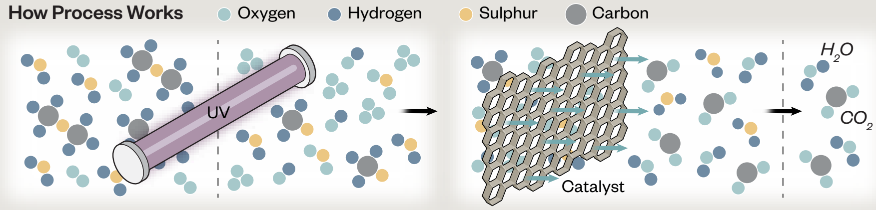
2 A recent upgrade of the Beaver Ruin Pump Station implemented three biotrickling filters for odor control, which has proven to be effective.

3 Hazen helped the Moulton Niguel Water District (CA) develop a revised force main pumping plan to reduce residence time of wastewater in the sewer overnight after a hydraulic study found flow periods were a critical factor driving odor complaints. Implementing the plan required no captial costs and only minimal maintenance, and effectively reduced odor complaints.

PHOTOCATALYTIC OXIDATION

Pilot Tests Show Promise for Emerging Technology

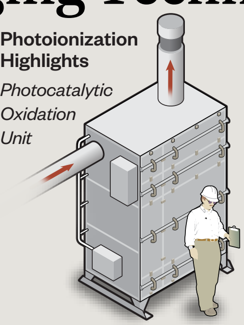
How Process Works



1 Odorous air is exposed to intense UV light, which creates free radicals that oxidize odorous compounds.

2 Air then passes through a catalyst, where remaining odorous compounds are adsorbed and broken down.

Photoionization Highlights



- small footprint
- handles very high concentrations of odorous compounds
- operates over wide temperature range
- low maintenance
- no water or chemicals
- very stable process
- low energy demand

One technology we expect further development of in the future is photocatalytic oxidation, which is currently more prevalent in Europe than in the United States. Photoionization is a two-step process: first, odorous air is exposed to intense ultraviolet light, which creates free radicals and hydroxyl radicals that will immediately begin oxidizing the odorous compounds. The air then passes to a catalyst, typically a metal impregnated carbon media, where the remaining compounds are either broken down, oxidized, or adsorbed by the carbon media. Photoionization is particularly efficient in treating high humidity gas streams.

While the process offers very limited control demand and is relatively easy, the technology can be very harmful to humans and should only be used in an enclosed chamber. The technology seems promising, but more pilot testing is required before further installations.

Hazen's Odor Control Expert

An internationally recognized odor control expert, Dick Pope has been involved in the planning and design of more than 230 odor control systems during his 37-year career, for clients including the New York City Department of Environmental Protection, Metropolitan Water Reclamation District of Chicago, and the City of Los Angeles Bureau of Sanitation. Dick is a contributing author to two WEF Manuals of Practice, acts as a reviewer for Water Environment Research Foundation odor research studies, and has made more than 100 presentations on air/odor related topics at colleges and various conferences. He is also the recipient of the 2015 Stanley E. Kappe Award from the American Academy of Environmental Engineering and Scientists.

Dick Pope, taking odor field measurements at waste lagoons in Israel.

AUTHOR: RICHARD POPE, PE, BCEE, VICE PRESIDENT

GRAPHICS BY JONATHON RIVAIT/HAZEN

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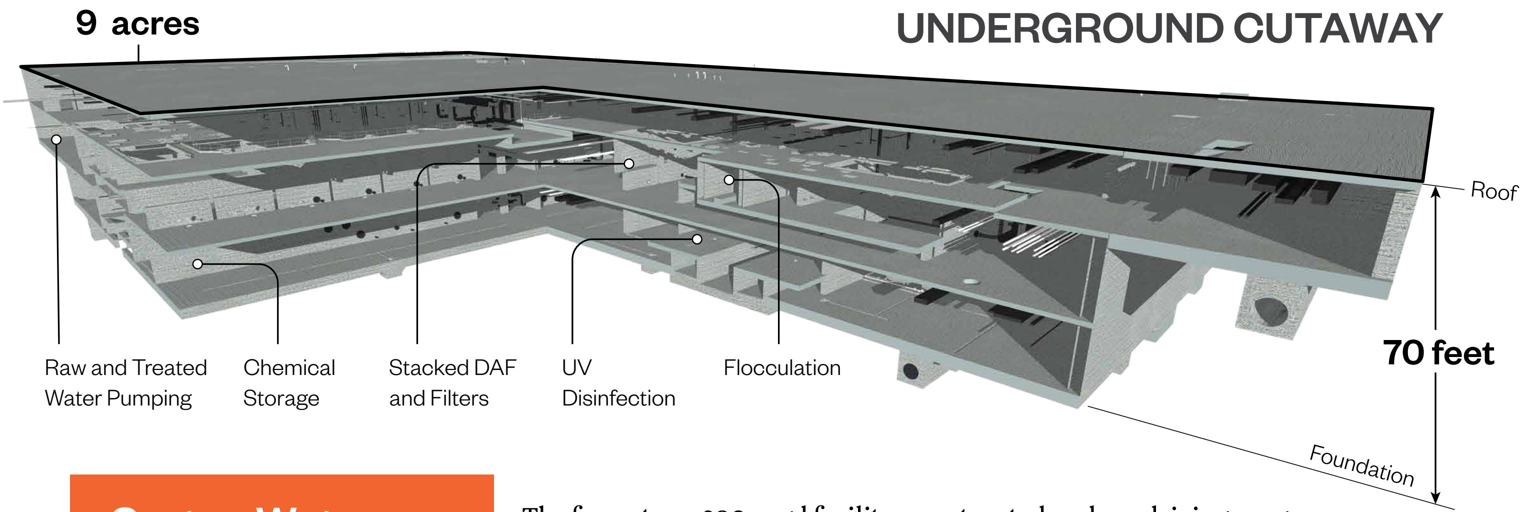
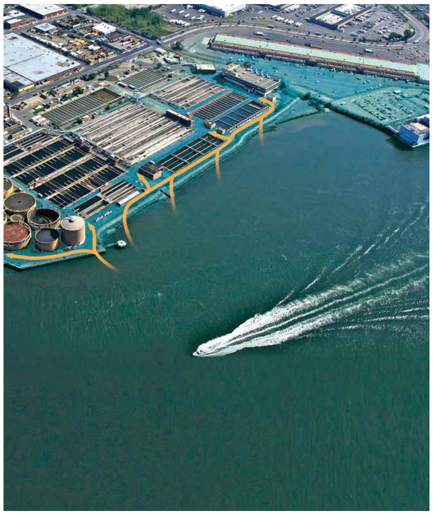


Croton Water Filtration Plant

ACEC-NY Diamond and MENY Project of the Year

The four-story, 290-mgd facility, constructed under a driving range, can provide roughly 30 percent of New York City's current daily water needs, providing critical system flexibility and redundancy. A high level of innovation was demonstrated by this project, including: use of stacked dissolved air filtration/flotation tanks (the largest in the world), followed by ultraviolet light disinfection (one of the largest in the world); state-of-the-art digital automation architecture and systems; and utilization of extensive Computational Fluid Dynamics and physical modeling throughout the design.



Climate Change Adaptation and Resilience

Hazen was honored for our leadership in climate change assessment and adaptation planning for water and wastewater utilities. In 2013, Hazen partnered with another firm on the NYC Wastewater Resiliency Plan, and in 2015, the firm began work (in joint venture) on the ongoing New York City Eastside Coastal Resiliency project. We have also performed studies on water and climate change for the American Water Works Association, Water Research Foundation, Water Environment Research Foundation, Water Services Association of Australia and other industry groups.

Nashville Metropolitan Government West Park Equalization Facility (Envision Platinum)

This is the first joint wastewater and park project in the U.S. to receive an ISI Envision rating award. By relocating this project in the park, the cost savings funded much needed park upgrades and new recreational facilities. The project's inter-agency collaboration provides two different community benefits: valuable park improvements and cleaner rivers and streams.

Bay Park Infrastructure Enhancements (ACEC-NY Platinum)

A vulnerability assessment of the Bay Park facility was performed using the 500-year flood elevation and projected 50-year sea level rise, leading to the unprecedented combination of a full perimeter barrier system and elevated non-submersible equipment.

Loxahatchee River Environmental Control District (FWEA Reuse System of the Year)

The innovative reuse program has grown to serve 13 golf courses and a 4-square-mile, mixed-use residential/commercial development with more than 6.6 million gallons daily. The 2015 actual daily benefit was over 8.0 mgd in direct conservation, as groundwater previously tapped by golf course water wells has now been made available for use by the local providers of the public water supply.

NYCDEP Water-Energy Nexus Study (ACEC-NY Platinum)

An important component of the Water-Energy Nexus study was to understand and model, for the first time, the relationship between program activities and resultant greenhouse gas co-benefits for green infrastructure, water demand management and conservation, wetland restoration, and forested conservation.

Learn more about these and other topics on our website.

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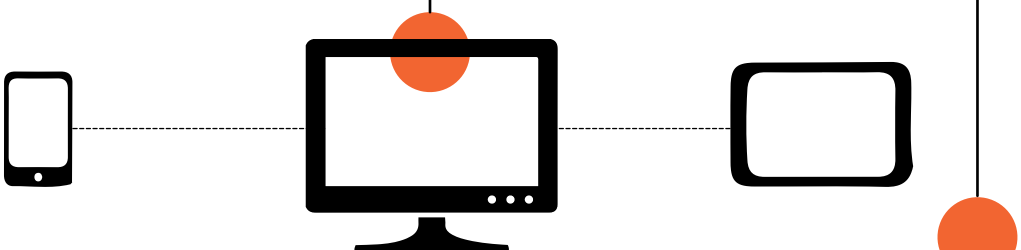

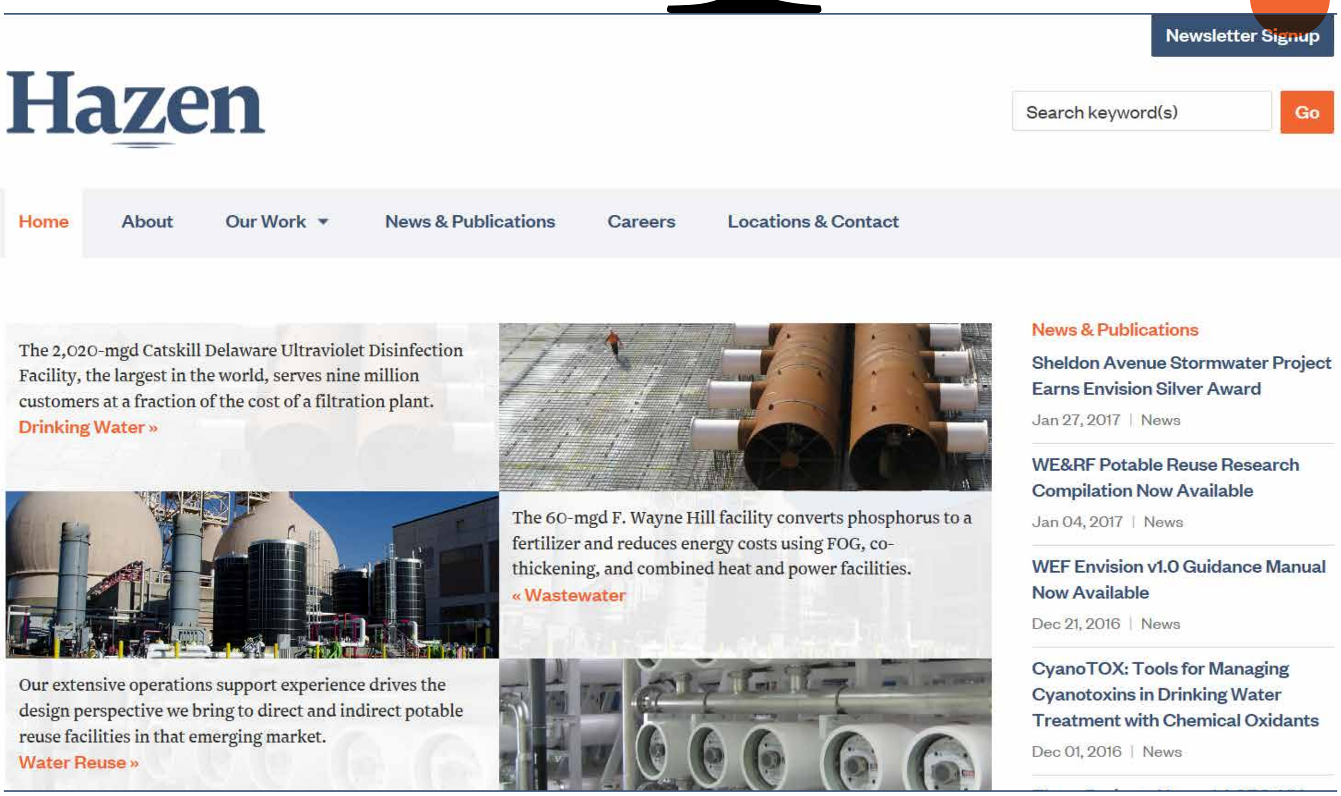

HORIZONS
water environment solutions

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Hazen

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