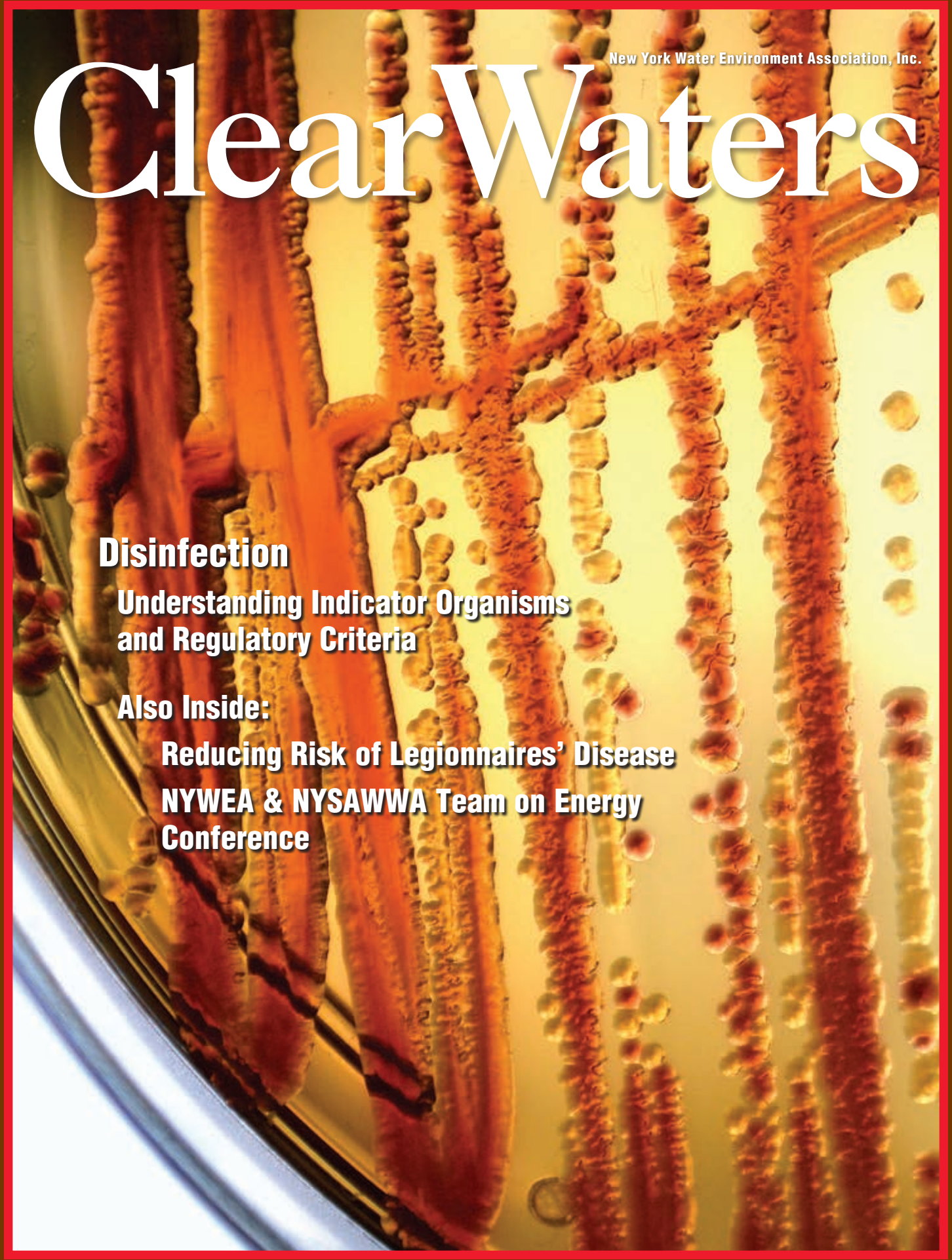
Winter 2016, Vol. 46, No. 4

New York Water Environment Association, Inc.

ClearWaters



Disinfection

Understanding Indicator Organisms and Regulatory Criteria

Also Inside:

Reducing Risk of Legionnaires' Disease

NYWEA & NYSAWWA Team on Energy Conference

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Clear Waters

New York Water Environment Association, Inc.

President's Message 4
Joseph L. Fiegl

Executive Director's Message 5
Patricia Cerro-Reehil

Highlights of NYWEA & NYSAWWA Joint Energy Conference 6–7

Water Views 9
James Tierney

Focus on Safety 9
Eileen Reynolds

Protection of Recreational Waters in New York 10
Jeff Myers

Survey Results Forwarded to New York State 14
Drew Smith

The Hunt for the Ideal Indicator Organism 16
Melanie Mann

Disinfection of Municipal Wastewater Effluent – What's in a Dose? 22
Katherine Y. Bell, Allegra K. da Silva and Joseph G. Jacangelo

USEPA's Proposed Bacteriophage Criteria for Recreational Waters 28
Thomas Worley-Morse and Samuel Jeyanayagam

Reducing the Risk of Legionnaires' Disease from Contaminated Water Systems 32
Dan Broder

Microfiber Pollution and the Apparel Industry 36
Bess Ruff, Nicholas Bruce, Niko Hartline, Stephanie Karba and Shreya Sonar

Recent Water-related Cases That May Impact NPDES/SPDES Dischargers 40
Libby Ford, Jesse Hiney, Alison Torbitt and Peter Trimarchi

WEF HQ "The Economic Impact of Water Infrastructure" 47
Marisa Tricas

WEF HQ " A Legitimate Reason to Have a Beer" 50
Rick Warner and Barry Liner

Team Has Eagle Eye on Floodplain Project 55
JoAnne Castagna

DEP Joins with the Billion Oyster Project 56
New York City Department of Environmental Protection

Operator's Quiz Test No. 113: Potpourri 61

Cover Image: Enterobacteria culture in agar jelly. The family of bacteria *Enterobacteriaceae* includes *Escherichia coli (E. coli)*. *E. coli* is one of the indicator bacteria used by regulatory agencies to evaluate water quality. *Photo: iStockphoto.com*

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NYWEA Disinfection Task Force

A few years ago, the New York State Department of Environmental Conservation (NYSDEC) notified the New York Water Environment Association (NYWEA) that it was studying indicator organisms to replace the fecal coliform standard promulgated in many State Pollution Discharge Elimination System (SPDES) permits. Since this modification would impact numerous water resource recovery facilities across the state, it drew the concern of NYWEA's Board of Directors. As a result, a separate task force was created to give this issue the attention it deserved.

Under Drew Smith's leadership, the Disinfection Task Force started a dialogue with the NYSDEC to ascertain the factors being considered in determining the path forward. Two bacteria indicator organisms have been evaluated by the NYSDEC based on federal regulations – *Enterococcus species* and *Escherichia coli (E. coli)*. Because there were limited data available on both, the Task Force's primary focus was to determine the effectiveness of existing disinfection systems on these indicator organisms. Many Operators across the state performed additional sampling and testing, and shared their information with the Task Force. Their results indicated that there was not necessarily a correlation between conformance with the existing fecal coliform standard and conformance with potential *Enterococcus* or *E. coli* limits.

Drew Smith's article on page 14 provides the latest on the Disinfection Task Force's efforts. I would like to specifically thank Drew, Tom Lauro and Mike Coley from Westchester County, and Brian Hilts from CDM Smith for their exceptional work on behalf of NYWEA. I also appreciate the work of Koon Tang, Meredith Streeter, and the other NYSDEC professionals that coordinated with the Task Force throughout. With the prospect of a new indicator organism being placed into SPDES permits, it is imperative that regulatory decisions are made with the best available data and science. As the NYSDEC evaluates changes to the disinfection standard, NYWEA will continue to keep its members informed.

Year in Review – Protecting and Enhancing Modern Society

I was told by many Past Presidents that my year as President would fly by. They were not kidding! While it has gone by quickly, I am very pleased with what the Association has accomplished over the last 12 months.

Funding Water Infrastructure. Early in 2016, there was a push by NYWEA and other stakeholders to address funding issues associated with critical water infrastructure systems. A multipronged approach was employed to educate state representatives on the need for grants to implement municipal capital improvements. It was announced in March 2016 that an additional $200 million would be made available through the "New York State Water Infrastructure Improvement Act." While this is a great start, NYWEA continues its work to increase grant availability for crucial water quality protection projects.

Legislative Outreach. NYWEA participated in meetings with elected officials to better inform them of issues facing our members. For the first time, NYWEA took part in "Great Lakes Day" in Washington D.C., to address the need for federal infrastructure funding. NYWEA reinforced that message later in the year by participating during the "WEF Fly-In." On the state level, NYWEA held its annual Legislative Dialogue in Albany to discuss our industry's concerns, including disinfection standards, nutrients, and funding. NYWEA also offered testimony during a state legislative public hearing on "Water Quality and Contamination" to provide an industry perspective on this topic.

Educational Programs. Strong educational programs continue to be a hallmark of NYWEA. NYWEA held its regular, well-attended events such as the Annual Meeting, a joint Spring Meeting with the New England Water Environment Association, and the New York City Watershed Science and Technical Conference. In addition to these offerings, NYWEA co-hosted an Energy Specialty Conference with the New York Section of the American Water Works Association. NYWEA also developed its first ever webinar to supplement the 18 in-person member education opportunities offered across the state.

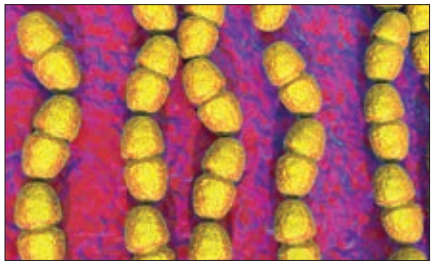
Messaging Initiatives. My chief focus as President has been on changing perceptions by promulgating a message touting the benefits and accomplishments of the clean water industry. In 2016, the NYWEA Board approved utilizing the term "water resource recovery" in lieu of "wastewater treatment" to modernize our vernacular and re-focus our terminology on the benefits of our services rather than the wastes that we process. Articles in *Clear Waters* on Lake Erie, Onondaga Lake, the Hudson River, and Jamaica *Bay* *(see page 56)* have highlighted a few waterways benefiting from improvements advanced by our industry. We are proud to have worked with the Long Island Chapter in developing their own messaging tri-fold to communicate to elected officials and the general public.

There have been many other ways NYWEA has promoted the work of our members; however, I am most pleased with NYWEA's progress on messaging initiatives. Khris Dodson and his staff at the Syracuse University Environmental Finance Center beautifully captured the importance of the clean water industry in two brand new endeavors – a professional messaging document and an associated messaging video. These products communicate how water resource recovery systems – and the people that operate, maintain, and improve those systems – protect and enhance our modern society. I look forward to unveiling both during the opening session of NYWEA's 89th Annual Meeting in February 2017.

There are many other items I look back on with pride: NYWEA winning the WEF Outstanding Member Association Award; sending three operations challenge teams to WEFTEC for the first time; completing NYWEA's 2016-2021 Strategic Plan; advancing new operator pre-certification courses; signing the next cooperative agreement to administer the state's Operator Certification program; and much more. I feel fortunate to have spent this last year as president of such a tremendous organization of great people. I know that the Association will flourish next year under the leadership of President-Elect Paul McGarvey.

Joseph L. Fiegl, PE, NYWEA President

Disinfection is the final and critically important part of the wastewater treatment process. Chlorine was once the most common disinfectant at water resource recovery facilities; that is no longer the case, as you will see from Drew Smith's article on page 14. NYWEA's Disinfection Task Force has shared the results of a survey of member facilities with NYSDEC to help shed some light on the real-life experiences at these plants. Many thanks to the people that participated in this survey. This survey and the importance of the disinfection process inspired the members of the Publications Committee to dedicate an entire issue to Disinfection. We hope it is useful and informative to you!



***Enterococcus faecalis* is one of the bacteria under consideration by NYSDEC as a possible fecal indicator. The Disinfection Task Force found that 21.7 percent of water resource recovery facilities responding to the survey currently monitor for *Enterococcus*.**

WEF Outstanding Member Achievement Award

I was honored to attend WEFTEC with NYWEA staff Maggie Hoose, Maureen Kozol and several members pictured here from the NYWEA Board of Directors to receive the WEF Outstanding Member Achievement Award. As President Fiegl stated in his Message in 2016 Volume 46, No. 1, "All members should be proud of this award, it is not for one individual or staff alone, it is the team of people who are involved and engaged and volunteer, who have helped shape the organization into what it is today."

89th Annual Meeting

Plan to attend NYWEA's 89th Annual Meeting! This three day conference includes 26 technical sessions, and carries the theme "Protecting and Enhancing Modern Society". The Opening Session will include a Keynote presentation by Elizabeth Royte, author of *Garbage Land* and *Bottlemania*. WEF President Rick Warner will also address members, and Pamela Elardo will talk about her new role and oversight at NYCDEP's 14 utilities that process 1.3 billion gallons of wastewater for the nearly 10 million people who live and visit NYC. Last year over 1,400 people attended the meeting, we are expecting this year to be bigger and better. Please plan to be with us in New York City, February 6-8, 2017.

An Invitation to Participate!

The end of one year and the beginning of a new one are reflective times. If you are one of the over 400 volunteers listed in the Who's Who we thank you wholeheartedly for your service to this great organization! If you are a member who has not been involved or engaged we have some newly posted videos on NYWEA's website that might just convince you to connect on a deeper level. We are sure you will not regret the time you spend helping to advance NYWEA's mission!

Patricia Cerro-Reehil
pcr@nywea.org

The broadest and maybe the most meaningful definition of volunteering:
"Doing more than you have to because you want to, in a cause you consider good." – *Ivan Scheier*

(L-r): Maggie Hoose, Administrative Manager; John Fortin, Senior WEF House of Delegates Representative; Maureen Kozol, IT Specialist; Joseph Fiegl, President; Patricia Cerro-Reehil, Executive Director; Steven Fangmann, Government Affairs Committee; Paul McGarvey, President-Elect; Geoff Baldwin, Vice President; Richard Pope, WEF House of Delegates Representative; and Robert Wither, Vice President-Elect.

Desmond Hotel, Albany, NY

Highlights of NYWEA & NYSAWWA Joint Energy Conference

On November 16th the NY Section American Water Works (NYSAWWA) along with the NY Water Environment Association (NYWEA) teamed together to hold a Joint Energy Conference at the Desmond Hotel in Albany.

The meeting was kicked off by a warm welcome from NYWEA's President Joseph Fiegl, and NYSAWWA chair, Mary Aman. One hundred-thirty individuals attended and gained knowledge from those municipalities who are taking steps to improve energy efficiency.

The keynote address was delivered by Diego Rosso, Associate Professor in the Civil and Environmental Engineering Department University of California Irvine (UCI). Diego is also the Director of the Water-Energy Nexus Center at UCI and gave an interesting and entertaining presentation on how much energy can be captured at water resource recovery utilities across the globe.

NYWEA President Joe Fiegl welcomes attendees to Joint Energy Conference.

NYSAWWA Chair Marty Aman introduces keynote speaker, Diego Rosso.

Samuel Jeyanayagam of CH2M

Silvia Marpicati

Paul Kohl from Philadelphia Water Department

Keynote speaker, Diego Rosso, inspires attendees on the Energy/Water Nexus.

(L-r) Diego Rosso, Brian Gackstatter of CH2M and Samuel Jeyanayagam of CH2M

Maggie Hoose and Garry Robinson at the Registration Desk.

Deborah Sills from Bucknell University and Cornell Energy Institute

Neil Stradling of Siewert Equipment

Right: (l-r) Jake Scherer of CPE and Tom Herd of Chesterton man their exhibit booth.

Bucky Brennan of Milton CAT

Gary O'Connor, AKZO Nobel

Water Views | Winter 2016

Tackling Toxic Algae

Recent *New York Times* "Science Times" articles (July 19, 2016) highlighted an increasing national and global problem of toxic algal blooms. But what can be done? A lot.

The main culprits are phosphorus in fresh water, and nitrogen in salt water. These nutrients fertilize our waters causing massive algae growths with resulting impacts like low dissolved oxygen, fish and shellfish kills, toxics from "harmful" algae, odors, beach closures and a cascade of potentially unhealthful impacts on drinking water.

Water resource recovery facilities (WRRF), septic systems, polluted urban runoff, lawn fertilizers, eroded sediment and animal feeding operations are just some of the nutrient sources, along with atmospheric nitrogen deposition from coal-fired boilers.

Here in New York, we have worked with partners to track, report and provide warnings on toxic algal blooms (visit the *DEC Harmful Algal Blooms Notifications* webpage). Heightened treatment systems have been placed on WRRFs discharging to troubled waters. We have developed state-of-the-art nutrient management programs for larger animal feeding operations, and a grant-supported voluntary program for other farms.

Other efforts benefitting water quality include: legislation enacted to reduce phosphorus in lawn fertilizer and dish-washing machine soaps; programs and initiatives to regulate and reduce combined sewer overflows and pollutants in urban runoff; install green infrastructure; and eliminate coal use in power plants.

Addressing nutrient pollution is not easy. Phosphorus and nitrogen compounds are essential elements of life, existing everywhere over the landscape. Compounding the difficulty, the quality of fresh water can be reduced by phosphorus levels exceeding only 20 parts per billion.

We do succeed. New York and Connecticut embarked on a successful program to reduced nitrogen discharged to Long Island Sound by 58 percent, with New York's investment of about $2 billion. The open Sound's nitrogen-induced "dead zone" is shrinking and the oxygen deficit severity has lessened dramatically. In the New York City Water Supply watershed, comprehensive management reversed the severe phosphorus impairment of the Cannonsville Reservoir.

In 2015, New York established a new three year, $400 million clean water infrastructure initiative, and this past year increased its environmental protection fund from $177 million to $300 million. Our water infrastructure loan fund is the largest and most innovative in the Nation. Aggressive location-specific initiatives and infrastructure projects, like those on Long Island's south shore, are underway. New York takes its responsibilities to enforce the Clean Water Act seriously.

What is missing is a sustained federal financial investment. A recent Congressional Budget Office Report stated only four percent of clean water infrastructure funding comes from the federal government. Perhaps it is time to put the "federal" back in the Federal Clean Water Act and the Federal Safe Drinking Water Act – to truly take on the menace of toxic algal blooms and much more.

– James Tierney, Assistant Commissioner for Water Resources
NYS Department of Environmental Conservation

Focus on Safety | Winter 2016

Managing Change with a Risk-based Approach

Many of you are familiar with the OSHA standard, "Process Safety Management of Highly Hazardous Chemicals" (PSM) and the USEPA's requirement for Risk Management Plans (RMP) for facilities that have a requisite amount of certain chemicals. Past tragedies such as Bhopal in India and Flixborough in the U.K. showed the need for a systematic manner to assess and control risk to protect both workers (OSHA) and the public (RMP).

Elements of the PSM standard are very useful for non-chemical processes as well, and the proactive manager or superintendent of a facility would be well-served to include these elements into their management plans. The use of the PSM structure in a non-PSM covered facility is a movement away from a regulatory-based structure to a risk-based approach.

Recently, I was involved with a manufacturing facility that needed to move a portion of their fabricating process from one location to another in that same facility. It was a significant change for this company. The staff were experiencing a great deal of change happening at one time, including personnel changes at key positions. While the staff involved in the move had a great deal of tribal knowledge and experience, their usual approach to managing change was to react to it after it happened. However, the scope of this move forced them to start thinking about change in a manner that was new to them. Using elements of PSM, staff were gathered from several department – including accounting, safety and engineering – and got the ball rolling. Key areas implemented included mutual agreements, safety considerations, timelines, inspections, standard operating procedure (SOP) development, shake down trials, training and documentation. These areas should be very familiar to those with PSM facilities but for the staff of this manufacturing plant, these were 'borrowed' ideas from the chemical world.

Reasons that organizations might not follow this type of risk-based approach include: contentment to operate under a regulatory limit without having to comply with another mandate; and the perception of higher cost to the business. However, imagine the positive outcomes if the food plant down the road that uses ammonia refrigeration didn't have a toxic release. Or the fertilizer plant in the next town didn't have an explosion. We have heard on the news of terrible accidents due primarily to process failures. Keep in mind that the 'process' referred to is not necessarily the process used in production but the process of organizational management, its changes and its risks. Any one of these businesses would probably look back in hindsight and wonder how their professional and personal lives would be changed if they had only been willing to think about risk in a different way.

If you would care to learn more about the concept of management of change, our own Mike Garland penned an excellent article for the American Institute of Chemical Engineers. Other resources can be found on the web, often tailored to specific industries – whether a PSM or non-PSM covered facility.

– Eileen M. Reynolds, Certified Safety Professional
Owner, Coracle Safety Management

There are many lakes and rivers in New York where people can canoe and fish.
New York City Department of Environmental Conservation

Rising Expectations: Protection of Recreational Waters in New York

by Jeff Myers

The concept of what constitutes a "recreational water" has changed significantly in the five decades since the New York State Pure Waters Program and subsequent federal Clean Water Act were adopted. Prior to the establishment of basic wastewater treatment requirements through these and other environmental laws passed in the 1960s and 1970s, recreation – swimming, boating, fishing – in many waterways of New York state was beyond imagination. Waters like the Hudson Estuary, New York Harbor, Onondaga Lake, Buffalo River and many others received millions of gallons per day of untreated or partially-treated municipal and industrial wastewater. In fact, New York state regulations at that time included water quality classifications for which the "best usage" was for "sewage or industrial waste disposal."

The first step toward the restoration of these recreational waters was the New York State Pure Waters Program proposed by Governor Rockefeller in 1964. A year later New Yorkers voted by a 4 to 1 margin to support the program with a $1 billion ($7.5 billion in today's dollars) bond issue, launching the largest and most comprehensive water pollution control program in the world.

New York's Pure Waters Program also laid the groundwork for the federal Clean Water Act. The 1972 amendments to the Federal Water Pollution Control Act declared a goal "which provides for the protection and propagation of fish, shellfish, and wildlife and provides for recreation in and on the water", also known as the "fishable/swimmable" goal. The 1972 amendments also established the National Pollutant Discharge Elimination System permit program (NPDES) that focused on technology-based standards for point sources, and provided additional billions of dollars in grants for sewage treatment plant construction in order to advance the fishable/swimmable goal.

Because of these actions, water quality throughout the state has rebounded remarkably over the ensuing years. Today it is easy to imagine water recreation in virtually any lake, river, stream or embayment in the state. Even those waters where recreation was previously thought to be out of reach are now commonly used for boating, fishing, swimming, and other contact recreational activities of growing popularity such as kayaking, paddle boarding and jet skiing.

The Last Piece of the Puzzle

However, despite the tremendous water quality gains for lakes, rivers, streams and estuaries of the state, one concern remains:

Karen Williamson

Water resource recovery facility discharge outfall

pathogen contamination. Pathogenic organisms of greatest concern in domestic wastewater include enteric bacteria, viruses, and protozoan cysts. These pathogens, if ingested, can cause human illness; most commonly, these are short-term gastrointestinal illnesses (stomachache/diarrhea). The primary mechanism for inactivating or destroying pathogenic organisms in sewage and preventing the spread of waterborne illness to downstream users and the environment is disinfection.

Disinfection of wastewater discharges was not broadly included among the requirements of early environmental regulation of the 1960s and 70s; in hindsight, this seems like an obvious oversight. In fact, disinfection *was* recognized to be an important element for the protection of public health and the requirement of year-round disinfection was *initially* considered for municipal wastewater discharges. But a 1974 review of the wastewater disinfection requirements by U.S. Environmental Protection Agency (USEPA) determined that such requirements inadvertently promoted an increase in chlorine discharged to the environment, since chlorine and chlorine compounds were almost exclusively employed for disinfection. This raised concerns regarding the toxic effects of chlorine on aquatic life, and the potential for the formation of chlorinated organic compounds which were identified as potential carcinogens. Chlorination followed by dechlorination prior to discharge – or the alternative, ultra-violet disinfection, which became a later option – eliminated aquatic life and water supply impacts, but at increased costs. Additionally, the idea of disinfecting *all* municipal discharges to protect swimming use in waters – including those where swimming was largely unimaginable – seemed dubious. In 1976, USEPA deleted disinfection requirements from federal wastewater treatment regulations and left future requirements for disinfection to the states. As a result, disinfection of wastewater in New York was generally required only where necessary to protect public health due to the use of the waterbody as a water supply (Class A waters) or a designated public bathing beach (Class B waters).

But times and expectations have changed. Because of the success of clean water legislation in the 1960s and 70s, New Yorkers today are likely to wade out to fish, launch a kayak or canoe, or jump off a boat into almost any lake, river, stream, canal, bay or harbor in the state. But while these waters look much cleaner, additional work – and public awareness – is necessary to fully protect the recreating public.

The first step is to address municipal wastewater sources of pathogens. Currently about ninety percent of the treated municipal wastewater discharged in New York state is disinfected. And the state is working to address the remaining ten percent of municipal wastewater where disinfection is not required. This effort includes identifying the remaining facilities that are likely to have the greatest impact on water quality and recreational use, evaluating the readiness of facilities to undergo upgrades, and providing grants (when available) to assist facilities with meeting new disinfection requirements.

The New York State Department of Environmental Conservation (NYSDEC) Division of Water has reviewed those wastewater facilities that are currently not disinfecting their effluent and has prioritized them based on the potential impact to public health and safety and environmental concerns. Potential impact factors evaluated include the facility's proximity to residential or recreational areas and waterbodies used as sources of drinking water or for swimming. Facilities were also evaluated for "readiness" for disinfection, which was measured by whether the facility has an existing plan to upgrade its treatment system.

To mitigate the financial impact of adding disinfection capability to these treatment plants, NYSDEC is working to identify funding through its Water Quality Improvement Projects (WQIP) and Engineering Planning Grant (EPG) programs to assist communities. It is likely that there will be insufficient funding to address all disinfection needs. However, assistance for the installation of disinfection of water resource recovery facility (WRRF) effluents is expected to remain one of the highest priorities for funding for the foreseeable future.

New York City Department of Environmental Conservation

Motor boating is a popular recreational activity.

The Remaining Steps

Expanding the requirement for disinfection to all municipal WRRFs is the obvious next step in the march toward the fishable/swimmable goal. But there are other sources that contribute to pathogen contamination, as well as other considerations that need to be addressed. These include:

- **Combined Sewer Overflows (CSOs) and Sanitary Sewer Overflows (SSOs)**

  Wastewater collection systems can be overwhelmed during high rainfall and other wet-weather events. In the case of CSOs, this is by design to protect the WRRF. SSOs are the result of infiltration and inflow that is largely due to aging infrastructure. Long-term Control Plans to minimize CSO impacts, infrastructure investment and asset management are necessary to address sanitary sewer system inadequacies so that the wastewater stream can get to the plant for disinfection before entering the waterways.

- **Smaller Wastewater Treatment Systems**

  While municipal wastewater systems are the focus of current efforts, smaller systems serving residential developments, trailer parks, schools, hospitals and other institutional facilities are not typically required to disinfect their effluent. Though wastewater volume from these facilities is much less than from municipal facilities, they also may discharge to smaller streams and cause localized pathogen impacts.

- **Seasonal Disinfection**

  Even where disinfection of WRRF discharges is required, in many cases the requirement is for seasonal disinfection, typically from May through October. This approach assumes that recreational contact in lakes, rivers, streams and estuaries occurs predominantly within these months. However, this assumption may be flawed; while recreational contact during the colder months

continued on page 12

continued from page 11

is less likely, it does occur. For example, the high temperature in many areas of New York state last Christmas Eve was in the 70s, and local weather reports featured people wading into waters to fish.

- **Nonpoint Stormwater Runoff**

  Stormwater runoff from roadways, rooftops and other impervious surfaces in densely populated areas does not soak into the ground but runs off or is conveyed by storm sewer systems into waterways. This runoff contains pathogens from a variety of sources including litter, garbage, pet wastes, and illegal discharges to storm sewers. Stormwater runoff from agricultural lands can also contain significant levels of pathogens if best management practices are not in place to reduce runoff and erosion, manage manure spreading, and keep cattle from streams. Failing and/or inadequate onsite wastewater treatment (septic) systems that serve individual residences can also be a source of pathogens to nearby lakes, streams and embayments.

- **Waterfowl and Wildlife**

  And then there are additional sources that may be beyond our ability to effectively control. A recent investigation of a discharge pipe to a lake in New York City revealed high levels of coliform bacteria. After eliminating CSOs and residential sanitary sewers as likely sources, it was determined that the coliform levels were attributable to droppings from the large flocks of geese and ducks that graze on the adjoining parade grounds. Interestingly there were several families and small groups recreating on the same parade grounds – seemingly unconcerned about the pathogen levels on the ground.

Public Awareness

Clearly, in the last half-century the progress that has been made to open more of New York's waters to recreational use has been remarkable. The efforts and investments to continue this progress are underway. At the same time, we should also evaluate the degree to which it is possible to completely control the occurrence of something as ubiquitous as pathogens in open waters. Certainly, a continued focus on maximizing the capture and treatment (disinfection) of domestic wastewater from municipal sources is needed; perhaps that effort should be expanded to smaller wastewater systems as well. Programs to address nonpoint sources – both urban and agricultural – are also gaining traction, despite challenges.

Although the progress will undoubtedly continue, there should be a recognition that such progress might not be at the pace some would hope for, or even equal to the pace of past progress. Additionally, it might not be feasible (either technically or economically) to push pathogen levels down to inconsequential levels in all waters, at all times. But if the goal for recreation in lakes, rivers, streams and estuaries is set at a similar bar as for other recreational activities – like biking, for example, which should generally be avoided during rainstorms, in the winter, and on crowded freeways – then New Yorkers will continue to have ample opportunity to enjoy recreation on and in the waters of the state.

Jeff Myers is the Director for the Bureau of Water Assessment Management in the New York State Department of Environmental Conservation. The mission of the Bureau of Water Assessment Management is to monitor the waters of the state, review data and information to evaluate these waters, and report on the quality and the ability of these waters to support uses. Mr. Myers may be reached at jeff.myers@dec.ny.gov.

New York City Department of Environmental Conservation

Tubing on New York's rivers can be relaxing or exhilarating.

From the Chair of the NYWEA Disinfection Task Force:

Survey Results Forwarded to New York State

by Drew Smith

Photo, Laura Mangerian

Drew Smith

The New York State Department of Environmental Conservation (NYSDEC) is reviewing the possibility of changing State Pollutant Discharge Elimination System (SPDES) permit fecal indicator bacteria (FIB) to *Escherichia coli (E. coli)* for fresh water and *Enterococcus* for salt water. This is due to pressure from the U.S. Environmental Protection Agency (USEPA) to bring the state into compliance with the 2012 national recommended Recreational Water Quality Criteria (RWQC) under the Beaches Environmental Assessment and Coastal Health Act (BEACH Act).

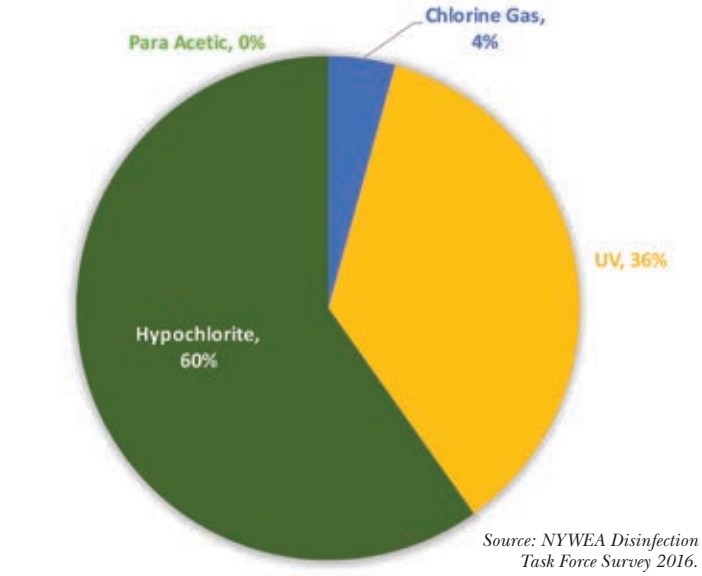
Although it was initially thought that this would be a no-cost change, NYWEA's Disinfection Task Force conducted a survey among the membership to see where our water resource recovery facilities (WRRFs) stand regarding disinfection technology employed to kill bacteria, including installation and operation and maintenance (O&M) costs. Due to the exceptional turnaround time from 50 contributors (approximately 10 percent of WRRFs in New York), we quickly forwarded the survey results to the state. The state was very appreciative for this information and the reasonable cost estimates we provided should help guide their review process.

The survey supplied much needed data on many variables for the state to consider in addressing fecal indicator bacteria. Let me throw out some statistics obtained from the survey:

- 60 percent of WRRFs disinfect year-round
- 100 percent of WRRFs measure fecal coliform as per the Environmental Conservation Law
- 4.3 percent of WRRFs measure *E. coli*
- 21.7 percent of WRRFs measure *Enterococcus*

From the data, it is evident that compliance with the 2012 RWQC will take more chemicals or more energy for an effective kill rate of bacteria at most WRRFs. Reports offered at a recent WEFTEC stated that a dose of between 150 to 400 percent of the chlorine would be needed to kill *Enterococcus* as opposed to fecal coliforms *(Sharp et al, 2016)*. That is a significant increase in operation costs.

Percent of NY WRRFs That Disinfect with:



Source: NYWEA Disinfection Task Force Survey 2016.

Additional results from the NYWEA disinfection survey provide information on how disinfection is performed at our members' facilities, and what the average costs are to install and maintain a system:

- 60 percent of WRRFs disinfect with hypochlorite
- 36 percent of WRRFs disinfect with UV
- 4.3 percent of WRRFs still use chlorine gas
- 0 percent of WRRFs use para acetic acid (PAA) despite this push from our technical conferences
- $1.25 million is the average capital cost to install a disinfection system
- $95,100 is the average O&M annual costs to operate a disinfection system
- 5.7 ppm is the average chlorine dose to meet permit requirements
- $8,800 is the average cost increase to double energy to treat a new FIB

With the potential increase in chemical use, and with chlorine as the most used chemical, permits will not only reflect a change in FIB but also an adjustment in strict chlorine residual numbers. This may lead WRRFs to reconsider the chemical applied or potentially look at UV as an alternative. Either way there will be capital costs associated with these changes.

The survey results reported by our membership relative to dechlorination indicated that:

- 18 percent of WRRFs dechlorinate their effluent
- $302,500 is the average capital cost for a dechlorination system
- $20,200 is the average annual dechlorination O&M costs

Of course, these costs are averages and the numbers vary wildly based on the application and the size of the plant. You can still get the impression that these changes are not a "no cost" change to our environmental permitting process.

NYWEA is committed to supporting all member WRRFs. We have a large membership that is highly dedicated to water quality. This is evident due to the responses we got when we asked our survey questions for FIB comparison data.

Stay tuned, I intend to stay in touch with the process at the state and give an update at the spring meeting in June 2017.

Drew Smith is the NYWEA Chairman of the Disinfection Task Force and Regulatory Compliance Manager for Monroe County in Rochester. He has 25 years of service to Monroe County and 33 total years in water quality. He can be reached at dsmith@monroecounty.gov

Reference

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The Hunt for the Ideal Indicator Organism

by Melanie Mann

Routine monitoring of indicator organisms is an important tool for reducing the risk of disease from waterborne pathogens, whether disease occurs from consumption of drinking water or from incidental ingestion of recreational waters. Recreational waters of concern include ambient waters at beaches, lakes, and rivers where ingestion of water may occur during swimming or water contact may occur during other activities such as fishing. Recreational waters also include venues that use treated water, such as public swimming pools and water parks. Indicator organisms are also used to monitor water quality and microbial risks in other arenas, including shellfish harvesting, food production, biosolids treatment, and non-potable water reuse applications such as irrigation and aquaculture.

Indicator organisms are used because it is not practical to test waters for each and every potentially waterborne human pathogen that may be present in a given water sample. Pathogenic microorganisms include bacteria, viruses, and protozoan parasites.

This article reviews current and proposed groups of fecal indicator organisms used to monitor water resource recovery facility (WRRF) effluents and ambient recreational waters in the U.S., as well as the characteristics of ideal indicator organisms as compared to indicator organisms currently in use.

Characteristics of an Ideal Indicator Organism

The perfect fecal contamination indicator organism has not been found, but it is useful to consider what properties an ideal indicator organism would have. The *ideal* indicator organism should:

1. Be present when fecal contamination is present (in raw and treated waters)
2. Occur at concentrations higher than pathogens of interest
3. Persist in the environment similarly to pathogens of interest
4. Should not reproduce outside the host organism
5. Be relatively safe compared to pathogens to reduce the exposure risk to laboratory staff
6. Be detectable by a method that is simple, fast and inexpensive, as compared to specific pathogen detection methods
7. Occur in fecal waste but not occur from other sources. (list adapted from *Pepper (2009)* and *Edzwald (2011)*).

Although none of the current fecal indicator organisms meet all the criteria of an ideal indicator as listed above, the U.S. Environmental Protection Agency (USEPA) has periodically refined its list of recommended indicator organisms to better meet many of these criteria. In the U.S., the indicator organisms that have been used to establish regulatory limits for WRRF effluents and recreational waters have been specific groups of bacteria. Viruses and protozoa have traditionally not been used as indicator organisms for these waters due to several limitations.

Individual pathogens do not make good fecal contamination indicator organisms. While human fecal waste always includes non-pathogenic bacteria, it will only include pathogens when individuals are infected. Moreover, concentrations of pathogens tend to be lower than concentrations of traditional indicator bacteria in fecal waste, which can make the pathogen quantification more difficult.

Viruses meet the ideal criterion of not reproducing outside the host organism, since they require host cells for reproduction. By contrast, typical indicator bacteria, which are usually present when fecal contamination is present, can reproduce outside their host organism in the environment, posing some challenges when assessing the presence of fecal contamination. However, detecting and enumerating viruses is more complex, more time-consuming, and more expensive than detecting and quantifying typical indicator bacteria.

Although bacteria are overall a better match with the ideal criteria than pathogens or viruses, all bacterial indicators used in the U.S. have some potential nonfecal sources. Since the ideal indicator organism has yet to be found, several bacteria species which best meet the criteria are currently used as regulatory indicator organisms.

Current Indicator Organisms in WRRF Effluents and Recreational Waters

Several bacteria species, or groups of bacteria species, have been used in the U.S. as fecal indicator organisms in WRRF effluents and in recreational waters. Regulated bacterial indicators have included total coliforms, fecal coliforms, *Escherichia coli (E. coli),* and *Enterococcus.* These indicators have been incorporated into many states' water quality criteria and into National Pollutant Discharge Elimination System (NPDES) permits for WRRF effluents. The concentration of indicator organisms in effluent is an indication of the effectiveness of the disinfection process at the facility; however, treatment processes upstream of disinfection also contribute to reducing the concentrations of pathogens and indicator organisms in the WRRF effluent.

Total coliforms are a large group of many bacterial species in the family *Enterobacteraceae.* Total coliforms are found in higher concentrations in fecal waste than any other fecal indicator, and for this reason they are a good indicator of potential fecal contamination. Some members of the total coliform group can also grow in the environment, so while the presence of total coliform indicates potential fecal contamination, total coliforms alone do not prove fecal contamination. For example, the Revised Total Coliform Rule for drinking water *(USEPA, 2013)* requires testing for total coliform to indicate potential fecal contamination, with a positive result requiring additional tests for fecal coliform or E. coli for added specificity. Total coliforms are also sometimes used as indicator organisms in WRRF NPDES permits; however, most states now use one of the other more specific bacterial indicators for this purpose.

Fecal coliforms are a subset of total coliforms, including *Escherichia coli, Enterobacter,* and *Klebsiella.* Fecal coliforms have fewer nonfecal sources than total coliforms and as such they are a more specific indicator of potential fecal contamination. However, some members of the fecal coliform group can also occur in nonfecal wastes. Fecal coliforms are still the primary regulated indicator organism for many WRRF effluents in the U.S.

E. coli is a member species of the fecal coliform group and is even less likely than fecal coliforms as a group to come from nonfecal sources. *E. coli* is thus a more specific indicator of fecal contamination than total coliforms and fecal coliforms. The USEPA also found *E. coli* was better correlated than fecal coliforms to rates of gastroenteritis in swimmers in fresh water, based on studies conducted in the 1970s and 1980s *(USEPA, 1986).* Therefore both

Photo courtesy of Raul Gonzalez

Environmental sampling for indicator organisms

USEPA's 1986 Ambient Water Quality Criteria for Bacteria *(USEPA, 1986)* and the more recent 2012 Recreational Water Quality Criteria (RWQC) *(USEPA, 2012)* recommended *E. coli* instead of total coliforms or fecal coliforms as a better indicator of fecal contamination of fresh waters. Many states that used total coliforms or fecal coliforms as indicator organisms for WRRF effluents in the past have changed, or are in the process of changing, to NPDES permit limits based on E. coli in fresh waters.

Enterococcus bacteria are a group of spherical-shaped bacteria that occur in raw wastewaters in similar concentrations as *E. coli*. *Enterococcus* can be found in nonfecal sources as well. While USEPA's studies in the 1970s and 1980s showed that *Enterococcus* and *E. coli* were both correlated to rates of gastroenteritis in swimmers in fresh water, the correlation in marine waters was much better for *Enterococcus* than for *E. coli*. Accordingly, the USEPA's 1986 and 2012 RWQC recommended Enterococcus as the indicator of choice for marine recreational waters. Many states that used fecal coliforms as indicator organisms for WRRF effluents discharging to marine waters have changed, or are in the process of changing, to NPDES permit limits based on Enterococcus in marine waters.

Other organisms have been used for various purposes and for water quality and epidemiology research efforts; however, in the U.S. fecal coliforms, *E. coli* and *Enterococcus* are the most widely used indicator organisms for WRRF effluents and recreational waters.

Potential Future Indicator Organisms

Viruses that infect the current indicator organisms may themselves be used in the future as indicator organisms. Bacteriophages are viruses that infect bacteria, and coliphages are a group of viruses that infect *E. coli* and other coliform bacteria. Coliphages are classified as either somatic coliphages or male-specific coliphages, depending on the way they access and infect *E. coli*. Coliphages are of interest to the microbial monitoring community because of the potential that a viral indicator will more accurately indicate the presence of viral pathogens as compared to traditional bacterial indicators. Coliphages are of fecal origin, and are always present in raw wastewater, although they are not present in fecal waste of all humans at all times. Coliphages are similar in size to many pathogenic viruses, and they may have similar response to wastewater treatment and disinfection processes as human enteric viruses. The U.S. Ground Water Rule *(USEPA, 2006)* already allows the use of coliphage to indicate potential fecal contamination of groundwater. Some water reuse regulations, such as those used in North Carolina *(NCAC, 2011)*, also allow the use of coliphage for monitoring adequate disinfection of reclaimed water.

Challenges of Using Indicator Organisms to Monitor Wastewater Disinfection

Water resource recovery facilities in the U.S. use a variety of disinfectants, and each disinfectant has different rates of inactivation for the various fecal indicator bacteria *(E. coli* and *Enterococcus),* for the two types of coliphages (somatic and male-specific), and for the large range of waterborne human pathogens (bacteria, viruses, and protozoa). In addition, the relative density of the different bacterial and viral indicator organisms can vary with each facility's effluent, and may even change with season. Therefore, effluents that have the same concentration of *E. coli* or *Enterococcus* may have different concentrations of coliphages or pathogens.

Wastewater NPDES permits are administered by each state, and WRRF disinfection process design and permit requirements vary among the states. As one example of differing permit requirements, some states require a chlorine contact time of 30 minutes at average flow rate, but require no minimum chlorine residual after the contact time as long as the effluent *E. coli* concentration is less than 126 colony forming units (cfu) per 100 mL, or the *Enterococcus* concentration is less than 35 cfu/100 mL, as a monthly geometric mean. Other states require the same 30 minutes of contact time with chlorine, and also require a minimum total chlorine residual such as 1.0 mg/L after the contact time, in addition to requiring the same *E. coli* or *Enterococcus* standard. The facility that is required to maintain a minimum total chlorine residual after the contact time is likely to use a higher chlorine dose and have lower effluent *E. coli* concentration and lower effluent pathogen concentrations than the facility that is required to meet the *E. coli* standard but has no minimum chlorine residual requirement.

A further difference among water resource recovery plants in the U.S. is that most of their effluents contain at least some ammonia. Therefore, upon addition of chorine, the free chlorine species combine with ammonia to form chloramines, which are a slower-acting disinfectant than free chlorine. In contrast, facilities with very low effluent ammonia can have faster-acting free chlorine species in the disinfection process. The facility with a free chlorine residual is likely to inactivate pathogens more effectively - even at a lower applied chlorine dose or residual - than the facility with a combined chlorine residual. Both facilities may have the same indicator bacte-

continued on page 18

continued from page 17

Photo courtesy of Patricia Drummey Stiegel

Sampling for fecal indicator bacteria prior to UV disinfection.

ria permit limit, but they are likely to have different concentrations of pathogens in the effluent.

More than twenty percent of larger U.S. WRRFs disinfect with ultraviolet (UV) radiation instead of chlorine. UV disinfection differs from chemical oxidative disinfection in that UV radiation does not kill microorganisms. In sufficient doses, UV radiation inactivates microbes by damaging their genetic material, leaving them unable to reproduce and therefore non-infective. Molecular methods for pathogen detection such as polymerase chain reaction (PCR) can detect the presence of pathogen DNA or RNA, and quantitative polymerase chain reaction (qPCR) methods have been developed to estimate pathogen concentration. However, neither PCR nor qPCR can distinguish live pathogens from dead pathogens. Among the living pathogens, PCR and qPCR do not distinguish those that are capable of reproducing and causing infection from those that are inactivated and non-infectious. Therefore, the use of PCR and qPCR techniques in recreational waters under the impact of UV-treated wastewaters is likely to overestimate the number of infectious pathogens, as many will have been rendered non-infectious via UV disinfection.

Summary

The USEPA 2012 RWQC recommends *E. coli* (in fresh water) and *Enterococcus* (in fresh and marine waters) as fecal indicator organisms. The USEPA no longer recommends total coliforms or fecal coliforms for this purpose. However, the USEPA is currently developing recommendations for the use of coliphages as viral indicator organisms in recreational waters. Assuming this effort results in the incorporation of coliphages into USEPA RWQC, states may eventually adopt coliphage limits into their NPDES permits for WRRFs. Research is currently underway by the USEPA and by other researchers to evaluate whether coliphages will be closer to the ideal indicator organism than *E. coli* or *Enterococcus*.

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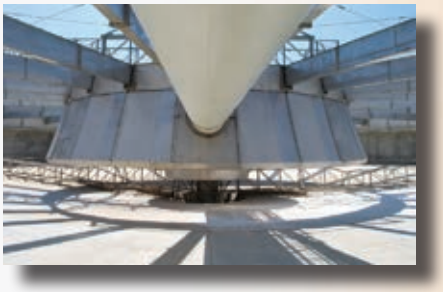

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Disinfection of Municipal Wastewater Effluent – What's in a Dose?

by Katherine Y. Bell, Allegra K. da Silva and Joseph G. Jacangelo

Requirements for Wastewater Disinfection

Public health agencies worldwide have long understood the relationship between fecal contamination in surface waters and associated human health risks. Because of the difficulties in identifying specific origins of illnesses associated with fecal contamination, as early as the 1960s the U.S. Public Health Service (USPHS) recommended using fecal coliform bacteria as an indicator for human health risks associated with primary contact. This was based on studies that reported a detectable health effect when total coliform exceeded about 2,300 colony-forming units (cfu) per 100 mL *(Stevenson, 1953)*. While correlations between fecal coliform bacteria and waterborne illnesses have been documented, it is understood that most fecal indicator bacteria are not pathogenic. Rather, viral, bacterial and protozoan pathogenic organisms are the etiological agents of observed illnesses. Fecal coliform bacteria are "indicators" for the potential for human infectious diseases; and while scientists recognize that this is not a perfect method for detecting the numerous pathogens that cause illnesses, it has been a useful monitoring tool for preventing human exposure to pathogens. Use of indicators is supported by epidemiological studies on human health relationships, and this approach overcomes issues associated with pathogen-specific enumeration methods for environmental waters *(USEPA, 2012)*. Further, indicator organisms have often served as the criteria that are the basis of a regulatory framework for wastewater disinfection.

In 1968, the National Technical Advisory Committee (NTAC) translated the total coliform level of 2,300 cfu per 100 mL *(Stevenson, 1953)* to 400 fecal coliforms per 100 mL, based on a ratio of total to fecal coliform, and then halved that number to 200 fecal coliforms per 100 mL *(USEPA, 2012)*. The NTAC criteria for recreational waters were then recommended by the U.S. Environmental Protection Agency (USEPA) in 1976, even though the criteria had been criticized on several issues associated with the design of the USPHS studies and the limited amount of epidemiological data and data quality. The 1976 USEPA criterion for bacteria in primary recreational waters required that fecal coliform densities not exceed a geometric mean (based on at least 5 samples collected over a 30-day period) of 200 organisms per 100 mL, and that no more than 10 percent of the total number of samples taken during any 30-day period exceed 400 fecal coliforms per 100 mL *(USEPA, 1976)*.

By 1986, as more data became available, USEPA recommended that *Escherichia coli (E. coli)* and *Enterococcus* be used for assessing microbiological water quality in recreational waters because concentrations of these organisms are more strongly correlated with swimming-associated gastroenteritis rates (USEPA, 1986). Regardless, many states questioned whether they should adopt the 1986 recommendations for setting water quality standards and some state regulators asked why it was necessary to change their programs, if the estimation of disease risk to swimmers had not significantly improved. Because of new studies and data, USEPA took the position that *E. coli* and *Enterococcus* were better indicators of public health risk in recreational waters than fecal coliforms. Results from epidemiological evidence associated *E. coli* and *Enterococcus* levels to swimming-related illness *(Cabelli, 1983; Dufour, 1984)*.

When developing criteria based upon *E. coli* and *Enterococcus,* USEPA did not propose criteria that were more stringent than the 200 fecal coliforms per 100 mL. Instead, they represented disease risk, estimated for swimmers at freshwater and marine beaches with exposures to the maximum fecal coliform limit. The 1986 criteria values were calculated to represent the ambient condition of the waterbody necessary to protect the designated use of primary contact recreation. These values were selected to carry forward the same level of water quality protection associated with USEPA's previous criteria for primary contact recreation use. The 1986 criteria values were also based on different water quality values and associated illness rates for marine and fresh waters. This was because the marine and fresh water epidemiological studies reported different geometric mean values for indicator bacteria associated with water quality corresponding to USEPA's fecal coliform criteria recommendations *(USEPA, 1986)*.

For decades, epidemiological studies have been used to evaluate how fecal indicator bacteria concentrations are associated with health effects of primary contact recreation on a quantitative basis. The 1986 criteria recommendations, noted above, are supported by epidemiological studies conducted by USEPA in the late 1970s and early 1980s. In those studies, *Enterococcus* and *E. coli* exhibited the strongest correlations to swimming-associated gastroenteritis. Both indicators continue to be used in epidemiological studies conducted throughout the world, including in the European Union (E.U.) and Canada *(EP/CEU, 2006)*. The World Health Organization (WHO) recommends the use of *enterococci* as water-quality indicators for recreational waters *(WHO, 2003)*. Meta-analyses and systematic reviews of epidemiological studies conducted worldwide indicate that these indicators generally provided substantial improvements over the indicators that were favored previously, such as total and fecal coliforms *(Wade et al., 2003; Zmirou et al., 2003)*. Thus, when USEPA most recently updated its recreational water quality criteria (RWQC) in 2012, *Enterococcus* and *E. coli* were again recommended as indicators for fresh water and *Enterococcus* as the indicator to be measured in marine water.

The criteria recommended in the 2012 USEPA RWQC ***(Table 1)*** are intended to protect the public from exposure to harmful levels of pathogens; the illness rates which the USEPA recommended are based upon use of the National Epidemiological and Environmental Assessment of Recreational Water (NEEAR) definition of gastrointestinal illness, which is limited to illnesses which exhibit a fever *(USEPA, 2010)*. This study allowed USEPA to provide better estimates of risk based on the new data. These recommendations have been issued as guidance to states, territories and authorized tribes for use in developing water quality standards to protect swimmers from exposure to water that contains organisms that indicate the presence of fecal contamination *(USEPA, 2012)*.

What Does This Mean for NPDES Permitting at WRRFs Today?

In the U.S., limits for microbial indicators are most typically enforced at the "end-of-pipe," meaning that the ambient water quality criteria must be met at the end of the treatment process, before it is discharged to the receiving water body. This issue is somewhat murky. While the USEPA, in documents such as the Ephraim King letter *(USEPA, 2008),* has indicated that there is a prohibition on the use of mixing zones for bacteria in primary contact recreation waters, individual primacy states may in fact use

Table 1. 2012 USEPA Recreational Water Quality Criteria *(USEPA, 2012)*

Criteria Elements	Recommendation 1 Estimated Illness Rate 36/1,000		Recommendation 2 Estimated Illness Rate 32/1,000	
Indicator	GM (cfu/100 mL)	STV (cfu/100 mL)	GM (cfu/100 mL)	STV (cfu/100 mL)
Enterococcus (marine & fresh)	35	130	30	110
E. coli (fresh)	126	410	100	320

GM = Geometric Mean

STV = Statistical Threshold Value approximates the 90th percentile of the water quality distribution and is intended to be a value that should not be exceeded by more than 10% of the samples used to calculate the GM

mixing zones to calculate the effluent limits for bacteria. However, while the mixing zone calculation should be allowable, most states typically implement bacteria criteria at the end-of-pipe and utilize the criteria directly in National Pollutant Discharge Elimination System (NPDES) permits as discharge limits.

While the USEPA issued its most recent update to RWQC in 2012, there are yet many states that have not fully implemented these criteria in their NPDES permits. Some of this is due to the timing of how criteria are adopted into individual state water quality regulations, while others can be attributed to the 5-year cycle that is used for NPDES permitting. In general, USEPA criteria are generally adopted into state water quality regulations upon the triennial water quality review process, and these new values are not imposed in permits until a permit comes up for renewal. Thus, it is no surprise that there are still states enforcing fecal coliform limits. However, as states advance toward full implementation of these new criteria, it is important to recognize the impact on the design and operation of disinfection systems at water resource recovery facilities (WRRFs).

Fundamentals of Microbiology

While some state agencies have claimed that the transition from fecal coliform to the new criteria will have a no-cost impact on WRRFs, there are fundamental reasons supporting otherwise. There have been numerous studies attempting to link the concentrations of *E. coli* and *Enterococcus* to historical fecal coliform data, but these are often conducted in the absence of an understanding of the microbiology of these indicators. And while there is a relationship that is evident between fecal coliform and *E. coli*, no such relationship exists for *Enterococcus*. This is because these bacteria are not only from different families, but their phylogeny is so different that they are not even in the same order, class or phylum, as shown in ***Table 2***.

Coliforms. Total coliforms are gram-negative bacteria that are found in soil, in water that has been influenced by surface water, and in human or animal waste. Fecal coliforms are a subgroup of total coliforms ***(Figure 1)*** that are considered to be present specifically in the gut and feces of warm-blooded animals. Because the origins of fecal coliforms are more specific than the origins of the more general total coliform group of bacteria, fecal coliforms are considered a more accurate indication of animal or human waste than total coliforms. *E. coli* is one of a few species in the fecal coliform group of total coliforms that is generally not found growing and reproducing in the environment. Consequently, *E. coli* is accepted as the species of coliform bacteria that is the best indicator of fecal pollution and the possible presence of pathogens *(NYSDOH, 2016)*.

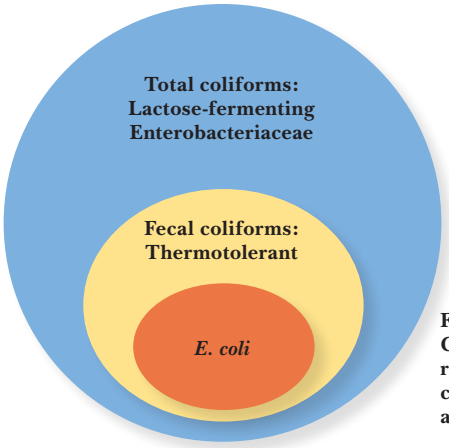

Figure 1. Conceptualization of the relationships among total coliform, fecal coliform and *E. coli*

Table 2. Classification of Indicator Organisms Used as the Basis of Ambient Water Quality Criteria for Recreational Use (*USEPA. 2012*).

Classification	*Gram-negative*			*Gram-positive*
	Total Coliform	**Fecal Coliform**	***E. coli***	***Enterococcus***
Domain	*Bacteria*	*Bacteria*	*Bacteria*	*Bacteria*
Kingdom	*Eubacteria*	*Eubacteria*	*Eubacteria*	*Eubacteria*
Phylum	*Proteobacteria*	*Proteobacteria*	*Proteobacteria*	*Firmicutes*
Class	*Gammaproteobacteria*	*Gammaproteobacteria*	*Gammaproteobacteria*	*Bacilli*
Order	*Enterobacteriales*	*Enterobacteriales*	*Enterobacteriales*	*Lactobacillales*
Family	*Enterobacteriaceae*	*Enterobacteriaceae*	*Enterobacteriaceae*	*Enterococcaceae*
Genus	Five genera including *Escherichia, Klebsiella, Enterobacter, Serratia,* and *Citrobacter* comprise total coliform; 16 species in these genera	Six species in five genera comprise fecal coliform.	*Escherichia*	*Enterococcus*
Species			*Escherichia coli*	36 species have been identified and are divided into five groups.
Strain			Many strains, both pathogenic and non-pathogenic	

continued on page 24

continued from page 23

Table 3. Proposed Schedule for Bacteriophage Criteria *(Nappier, 2016)*

Date	Milestone
04/17/2015	*Review of Coliphages as Possible Viral Indicators of Fecal Contamination for Ambient Water Quality* published by USEPA
10/15/2015	EPA Webinar for Stakeholders
03/01/2016	Coliphage Expert Workshop
07/2016	Coliphage Fact Sheet issued by Office of Water, USEPA (EPA 823-F-16-001)
Throughout 2016	Listening sessions/Webinars • Conferences (New Orleans and Chapel Hill) • States • Other stakeholders (Industry/Environmental groups)
Summer 2016	Analytical method multi-laboratory validation
Winter 2017	Coliphage Expert Workshop proceedings, anticipated
Late 2017	Draft Criteria released for public review, anticipated

Enterococcus. On the other hand, gram-positive cocci can often persist in harsh environmental conditions. The genus includes all streptococci that share certain biochemical properties and have wide range of tolerance to adverse growth conditions. In fact, the *Enterococcus* category was previously named fecal streptococcus, but was reclassified in the 1990s. Their salt tolerance, demonstrated by their ability to grow in a 6.5 percent salt solution, is why they are proposed to be useful for evaluating contamination of marine waters. It is also important to keep in mind that this group, in addition to being found in the gastrointestinal and genital tracts of humans and animals, can be found in soil, water and plants. There are over 17 species of the *Enterococcus* genus, but in most cases the isolates are typically *E. faecalis (Švec and Devriese, 2009)*. But fecal streptococci, which are now called *Enterococcus*, do have the advantage of rarely multiplying in the environment and they are much more resistant to environmental stress than coliforms; these characteristics are why they have been proposed as good indicators for fecal pollution. This means that fecal coliforms can grow in the environment and *Enterococcus* will generally not, although this is up for debate in the scientific literature. Additionally, some of these characteristic differences in the groupings can provide information about how they will respond to disinfection.

What's in a Dose?

With respect to wastewater disinfection, it is important to understand the difference between gram-positive and gram-negative bacteria. Gram-negative bacteria do not have the thick mesh-like cell wall made of peptidoglycan that gram-positive bacteria have. In gram-positive bacteria, about 50 to 90 percent of the cell envelope is comprised by this molecule, and thus are stained purple by crystal violet. The gram-negative bacteria have a thinner cell envelope, with only about 10 percent being comprised of peptidoglycan.

Many studies have been conducted to show that gram-positive bacteria are more resistant to disinfection than gram-negative bacteria. One study showed that nearly all the bacteria surviving chlorine disinfection were gram-positive or acid fast (*Norton & LeChevallier, 2000),* likely because gram-positive bacteria have thicker walls than gram-negative ones. There have also been numerous studies conducted showing similar findings for resistance to UV *(Arrage, et al., 1993)*. In short, for disinfection, this means that the dose required to achieve the same level of inactivation for coliform organisms may be lower than that for *Enterococcus*. For chlorine-based disinfection, this could translate to a higher dose or longer contact time to inactivate or kill *Enterococcus* compared to coliform bacteria. While the increases in dose, either chemical oxidant or UV, are related to site-specific factors, a good rule of thumb is that it will take approximately 30 to 50 percent more dose to achieve the same level of inactivation for *Enterococcus* than its coliform bacteria counterparts.

What's Next from USEPA?

Some previous work that suggests the current USEPA Ambient Water Quality Criteria, based on fecal indicator bacteria (FIB), such as *E. coli and Enterococcus,* do not adequately predict the presence of human viral pathogens in receiving waters *(USEPA, 2015)*. However, there is also no clear cut epidemiological evidence linking viral gastroenteritis outbreaks from exposure to bathing waters that do not meet criteria based on fecal indicator bacteria *(Dorevitch, 2016)*. Thus, while FIB may not predict viral pathogen concentrations, it is difficult to conclude that FIB are entirely inadequate for their intended purpose – protecting public health. Regardless, USEPA is advancing the development of a new criteria for bacteriophage. The schedule of activities in criteria development has been recently presented by USEPA ***(Table 3)***.

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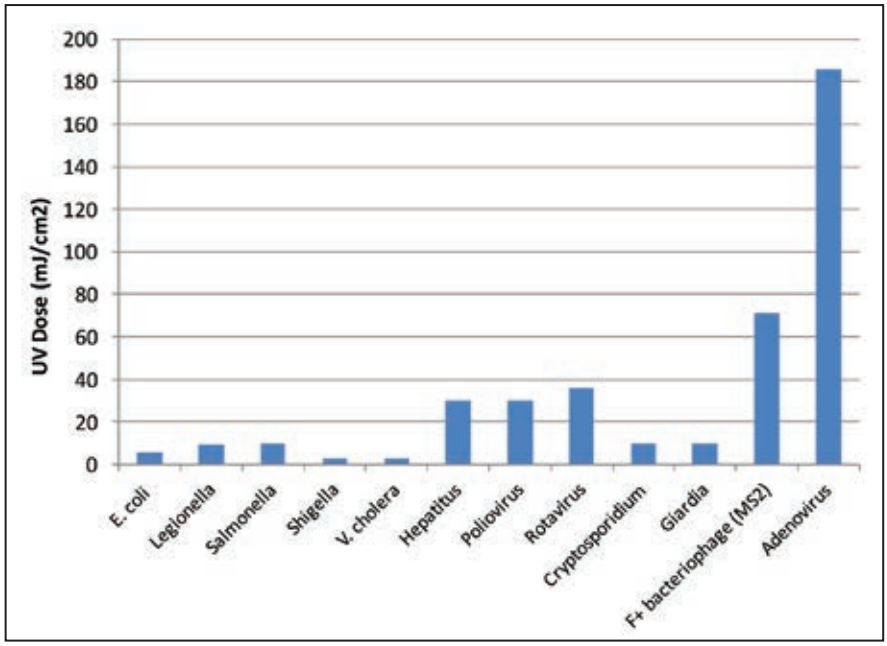

Figure 2. Low pressure UV dose requirements for meeting 4-log inactivation of various microorganisms (adapted from *USEPA, 2006*)

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continued from page 24

The timetable for implementing such criteria into NPDES permits is unclear, but if ambient water quality criteria are, in fact, updated to reflect coliphages, many utilities may need to initiate more site-specific investigations to address new permit limits. The leap from fecal coliforms to *Enterococcus* has had a relatively small impact on facilities, with many facilities having adequate treatment capacity (through conservatism in design) to meet the 2012 criteria; however, this may not be the case for bacteriophage. Facilities practicing chloramination may be forced to move to breakpoint chlorination, because bacteriophages are not readily inactivated by chloramines at doses used for bacterial disinfection. For facilities utilizing UV disinfection, the difference in UV sensitivities are 3 to 5 times between coliform organisms and bacteriophage ***(Figure 2**, USEPA, 2006)*.

Thus, while there is evidence to demonstrate that current methods of wastewater disinfection that are most commonly employed to protect human health are adequate *(Dorevitch, 2016),* there is yet potential for a new bacteriophage criteria to be applied to NPDES permits. The result may be that individual utilities will revisit the current technologies that have been proven effective for decades. If pressed, utilities may also have to explore the benefits of mixing zones to leverage dilution factors that could be used in permitting, which could be an unintended consequence of this regulatory criteria development.

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USEPA's Proposed Bacteriophage Criteria for Recreational Waters

by Thomas Worley-Morse and Samuel Jeyanayagam

The U.S. Environmental Protection Agency (USEPA) plans to update the 2012 Recreational Water Quality Criteria (RWQC) with criteria for bacteriophages, and it is expected that the USEPA will issue draft bacteriophage criteria in late 2017. The USEPA has identified coliphages, a class of bacteriophages that infect *Escherichia coli (E. coli),* as the most likely new indicator for the presence of fecal contamination and viral pathogens in water. The coliphage RWQC may ultimately result in National Pollution Discharge Elimination System (NPDES) coliphage effluent limits for water resource recovery facilities (WRRFs). NPDES permit limits for coliphages will likely have the greatest impact on facilities which use conventional activated sludge processes and which disinfect with chlorine in effluents that contain significant ammonia. Uncertainty exists regarding the scientific gaps that remain, the specifics of the USEPA's plans, the extent of the potential upgrades to WRRFs, and the economic impacts of water quality criteria for bacteriophages. To address some of these gaps, the Water Environment & Reuse Foundation (WE&RF) is funding a coliphage research project.

Introduction to Bacteriophages

Bacteriophages are viruses that infect only bacteria, and coliphages are bacteriophages that infect only *E. coli*. Research has estimated that globally bacteriophages outnumber bacteria 10 to 1, suggesting that bacteriophages are the most prevalent form of life on the planet *(Hendrix, 2002)*. Coliphages are common in wastewater influents and, depending on the treatment process configuration, coliphages are also common in disinfected wastewater effluents *(Rose, et al. 2004)*. However, gaps exist regarding the overall fate and treatability of coliphages in WRRFs.

Like the existing bacterial indicators – *E. coli* and *Enterococcus* –0 recommended in USEPA's 2012 RWQC, bacteriophages are considered non-pathogenic towards humans, making laboratory work with bacteriophages safer than laboratory work with actual pathogens such as enteric viruses. However, certain bacteriophages can induce human pathogenicity in their host bacteria, such as the Shiga toxin encoding coliphages in *Escherichia coli* O157:H7 *(Shaikh and Tarr, 2003)*.

Typical plaques are shown for the coliphage EC9 on a lawn of *E. coli* after overnight incubation. The clear zones correspond to zones of bacterial lysis due to the phage infection of bacteria.

Photo courtesy of Thomas Worley-Morse

Coliphages as Indicators of Fecal Contamination

The academic and regulatory communities have been exploring the feasibility and potential benefits of using coliphages as indicators of fecal contamination and viral pathogens *(USEPA, 2015)*. This work is motivated by research that suggests viruses cause a significant overall disease burden in the United States and that viruses in recreational waters are contributors to human illnesses *(Sinclair, et al. 2009; Hlavsa, et al. 2014; Hlavsa, et al. 2015)*. Although the USEPA has expressed interest in developing water quality criteria for enteric viruses, methodological constraints as well as safety and cost concerns make enteric virus criteria unfeasible at present. Therefore, coliphages have been proposed to serve as indicators for viruses in recreational waters for the following reasons:

1. Bacteriophages satisfactorily mimic the fate and transport of viruses in the environment.
2. Coliphages are generally specific to mammalian fecal matter.
3. Some epidemiology studies have demonstrated a relationship between the presence of certain types of coliphages and the occurrence of gastrointestinal illnesses in recreational waters.
4. When compared to culturable virus methods, culturable coliphage methods allow regulatory agencies to cost effectively and rapidly assess the presence of infective coliphages, such that beach closure notifications can be issued in a timely manner.

Recreational Water Quality Criteria

The USEPA uses RWQC for the following three objectives:

- to prevent illness;
- to identify impaired waters; and
- to identify potentially hazardous conditions.

RWQC also serve as the USEPA's recommendations for states to use when establishing or revising water quality standards. The states can also adopt criteria that differ from the USEPA's recommended criteria, if the adopted criteria are scientifically defensible. The USEPA is updating the RWQC because Section 304(a)(1) of the Clean Water Act requires the USEPA to periodically revise and update the RWQC to reflect the latest scientific knowledge. Of concern to the wastewater industry, the USEPA is not required to consider the economic implications when evaluating or developing updates for the RWQC, unlike regulations that result from the Safe Drinking Water Act.

Regarding the proposed coliphage criteria, the USEPA has not yet clarified what class of coliphage they plan to use. The USEPA's initial publications have suggested two different coliphage types: male-specific coliphages and somatic coliphages *(USEPA, 2015)*. The USEPA has not yet announced whether new criteria will be for one, both, or a choice between the two types of coliphages, nor has the USEPA announced whether the phage criteria will be in addition to, or in place of, the current bacteria criteria.

Thomas Worley Morse

A technician collects a wastewater sample for indicator organism quantification.

Treatability of Coliphages in WRRFs

The wastewater disinfectants currently used in WRRFs can effectively inactivate coliphages given a sufficiently high dose and contact time; however, at the typical doses and contact times used in WRRFs for inactivating bacterial indicators, the performance of these disinfectants varies for inactivating coliphages. ***Table 1*** qualitatively rates each major disinfectant's ability to inactivate coliphages at doses and contact times typical of current usage at WRRFs in the U.S.

Table 1. Relative Ability of Wastewater Disinfectants to Inactivate Coliphages at Typical Doses and Contact Times.

Disinfectant	Coliphage Inactivation Rate
Free Chlorine	Quick
Chloramines	Slow
Ozone	Quick
UV	Moderate
Peracetic acid	Slow – Moderate

Of the disinfectants used in WRRFs, free chlorine and ozone both quickly inactivate coliphages. UV performs moderately, and chloramines and peracetic acid (PAA) are slower at inactivating coliphages. In this context, disinfection with chloramines refers to disinfection with chlorine in effluents that contain significant ammonia. Although most WRRFs in the United States use some form of chlorine for disinfection – a 2008 Water Environment Research Foundation report suggested that 75 percent of all WRRFs in the United States disinfect with chlorine – most these facilities do not fully nitrify their wastewater, which results in the formation of chloramines when chlorine is applied, as opposed to a free chlorine residual *(Leong, et al. 2008)*. As a result, a large fraction of WRRFs in the United States practice *de facto* chloramine disinfection, a disinfection method that slowly inactivates coliphages. For example, residual CTs (the product of the residual concentration and the contact time) of 18 mg-min/L have been

continued on page 31

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A view of the North Carolina coast at the Outer Banks


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continued from page 29

shown to provide a range of 0.1 to 2.4 log coliphage inactivation, depending on the WRRF *(Tyrrell, et al. 1995)*. However, other work has shown that much larger CTs of greater than 1000 mg-min/L were required to provide a 2-log reduction for certain coliphages *(Dee and Fogleman, 1992)*.

In contrast to chloramines, free chlorine quickly inactivates coliphages; however, WRRFs with free chlorine residuals are not typical. Although more chlorine could be added to non-nitrified effluents to reach breakpoint and form a free chlorine residual, the chlorine dose required can be financially prohibitive. Further, at many WRRFs, the high dose of chlorine required to achieve breakpoint chlorination and a free chlorine residual would also increase the formation of chlorinated byproducts in the final effluent.

Regarding the other common wastewater disinfectants, the limited data on ozone disinfection at WRRFs suggests that ozone quickly inactivates coliphages; however, facilities with ozone often have advanced tertiary processes that also contribute to higher levels of coliphage reduction. Typical doses of UV radiation inactivate coliphages at satisfactory rates. For example, approximately 20 millijoules per square centimeter (mJ/cm^2) corresponds to a 1-log reduction of male-specific coliphages *(Jacangelo, et al. 2003),* whereas 20 mJ/cm^2 typically provides 2 to 4 logs of inactivation of somatic coliphages. PAA at the typical doses and contact times used in WRRFs slowly inactivates coliphages. For example, a dose of 1.5 mg/L with a contact time of one hour was shown to provide a 1-log inactivation of male-specific coliphages *(Gehr, et al. 2003)*. Finally, the potential impact of new coliphage RWQC on disinfection processes cannot be precisely quantified until the numerical criteria are published by USEPA.

Regarding the impact of secondary and tertiary treatment, limited research has indicated that WRRFs with secondary processes that typically operate at longer solids retention times and with higher mixed liquor suspended solids have increased indicator organism removal prior to disinfection *(Rose, et al. 2004)*; however, further research is needed to quantify these findings. Likewise, tertiary filters may be expected to enhance coliphage removals.

Implications

Because the USEPA has not yet released the recommended numeric coliphage criteria, the implications of the coliphage RWQC for the wastewater industry cannot be fully quantified at present. Ultimately, the implications for each utility will depend on the treatment processes in place, prior to and including disinfection, and the state water quality standards. However, based on the relative effectiveness of traditional disinfectants on coliphages, WRRFs with conventional activated sludge processes which are not performing biological nutrient removal and which are using chlorine disinfection have the highest probability to be affected by the coliphage RWQC. These facilities may require process changes to meet NPDES coliphage effluent limits.

To provide needed information on the fate and persistence of coliphages, the treatability of coliphages, and the potential cost of the coliphage criteria, WE&RF has funded a coliphage research project entitled "Evaluating the Fate of Coliphages in WRRFs and the Potential Costs to Reduce Coliphages in WRRF Effluents." This study, project U3R15, is in progress and the final report will be available in 2018.

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One of the difficulties in *Legionella* testing is to discriminate between *Legionella* and non-target organisms without inadvertently reducing the culturable *Legionella* organisms in the sample.

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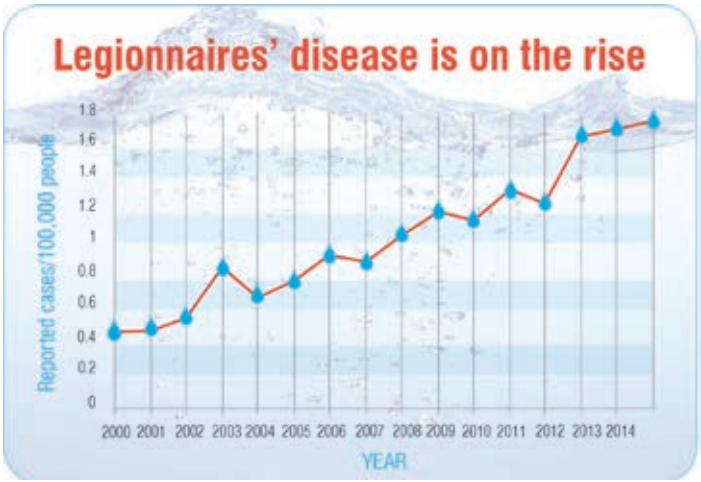
Knowledge Is Power: Reducing the Risk of Legionnaires' Disease from Contaminated Water Systems

by Dan Broder

Legionnaires' disease, a severe and potentially deadly form of pneumonia, is increasingly a threat to public health. According to the Centers for Disease Control and Prevention (CDC), cases of the disease caused by *Legionella* (the genus of waterborne bacteria responsible for causing Legionnaires' disease; most frequently the *Legionella pneumophila* species) almost quadrupled between 2000 and 2014 *(Garrison et al, 2016)*. Legionella accounts for more drinking water-related outbreaks in the United States than all other contaminants combined, has a case-fatality rate of greater than 9 percent, and leads to annual health care-associated costs of more than $430 million *(Collier et al, 2012)*. This is a critical time to turn the tide against Legionnaires' disease, and water treatment officials, building managers, and regulators are on the frontlines



Trends in reported cases of Legionnaires' disease, 2000-2014

National Notifiable Disease Surveillance System, CDC, 2000-2014

What You Need to Know About *Legionella*

Legionella bacteria can be free-living, survive in a host amoeba, or be part of biofilm. All three situations can be present in potable and non-potable water systems. People can become ill when *Legionella* are aspirated and infect macrophages in the lungs. People at high risk for Legionnaires' disease include those with chronic lung disease, those with compromised immune systems, and people 50 years of age or older. In addition to the susceptibility of the patient, other key risk factors include the extent of exposure, and the virulence of

the strain of *Legionella*. Of the more than 60 species of *Legionella*, *L. pneumophila* is the species responsible for the vast majority of Legionnaires' disease cases.

Further exacerbating the public health issue is the burgeoning threat of antibiotic resistance. According to a recent study at Tufts University, up to two percent of hospitalizations for infections from premise pathogens like *Legionella* show evidence of resistance, and those patients cost 10 to 40 percent more than patients with nonresistant infections. The study's authors warn that the lack of regulation of premise plumbing systems can lead to inconsistent monitoring and reporting of potentially dangerous deficiencies in an aging infrastructure, and call for policymakers and researchers to pinpoint public health interventions that could reduce the risk of infections caused by bacteria in plumbing *(Naumova etal., 2016)*.

Growing Demand for Testing

Outbreaks of Legionnaires' disease have been traced to U.S. hospitals and chain hotels in just the last few months alone. The good news is that the spread of *Legionella* can be successfully managed by following thorough water safety plans, which should include periodic testing to ensure the building water system is well controlled.

Growing awareness of the risks of *Legionella* – in part due to the connection between Legionnaires' disease cases and the change of source water in Flint, Michigan – is raising fresh questions about water quality and safety that water quality engineers, treatment plant technicians, scientists, government officials, regulatory agency personnel, manufacturers, and other groups and individuals must be prepared to address.

Currently, New York is the only state in the nation to have laws mandating testing for *Legionella*. The new regulations in New York grew out of emergency regulations that were enacted when 133 residents of the South Bronx were sickened with *Legionella* and 16 people died *(City of New York Department of Health and Mental Hygiene, 2016)*. The source of the outbreak was determined to be a cooling tower, but potable water, especially in hospitals and other buildings with complex hot water systems, is an equally important source of *Legionella* transmission. New York now requires both that cooling towers be registered and tested for *Legionella*, and that all general hospitals and residential health care facilities in the state perform quarterly *Legionella* culture sampling and analysis

On a national level, the American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) offers nonbinding guidelines and standards establishing minimum *Legionella* risk management requirements for building water systems for all

continued on page 34

Fotolia

Potable water, especially in hospitals and other buildings with complex hot water systems, is an equally important source of *Legionella* transmission.

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Potentially dangerous deficiencies in an aging infrastructure and lack of regulation of premise plumbing systems can lead to inconsistent monitoring and reporting.

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Water quality engineers can help with understanding the value of looking at the concentration of *Legionella* at a given point in the system to gauge risk and establish appropriate control measures.

continued from page 33

buildings (other than single family residences) for potable and non-potable water. The Department of Veterans Affairs has gone a step further. The VA has developed a policy for the prevention of healthcare-associated Legionnaires' disease, which includes mandatory testing of its buildings' potable water distribution systems for *Legionella pneumophila* to determine if their engineering controls are successfully inhibiting *Legionella* growth.

Water Quality Professionals and Government Regulators Play an Important Role in Reducing Public Health Risk

According to the CDC, all building owners should determine whether their building water systems are at increased risk for growing and spreading *Legionella*. The CDC also states that building owners should, as needed, develop and follow *Legionella* water safety plans that are tailored to their specific building water systems. Regional water experts and government officials should also encourage this practice. A recent literature review published by the U.S. Environmental Protection Agency (USEPA) offers review of several options available to building owners *(USEPA, 2016)*. Once in place, routine testing is an essential part of measuring whether these water management plans are effectively controlling the building's *Legionella* risk.

Accurate and reliable quantitative test results are required for decision makers to understand where there are the greatest risks in a water system so they can reduce them. Water quality engineers can help building owners and the public understand the value of looking at both the concentration of *Legionella* at a given point in the system and frequency of *Legionella*-positive outlets throughout the system to gauge risk and establish appropriate control measures. It should be noted that *Legionella* is virtually impossible to completely eradicate in complex water systems, but it can be effectively controlled through proper monitoring and control measures.

Focusing detection and control efforts on *Legionella* pneumophila, the primary causative agent of Legionnaires' disease, may increase the efficiency and efficacy of a water safety plan. *Legionella pneumophila* is the most common and clinically relevant species of *Legionella*. It thrives in low-nutrient conditions and grows as biofilms on the inner surfaces of pipes. Biofilms allow these pathogens to resist disinfectants and environmental stressors, and aid in the spread of antibiotic resistance and virulence genes. Water management plans that include measures to address these conditions and effectively control *Legionella pneumophila* will also control other species of *Legionella* at the same time. This focus may help building operators avoid the costs and dangers of unnecessary shutdowns and/or treatment triggered by the detection of *Legionella* species that are far less virulent than *Legionella pneumophila*

State-of-the-Art Testing

Historically, accurate testing for *Legionella* has been hard to do well without years of experience. Traditional membrane filtration culture methods are complex and often require more subjectivity and expert judgement than regulators and other officials would like. Even within the canon of standard methods, variations in technique and results are common from laboratory to laboratory and even from bench to bench. Testing protocols include many homebrew hybrids of standard culture methods that have evolved over the years as microbiologists seek to improve the precision of their counts. Indeed, some laboratories routinely run as many as 11 plates to come up with a count for a single water sample.

Scientists at IDEXX have been studying the best way to detect *Legionella* for years. One of the difficulties in *Legionella* testing is to discriminate between *Legionella* and non-target organisms without inadvertently reducing the culturable *Legionella* organisms in the sample or having overgrown plates that are difficult to accurately read and count. Samples that are not readable must be retested, which often requires time-consuming resampling. Key opinion leaders in the fields of both water quality and human disease helped identify the need for a culture test that was simple to run, met or exceeded the accuracy of existing culture methods and could specifically detect and quantify *Legionella pneumophila*, the primary causative agent of Legionnaires' disease.

Beating *Legionella*

CDC investigations show that almost all outbreaks of Legionnaires' disease in the United States over the past 14 years could have been prevented with more effective water safety management programs. Incorporating the ASHRAE standard into licensing and accreditation requirements and public health codes across the United States will substantially reduce the public health risk posed by *Legionella*. Making water safety plans a priority and a routine part of building ownership and management will reduce deaths from this illness, but will also require education, enforcement, and the right testing to be sure the *Legionella* control measures in these plans are effective over time.

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Microfiber Pollution and the Apparel Industry

by Bess Ruff, Nicholas Bruce, Niko Hartline, Stephanie Karba and Shreya Sonar

Microplastic pollution is increasingly becoming a national issue. On December 31, 2015, President Obama signed the "Microbead-Free Waters Act of 2015", an amendment to the Federal Food, Drug, and Cosmetic Act that bans the manufacturing of products with plastic microbeads by 2017 and the sale of these products by 2018. Cosmetic companies such as Unilever and L'Oréal Paris have already begun to transition from microbeads to natural alternatives such as sugar, sand and ground seeds.

Among the various types of microplastics identified in aquatic systems, microfibers have been found to be the most prominent form in some habitats, specifically near dense human populations. Once in the environment, these fibers are readily consumed by aquatic organisms, which can result in gastrointestinal blockages and starvation in smaller organisms. Furthermore, microfibers readily sorb chemicals they encounter during the wastewater treatment process as well as in the aquatic environment; when organisms consume fibers, they also ingest these toxic substances which have been found to cause organ stress and reproductive disturbances in some species.

Microfibers have been found in a variety of aquatic organisms, from zooplankton to whales, and are especially prevalent in filter feeders such as mussels and oysters. Humans consume many of these species, making us susceptible to ingesting microfibers as well. Of further consequence to human health, the surfaces of microfibers have been found to host bacterial assemblages, some of which are associated with human gastrointestinal infections.

Apparel Industry's Interest in Microfibers

Unlike microbeads, which have economically feasible alternatives that fulfill the function of their plastic counterparts, the apparel industry faces a more difficult situation as substitutes for synthetic textiles are limited and struggle to mimic the performance capabilities of materials like polyester. As such, the elimination of synthetic textiles is extremely unlikely, and mitigation appears to be the only means by which microfiber pollution will be reduced. In order to develop strategies to limit microfiber release, apparel companies need to understand how much their products shed and what factors contribute to higher shedding so that they can implement mitigation strategies as well as educate consumers on the issue.

Patagonia, Inc. is part of an apparel industry that contributes to microfiber pollution through their production facilities, in addition to that generated by consumers washing their products. Information is lacking for Patagonia – and the apparel industry as a whole – in terms of the magnitude of their role in microfiber pollution and the extent of the impacts this pollution has on the ecosystems in which it is found.

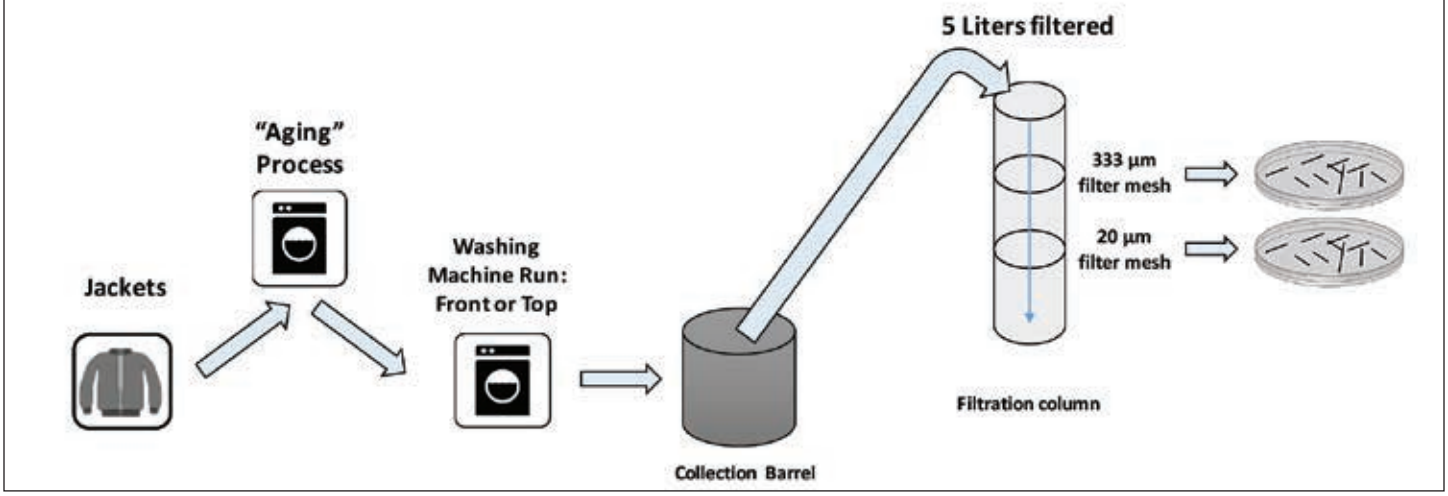
With these issues in mind, the Bren Microfiber Project assisted Patagonia in assessing the quantity of microfibers shed by their products and the potential ecological impacts of those fibers, as well as developed recommendations to inform future steps to mitigate this pollution. Our extensive literature review of the distribution and ecological impacts, in addition to our original and easily replicable experimental design, provide the requisite infrastructure for Patagonia and other apparel companies to assess their contributions to microfiber pollution.

Wash Trials Methodology

The first step of this project was to quantify the mass of microfibers shed from clothing. To accomplish this, we conducted wash trial experiments on four Patagonia jackets. One generic brand jacket of a similar style to one of the Patagonia jackets was also included in the trials for comparison purposes. The goal of the wash trials was to test how washing machine type and garment age impacted the mass of microfibers shed.

The effect of washing machine type (front-load vs. top-load) on microfiber shedding was evaluated for each jacket. A new garment of each jacket style was washed in a traditional top load and a front load washing machine. The effluent from the washing machines was filtered through a uniquely designed filtration column ***(Figure 1)***, and shed fibers were collected on the filters in the column and removed for later massing.

Our Experimental Design



Source: Stephanie Karba

Figure 1. Conceptual graphic of experimental design

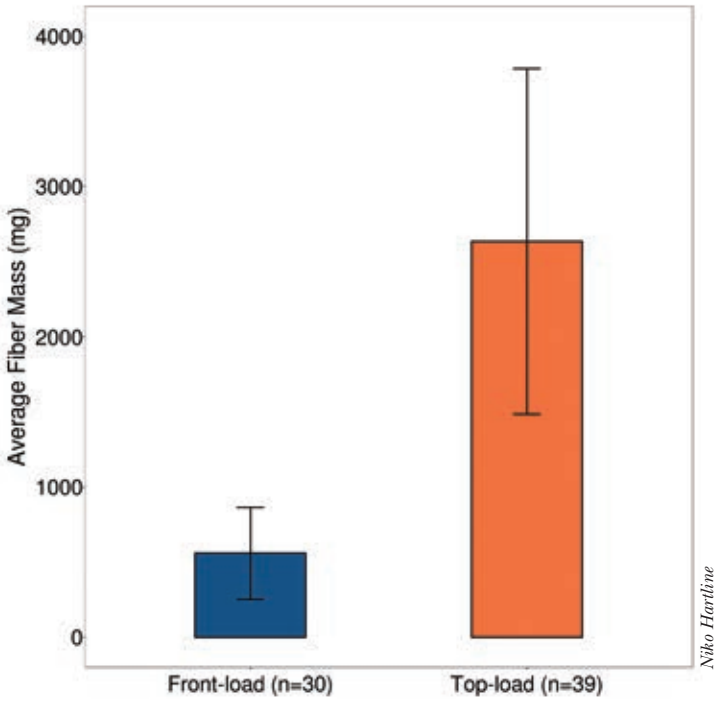


Figure 2. Average combined fiber mass shedding per wash for all trials by Front-load (n = 30) and Top-load (n = 39) washing machines. Error bars are ± one standard deviation. Jackets washed in top-load machines shed roughly 430 percent more fiber mass.

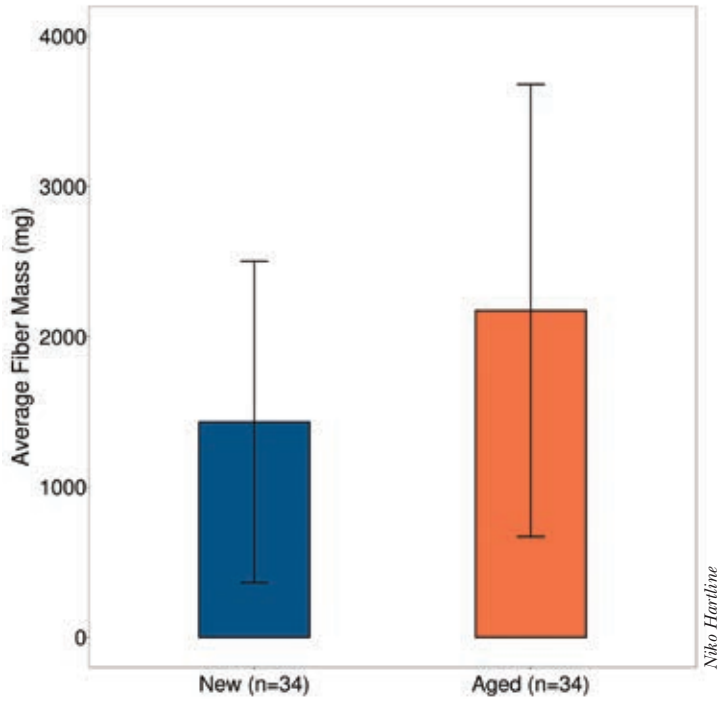


Figure 3. Average combined fiber mass shedding per wash for all trials by new treatment (n = 34) and aged treatment (n = 34). Error bars are ± one standard deviation. Aged jackets shed roughly 80 percent more fiber mass than new jackets.

To analyze the effect of jacket age on microfiber shedding, the jackets were then put through a Patagonia test called a "killer wash". The killer wash is a modified 24-hour wash cycle that simulates a lifetime of wear. After the killer wash, the jackets were washed again in a front or top load washing machine. The washing machine effluent was processed in the same manner as the washing machine experiment outlined above.

Wash Trials Results

During our wash trials, microfiber shedding per jacket ranged between 160 mg to 2,700 mg per wash, which equates to approximately 8,500 to 250,000 fibers. Both the type of washing machine and age of jacket significantly impacted shedding ***(Figures 2** and **3)***. Our experiment shows that an aged generic brand jacket washed in a top load machine shed the most microfibers.

As important as the actual shedding of the fibers is what happens to them after they leave the washing machine. We developed a model of microfibers in wastewater treated at wastewater treatment plants (water resource recovery facilities, excluding potable reuse and water recycling processes) and, based on a literature review, we estimated the mass of microfibers entering local water bodies from these plants using a microfiber removal rate between 65 and 92 percent.

Based on these removal rates, a city of 100,000 people produces 170 to 441 kilograms of microfibers from washing synthetic clothing per day. Of the amount of microfibers that enter the treatment facility, 9 to 110 kg of microfibers would be released into local water bodies daily, which is an average of 15,000 plastic bags.

Summary

This study highlighted current research regarding microfiber pollution and analyzes the impacts of two variables on microfiber shedding: garment age and washing machine type. The results of our wash experiments show:

- Aged jackets shed higher masses of fibers than new jackets
- Jackets washed in the top-load washing machine shed more than those washed in the front-load

Higher shedding in aged jackets is most likely due to the weakening of fibers as a result of wear, and higher shedding from the top-load washing machine is likely influenced by the central agitator found in these appliances. These results were significant; however, several other variables were identified that could affect shedding and should be evaluated further including water temperature, cycle length, and detergent type. Future work should also evaluate differences in shedding between traditional top-load machines with a central agitator (like the one used in this study) and high-efficiency top-load washers without a central agitator.

Bess Ruff is a graduate researcher at the Bren School of Environmental Science & Management, and is the primary contact for questions concerning material in this article. She may be reached at eruff@bren.ucsb.edu. The co-authors of this article are also graduate researchers at the Bren School of Environmental Science & Management: Nicholas Bruce (nicholasjbruce@live.com); Niko Hartline (nikohartline@gmail.com); Stephanie Karba (stephanie@karba.com); and Shreya Sonar (shreyasonar19@gmail.com).

This study was published in Environmental Science and Technology under the title ""Microfiber Masses Recovered from Conventional Machine Washing of New or Aged Garments" (Web Publication Date September 30, 2016. 50(21): pp 11532–11538. DOI: 10.1021/acs.est.6b03045)

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Recent Water-related Cases That May Impact NPDES/SPDES Dischargers

by Libby Ford, Jesse Hiney, Alison Torbitt and Peter Trimarchi

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While most State Pollutant Discharge Elimination System (SPDES) permit holders are used to watching for new regulations that may impact their discharges, sometimes they are completely blindsided when changes are thrust on their permit issuing agency due to a court decision. While there has been much focus placed on the so-called "Waters of the United States" rule over the last year, there are actually a number of other cases that could dramatically shift the wastewater permitting regulatory universe. Five of these are briefly discussed below.

Case #1: POTW Blending and Bacterial Mixing Zones – Where They Are and Are Not Allowed

In 2010 the U.S. Environmental Protection Agency (USEPA) issued a series of letters and other documents that effectively banned the use of mixing zones and blending by publicly owned treatment works (POTWs). In March 2013, the *Iowa League of Cities v. USEPA* (ILOC) ruling vacated USEPA's blending and bacteria mixing zone prohibitions as illegal rulemakings and/or beyond statutory authority. Following this decision, USEPA indicated that the Agency would limit the application of the ILOC decision to the 8th Circuit. This effectively allows wastewater facilities to blend and utilize bacteria mixing zones in the 8th Circuit states while continuing to ban such practices elsewhere. This patchwork application of a national rule has led to regulatory confusion. The 8th Circuit is composed of seven states in four different USEPA Regions (5, 6, 7 and 8). As a result, not only do different rules apply to different areas of the country, the USEPA rules will also inconsistently regulate states within the same USEPA Region.

On August 12, 2014, the Center for Regulatory Reasonableness (CRR) filed suit against USEPA in the U.S. Court of Appeals, D.C. Circuit, arguing that USEPA must apply the ILOC decision uniformly across all states.

Currently, USEPA has not appealed the ILOC ruling. Briefs have been filed in the CRR case, but oral arguments have not occurred.

The questions of municipal implications arising from these two cases are four-fold:

1. Can municipalities design and operate wastewater treatment systems, termed "POTWs", utilizing "blending", as long as their effluent meet secondary treatment and other SPDES and National Pollutant Discharge Elimination System (NPDES) requirements?
2. Can their SPDES/NPDES bacteriological limits allow for a mixing zone?
3. Can USEPA adopt positions in letters and other documents that have not gone through the formal rule-making process and then apply those positions as if they were rules?
4. Can USEPA implement Clean Water Act (CWA) requirements differently in different areas of the Country?

The current court cases to watch for these issues are: *Iowa League of Cities v. USEPA,* 711 F.3d 844 (8th Cir. 2013); and *Center for Regulatory Reasonableness v. USEPA,* U.S. Court of Appeals for the District of Columbia Circuit, case number 14-1150.

Case #2: Municipal Stormwater – Is the New York MS4 General SPDES Permit Valid and in Effect?

In 2012 a New York judge struck down the Department of Environmental Conservation's (NYSDEC's) municipal separate storm sewer system (MS4) General Permit. It held that the Permit did not require strict compliance with water quality standards and did not allow the public to comment on Notices of Intent (NOI) or MS4s' Stormwater Management Plans (SWMPs). The Natural Resources Defense Council (NRDC) had asserted that the General Permit created an "impermissible self-regulatory system" that did not force small MS4s to reduce pollutant discharges to the Maximum Extent Practicable (MEP), the standard established by the CWA for municipal stormwater. They claimed that the CWA requires that each NOI and SWMP receive a full agency review and that each must be subjected to public notice and comment.

New York's Court of Appeals disagreed, finding that the state's MS4 General Permit fully complied with the CWA. Stating that the challengers "blur the distinction between General and Individual Permits", the Court held that the required public participation process CWA was satisfied when the public was given the opportunity to comment on the draft General Permit. According to the Court, each individual NOI and SWMPP need not be subjected to public notice and comment because they are not permits.

The next "generation" of New York's MS4 Permits may look significantly different from the current Permit. In 2003 the United States Court of Appeals for the 9th Circuit in *Environmental Defense Center, et al. v. USEPA* held that the regulations for providing coverage under small MS4 General Permits did not provide for adequate public notice and opportunity to request a hearing. Additionally, the court found that USEPA failed to require permitting authority review of the best management practices (BMPs) to be used at a particular MS4 to ensure that the permittee reduces pollutants in the discharge to the "maximum extent practicable". USEPA, after additional prodding from federal courts, has proposed significant changes to its MS4 permitting rules.

In January 2016, USEPA put forward three Regulatory Proposals: Traditional General Permit Approach; Procedural Option; and State Choice. *(USEPA 2016, WEF 2016)*

Option 1 ("Traditional General Permit Approach")

Each Phase II MS4 permit (whether Individual or General) must

continued on page 42

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- PureAir Filtration
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- Redzone Robotics, Inc.
- S.P. Kinney Engineers, Inc.
- STT Enviro Corp
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Rev. 10/13/16

continued from page 40

include all requirements necessary to meet the standard of "reducing pollutant discharges from the MS4 to the maximum extent practicable, to protect water quality, and to satisfy the appropriate water quality requirements of the CWA".

The permittee is still required to submit an NOI and to develop a stormwater management program, but neither the NOI nor the SWMP would function as an individual permit application because the General Permit must include the effluent limits that apply to all MS4 dischargers. Similarly, the permittee would have no ability to establish its own permit requirements or to modify the permit's requirements through the NOI or SWMP. MS4s would still have flexibility to develop the specifics of how they would meet the requirements established in the permit.

Option 2 ("Procedural Option")

This second option retains the existing General Permit framework that requires MS4s to submit NOIs that include specific BMPs that the MS4 proposes to reduce discharges to the MEP. It also establishes a second permitting step so that specific details of the MS4's NOI get put into the MSA permit as enforceable requirements. Each NOI would be subject to review and approval by the permitting authority, where the purpose of the review would be to ensure that each MS4's BMPs and measurable goals meet the regulatory standard. During permitting authority review, changes to the NOI can be required. Following initial approval by the permitting authority, each NOI would be subject to public comment and the opportunity to request a public hearing. The final decision on approval and the requirements to MEP would be publicly available.

This process is similar to the regulatory process required in the NPDES regulations for modifying a permit *(40 CFR 124)* or for establishing the enforceable requirements of a nutrient management program for concentrated animal feeding operations. The proposed rule's preamble explains in detail what the regulatory provisions would be for Option 2.

Option 3 ("State Choice")

Under this option, each permittee would be obligated to establish requirements that reduce the discharges to the MEP, protect water quality, and satisfy the water quality requirements of the CWA. The permitting authority could achieve this through the state General Permit (Option 1), by adopting a procedural mechanism for review and approval of individual MS4 programs (Option 2), or by using a hybrid of the two. This option enables the permitting authority to choose which option is best suited for them.

Under the hybrid approach, the state could develop one permit using the Option 1 approach, and establish a second permit that relies on the Option 2 approach. A permitting authority could establish some minimum requirements that meet the regulatory standard (Option 1), but then choose to rely on the MS4 to propose BMPs and other requirements and conduct another round of public notice and permit authority review (Option 2).

The USEPA selected Option 3 for the final MS4 General Permit Remand Rule, signed by USEPA Administrator Gina McCarthy on November 17, 2016. New York's MS4 Permit No. GP-0-15-003 expires on April 30, 2017.

The main current case on this matter is the *Natural Resources Defense Council v. NY Dep't of Environmental Conservation,* Case No. 48 (N.Y. May 5, 2015) *NY Court of Appeals NY Slip Op 03766 Environmental Defense Center, et al. v. USEPA,* 344 F.3d 832 (9th Cir. 2003).

The municipal implications are that current MS4 General Permits are valid and are being enforced. But by 2017 both the New York MS4 NOI and permit requirements may be significantly different.

Case #3: So What Is MEP Anyway?

In separate administrative actions both the Army and the Air Force challenged MS4 permits that they alleged impermissibly contained limits on stormwater flow and imposed stormwater retention requirements that go beyond the "Maximum Extent Practicable" (MEP) requirements. Both permits had rigid stormwater retention requirements basically requiring mimicking/restoring predevelopment hydrology. The two armed services claimed that the retention standards were numeric standards rather than BMPs and that the retention requirements were absolute with no consideration of cost or feasibility.

In several separate Maryland cases, that state's MS4 Permit was challenged by environmental groups for not including numeric effluents to ensure that MS4 discharges comply with numeric water quality standards, including imposing requirements that go beyond BMP-based MEP compliance.

USEPA settled both the armed services cases and revised both permits. The permits still require certain construction projects to mimic redevelopment hydrology. Consistent with the MEP standard however, this requirement will apply only to the extent that doing so is practicable using BMPs.

Three of the Maryland cases have been decided at the trial court level so far. Two judges have held that the CWA does not mandate strict compliance with water quality standards for MS4s. However, a judge in Montgomery County issued a contrary decision in favor of the environmental group challengers, holding that the CWA requires strict water quality standard compliance. This latter decision was appealed to the State Court of Special Appeals. In its decision, the court overruled the Montgomery County judge by holding that the MEP standard was intended to replace the CWA 301/303 standards for MS4s, resolving the question in Maryland. According to the Wet Weather Partnership, "this decision sustains a series of 15 or so court decisions which support imposing BMPs meant to achieve MEP on MS4 dischargers rather than a requirement to comply with numeric WQS."

New York's current MS4 Permit No. GP-0-15-003 expires on April 30, 2017 and a draft of its proposed revised MS4 permit should be available during the first quarter of 2017. For municipal planning implications, it will be very important to comment on New York's next draft MS4 Permit, especially any numeric limits and conditions related to stormwater retention or other elements that seem to require specific potentially costly retrofits. Under court decisions to date, these types of standards are not required by the CWA. If these types of standards are included in the next MS4 Permit, permittees may have lost the ability to challenge them when they seek coverage under the Permit.

The cases relevant to this matter are:

- In re *Buckley Air Force Base MS4,* NPDES Appeal No. 13-17 (EAB);
- In re *Joint Base Lewis-McChord MS4,* NPDES Appeal No. 13-109 (EAB);
- *Chesapeake Bay Foundation v. Md. Dep't of the Envt.,* Case No. 02-C-14-186144 (Anne Arundel Cir. Ct. Dec. 2, 2014);
- In re *Baltimore County MS4 Permit,* Case No. 03-C-14-000761 (Baltimore Cir. Ct. Oct. 7, 2014);
- *Md. Dep't of the Envt. v. Anacostia Riverkeeper,* Case No. -2199 Sept. Term 2013 (Md. Ct. Sp. App.).

Case #4: Does My SPDES Permit Still Act as a Shield?

In general, and consistent with past court decisions, compliance with a NPDES/SPDES permit will be deemed compliance with the relevant portions of the CWA, if two conditions are met:

1. The permit holder must comply with the express terms of the permit and with the CWA's disclosure requirements; and
2. The permit holder must discharge pollutants that were not within the reasonable contemplation of the permitting authority at the time the permit was granted.

This is termed the "Piney Run" test. Recent court decisions have shed additional light on these two conditions. In the first, an environmental group filed a CWA citizen suit against a Virginia coal mine operator alleging that its wastewater contained excessive levels of selenium. The operator held a NPDES permit, but it had not listed selenium as a pollutant it would be discharging on its application. The coal company argued the CWA's permit shield (CWA §402(k)) protected it from liability because in its application it had listed all pollutants it reasonably believed would be in its mine discharge and even though it hadn't listed selenium, the regulators should have been aware that discharges from coal mines could contain selenium.

The court held that the permittee failed Prong 1 of the Piney Run test, and therefore could not invoke the permit shield, because it failed to fill out the part of the permit application that asked whether it believed selenium would be present in the discharge and it failed to conduct discharge testing required by the application instructions.

In the second case, also related to a mining discharge, a Kentucky coal mine operating under General Permit was discharging selenium and the General Permit did not include a selenium effluent limit. The mine operator also argued that it was insulated from liability by the CWA's permit shield. The court concluded first that the CWA's permit shield provision applies equally to General Permits and Individual Permits. It then applied the two-part Piney Run test to determine if the mine operator was protected by the permit shield. Under the first prong, the court found that the operator complied with the disclosure requirements because it submitted an effluent sample result that contained selenium when it applied for coverage under the General Permit. The second prong was satisfied, according to the court, because the Kentucky Division of Water was aware that mines operating under the permit sometimes discharged selenium. The General Permit explicitly acknowledged the possibility of the selenium discharges and required a one-time effluent sampling requirement – which included testing for selenium – as a condition.

In the third case coal dust from a railroad company's loading system spilled into an Alaskan bay. Environmental groups filed a CWA citizen suit alleging that the coal dust release was an unpermitted discharge. The railroad argued that the discharges were covered by its stormwater General Permit, and therefore it was not liable due to the CWA permit shield. The court found, however, that the General Permit prohibits "non-stormwater discharges," including the coal dust falling from the railroad's loading system. Therefore, the court held that the railroad failed to comply with the General Permit and therefore could not invoke the permit shield.

In the last case, a Riverkeeper group filed a CWA citizen suit against a cellulose product manufacturer. The suit alleged that the manufacturer was discharging wastewater that violated Georgia's narrative water quality standards for color, odor and turbidity. The manufacturer argued that it was shielded from liability because its discharge was compliant with the terms of its NPDES permit. Even though the court assumed that the discharge may be violating state water quality standards, the court concluded that compliance with the narrative water quality standards had not been made a condition of the Permit. Because the Riverkeeper had failed to show that the manufacturer was in violation of a condition of its NPDES Permit, the court dismissed the suit.

The municipal implications are to be aware of whether any SPDES Permit you accept has a general mandate to comply with Water Quality Standards. The cases relating to this matter are:

- *S. Appalachian Mountain Stewards v. A&G Coal Corp.,* 758 F.3d 560 (4th Cir. 2014);
- *Sierra Club v. ICG Hazard LLC,* No. 13-5086 (6th Cir. 2015);
- *Alaska Community Action on Toxics v. Aurora Energy Services,* 765 F.3d 1169 (9th Cir. 2014);
- *Altamaha Riverkeeper v. Rayonier Inc.,* CV 214-44 (S.D. Ga. Mar. 31, 2015).

Case #5: Do Satellite Collection Systems Need S/NPDES Permits?

USEPA Region 1 issued a NPDES permit renewal for the Charles River Pollution Control District POTW, which included four towns as co-permittees. Each town had their own independent collection systems that sent wastewater to the POTW. The Permit was issued without prior consultation with the four towns. The Permit required substantial collection system upgrades for the four towns to minimize excessive wet weather peak flows during wet weather events. The towns challenged the Permit administratively, arguing that their collection systems are legally separate from the POTW, and that the transfer of wastewater from the towns' collection systems to the POTWs is not a "discharge" that would give USEPA authority to regulate the collection systems. USEPA's Environmental Appeals Board (EAB) rejected the towns' petition for review of the permit. The EAB found that the definition of "treatment works" in CWA § 212 includes "collection systems." Therefore, it held, the towns' satellite sewage collection systems are part of the POTW covered by the permit.

This was only a USEPA Administrative Decision, therefore with regards to municipal implications it has no applicability in New York. However, it may be an indication that USEPA will be pushing states to start to include satellite collection systems in their POTW SPDES Permits. The case to follow relating to this matter is In re *Charles River Pollution Control District,* NPDES Appeal No. 14-0 (Envtl. App. Bd. Feb. 4, 2015).

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Much of the information in this article is adapted from Significant CWA Case Summaries prepared for the Wet Weather Partnership and available at http://www.wetweatherpartnership.com/wp-content/uploads/sites/9/2015/05/2015-05-21_WWP-CWA-Case-Summaries.pdf

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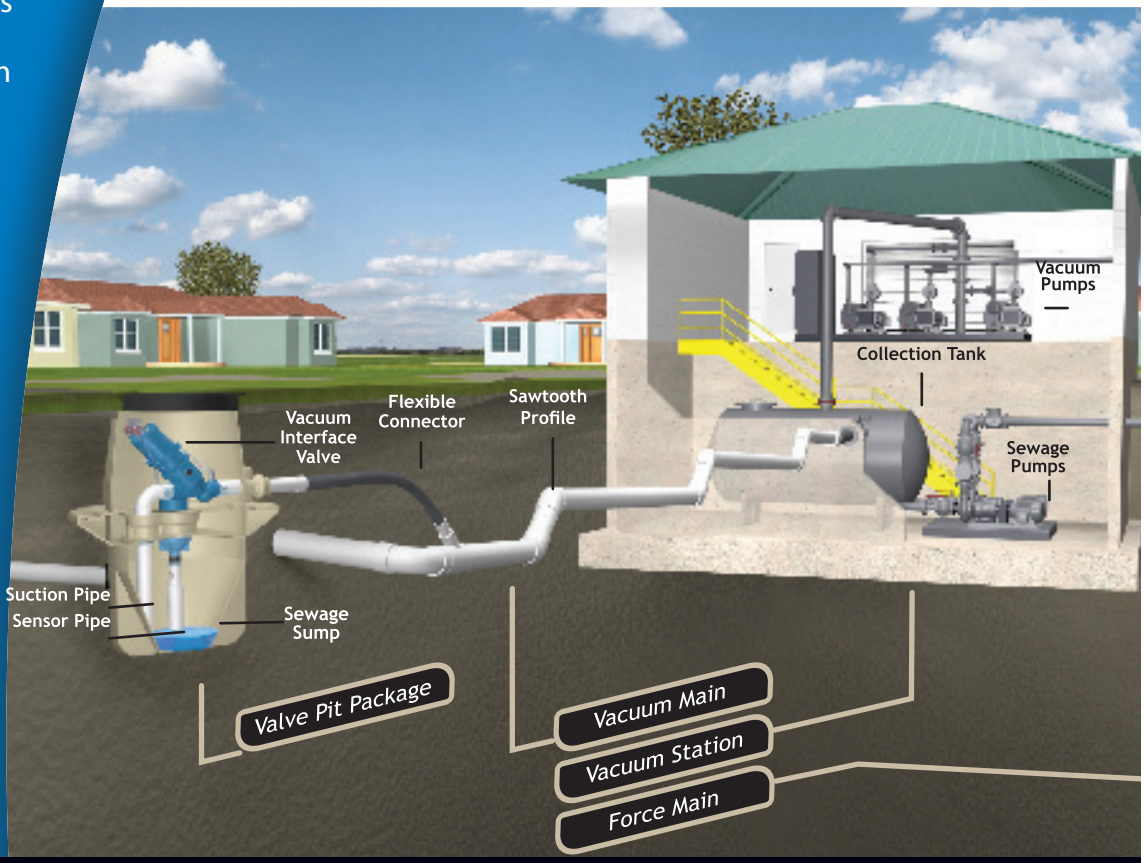

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The Economic Impact of Water Infrastructure

Learning from the Transportation Sector

by Marisa Tricas

A paradigm shift in the water sector is taking place, where treated wastewater is being recognized as a high-quality resource that can be recovered. This shift has enhanced the status of water reuse as an alternative water source in integrated water supply planning. Economic evaluations of water reuse often focus on the project itself and its direct benefits to the utility. But as utilities expand their analyses beyond the project itself, the economic development indicators sometimes are seen in the social leg of the triple bottom line, such as the number of jobs created and the water resources used for recreation.

To help decision-makers better quantify the indirect and induced economic development impacts of water investments, we can look at the metrics from existing economic frameworks in other sectors, such as transportation. These frameworks can be applied to the water sector to help planners see holistic economic alternatives and sustainable investments that water reuse and reclamation projects can contribute to their local communities.

Adopting Tools from Transportation

Other infrastructure sectors are much more developed than the water sector when it comes to identifying the economic impacts for project investments. Full economic frameworks and tools already exist in the transportation sector and have been successfully implemented in communities throughout the country and the world. The Transportation Economic Development Impact System (TREDIS) is a commonly used model used to provide economic development impact evaluation and benefit-cost analysis. Currently, 45 U.S. governmental agencies use this tool in 35 states.

In 2014, the Water Research Foundation (Denver, Colo.) and the Water Environment Research Foundation (Alexandria, Va.) released the report National Economic & Labor Impacts of the Water Utility Sector. This study examined the actual or planned expenditures of 30 water utilities across the United States and quantified direct, indirect, and induced economic benefits. This report was the first to aggregate the national economic impact of water utilities' planned and capital budgets using an economic input-output analysis. The study used the IMPLAN model, which is part of TREDIS to model the way a dollar injected into one sector is spent and re-spent in other sectors of the economy, generating waves of economic activity. The study found the expenditures resulted in a combined total of 289,000 jobs and $52 billion per year generated in economic activity. The utilities involved in the study directly employ 36,500 workers.

In 2016, the Water Environment Federation (WEF) and the WateReuse Association, both headquartered in Alexandria, Va., conducted an analysis to estimate the economic impact of the Clean Water and Drinking Water State Revolving Fund (SRF) programs. These programs are considered to be among the most successful infrastructure funding programs administered by the federal government and implemented by individual states, having provided billions of dollars in low-interest loans for thousands of projects.

The study showed that for every SRF dollar spent, 21.4% is returned to the federal government in the form of taxes. An advantage of the SRF program is the leveraging of state program funds to enhance the investment. Thus, the proposed $34.7 billion in federal allocation will leverage an additional $116.2 billion in state spending. Together, the proposed federal allocations and state SRF program funds will result in $32.3 billion in federal tax revenue. When these leveraged state funds are taken into account, $0.93 of federal tax revenue is generated for every $1 of federal investment. The study also documented increased employment and labor income as well as increases in total economic output.

WEF and WateReuse also used the IMPLAN model to evaluate the economic impacts of proposed federal SRF allocations used (results per $1 million of SRF spending). SRF spending generates high-paying jobs — each job is estimated to bring about $60,000 in labor income. On average, 16.5 jobs are generated for every million dollars in water and wastewater capital investments.

The water sector gains between 10 and 25 jobs per million dol-

continued on page 49

continued from page 47

lars of capital expenditures. Comparatively, the transportation sector shows equivalent impacts, with job creation estimates ranging between 13 and 20 jobs per million dollars invested. The most important areas that overlapped in both sectors were syphoned down to six categories: The economic role of water reuse, impact of water spending; benefit of water reuse investment; economic return on investment; impact of future scenarios for strategic planning; and online performance tracking. The framework developed is outlined below with specific impact measure questions that planners can refer to when evaluating their utilities:

- **Category 1: The economic role of water reuse.** What is the role of current water supply facilities and services in supporting the local economy? What are the stakes associated with failure to continue to support them?
- **Category 2: Impact of water spending.** How does ongoing and planned water spending affect the regional economy, and what is the income benefit from it?
- **Category 3: Benefit of water reuse investment.** How does ongoing and planned spending on water reuse provide benefits for users of those facilities?
- **Category 4: Economic return on investment.** How will planned future capital investments affect the future competitiveness, productivity, and growth of the region's economy? What is the payback from it?
- **Category 5: Impact of future scenarios for strategic planning.** How will alternative scenarios for future water supply capital investments affect the future competitiveness and growth of the region's economy? How can that information help identify investment gaps that require funding to allow economic growth?
- **Category 6: Ongoing performance tracking.** How can the evaluation and selection of future projects incorporate economic impacts and benefit-cost relationships? How can this approach apply to integrated water resources planning?

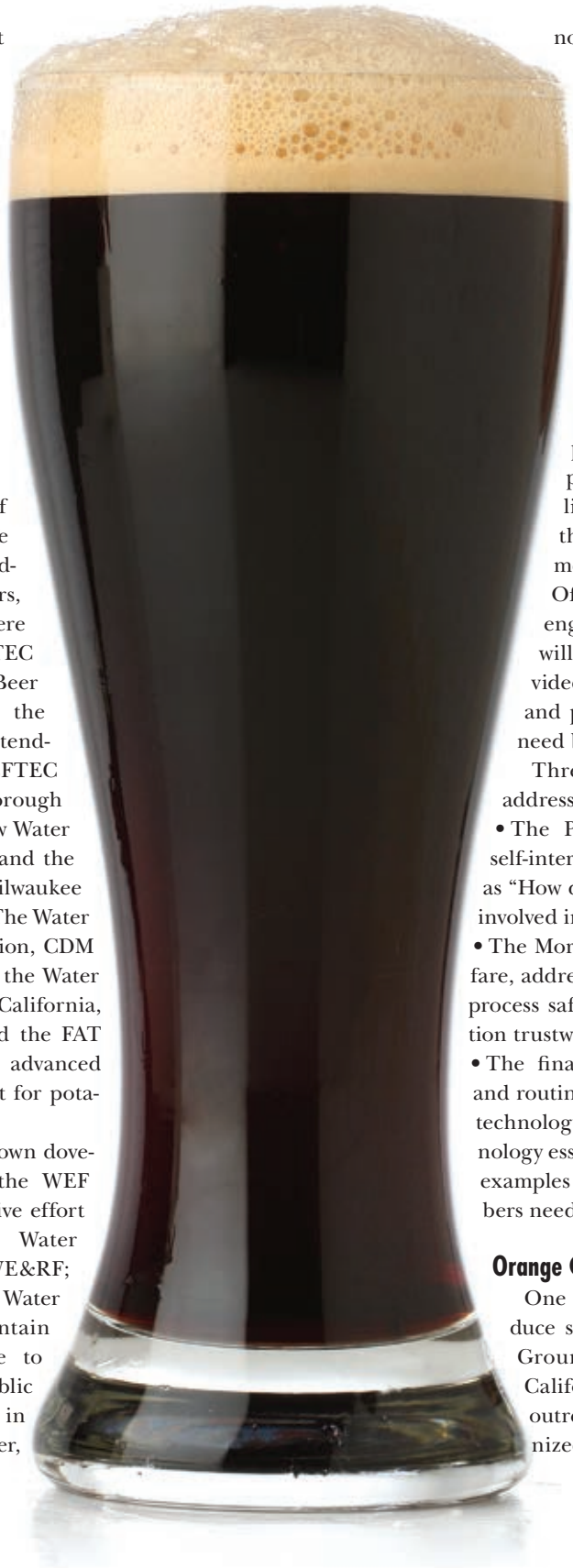
The water sector can learn from the transportation sector and better identify the indirect and induced impacts of a water project. By highlighting these impact measure categories that help drive economic growth, water reuse projects may have opportunities for additional allies in a region's economic development initiatives, especially since water sector investments are comparable to transportation investments on a job creation and return-on-investment basis.

Marisa Tricas, MS, ENV SP is Manager, Water Resources, Innovation & Policy in the Water Science & Engineering Center at the Water Environment Federation.

A Legitimate Reason to Have a Beer

Microbrews Give Communities a Taste of High-purity Potable Reuse

by Rick Warner and Barry Liner



Beer is a product that everybody likes to talk about. The explosion of microbreweries around the United States gave Clean Water Services (Portland, Ore.) an idea for a program to start conversations about the reusable nature of all water. The utility began partnering with Oregon home brewers in 2014 to brew beer from reclaimed water to demonstrate that water should be judged by its quality, not its history.

Sustainable Beer Smackdown

The utility produced a batch of high-purity water that far exceeds safe drinking water standards and provided it to local home brewers. The beers, using the Pure Water Brew brand, were featured at WEFTEC 2014 and WEFTEC 2015 as part of the Sustainable Beer Smackdown. Each successive year, the Smackdown has gained new contenders. In September 2016, at the WEFTEC 2016 Innovation Pavilion, Hillsborough County in Florida introduced its New Water Brew, joining Clean Water Services and the Activated Sludge beers from the Milwaukee Metropolitan Sewerage District and The Water Council (Milwaukee, Wis.). In addition, CDM Smith (Boston), in partnership with the Water Replenishment District of Southern California, served up an Indian pale ale called the FAT Californian, named after the full advanced treatment (FAT) model of treatment for potable reuse applications.

This year, the Reuse Beer Smackdown dovetailed nicely with the release of the WEF Water Reuse Roadmap, a collaborative effort by WateReuse (Alexandria, Va.), Water Environment & Reuse Foundation (WE&RF; Alexandria, Va.), and the National Water Research Institute (NWRI; Fountain Valley, Calif.). Such efforts serve to engage industry professionals, public leaders, and imbibers everywhere in this conversation about clean water, not only for its role in health, but also in supporting big and small businesses.

The Importance of Legitimacy in Reuse

While the beer events are fun and engaging, the most important aspect of these efforts is the focus on creating an authentic conversation with the larger community about water quality. These conversations are the cornerstones of a sociological concept known as "legitimacy."

Legitimacy is more important as communities consider reuse projects, particularly potable water reuse. Reuse projects have often been met with public opposition, despite having proven that the technology and water quality meet or exceed drinking water standards. Oftentimes, technical professionals such as engineers and scientists believe the public will accept new technologies when it is provided with information through marketing and public education. Such outreach efforts need be authentic to achieve public support.

Three levels of legitimacy need to be addressed to have a successful project.

- The Pragmatic level focuses on the user's self-interest, seeking to answer questions such as "How do I benefit personally?" and "How am I involved in the decision-making process?"
- The Moral level deals with social values and welfare, addressing questions like "How is quality and process safety guaranteed?" and "Is the organization trustworthy?"
- The final level, Cognitive, deals with customs and routines that are taken for granted. "Does the technology fit with my daily life?" and "Is the technology essential, with no feasible alternatives?" are examples of the inquiries that community members need answered.

Orange County and Nevada Strive for Legitimacy

One example of how legitimacy can produce successful results is the Orange County Groundwater Replenishment System in California. Through its dedication to the outreach efforts, utility managers were recognized as trustworthy and competent experts

Water Environment Federation

Local beers created by utilities and microbreweries were showcased at WEFTEC 2016.

in the community. *(Learn more in the publications listed in "Further Reading".)* Taking the lessons that Orange County learned to heart, a northern Nevada utility values legitimacy as part of a feasibility study that may someday lead to Nevada's first potable reuse project.

Essentially, the feasibility study must show that every aspect of the treatment train is robust and redundant. The utility takes full ownership from the home lateral to the final compliance testing, ensuring the public it should have the full confidence in the water utility. This also includes looking carefully at pretreatment ordinances, collection systems, resource recovery treatment processes, and the most advanced water purification processes.

One cornerstone of the feasibility study is a demonstration-scale project. Not only will this project show that treatment technologies are able to perform and meet stringent regulations, but community leaders and the general public also will be able to visit and see water purification processes in action. The public will be able to meet with the utility's operations and laboratory staff, and these events will showcase the agencies' technical skills and dedication to quality and also give the utility an opportunity to interact and share ideas with customers.

Building trust and confidence with each community is vital. The Northern Nevada Regional Effluent Management Team driving this feasibility effort includes representatives from the City of Reno, Truckee Meadows Water Reclamation Facility, Truckee Meadows Water Authority, the City of Sparks, Washoe County, and the Northern Nevada Water Planning Commission. It is an exciting time to be in the water business, and the Northern Nevada Effluent Management Team demonstrates that utility leaders take the trust the public has afforded them very seriously.

Rick Warner is a senior engineer at Washoe County, Nev., and President of the Water Environment Federation (Alexandria, Va.). Barry Liner is director of the Water Science & Engineering Center at WEF.

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Team Has Eagle Eye on Floodplain Project

by JoAnne Castagna

A group of people are wading slowly through high grass under a hot summer sun as they begin a guided walking tour of the Walton Floodplain in Delaware County, New York.

Suddenly there's excitement in the air as an eagle perches on a nearby branch hanging over the West Branch Delaware River. The group swiftly changes its focus, and cameras, from the tour to this majestic bird.

It seems the group is no longer interested in what their guide has to say. On the contrary, this group is an inter-agency team that is looking over the land because they're starting a reclamation project that will improve the floodplain's environment for that eagle, reduce flooding for the local community and protect New York City's drinking water.

The Walton Floodplain Reclamation Project is part of the U.S. Army Corps of Engineer's New York City Watershed Environmental Assistance Program.

"The program funds projects that are protecting the water quality of New York State's watersheds that provide drinking water to millions of New York City residents and businesses," said Rifat Salim, project manager, U.S. Army Corps of Engineers, New York District.

On this project, the Army Corps is working in collaboration with the Delaware County Soil and Watershed Conservation District, New York State Department of Environmental Conservation, New York City Department of Environmental Protection, Village of Walton and the Town of Walton.

A floodplain is the land bordering a river. Over the years, the 13-acre Walton Floodplain that borders the West Branch Delaware River has been filled with gravel that has raised and hardened the floodplain and degraded the natural vegetation.

Graydon Dutcher, stream program coordinator with the Delaware County Soil and Water Conservation District who was the team's guide on the floodplain tour, said, "The floodplain has been filled through the years one dump truck at a time as a place of easy disposal of materials."

As a result, when the river floods the water that would naturally be absorbed, filtered, and transported by the floodplain, is unable to. So, floodwater backs up because of the over filled floodplain and stays trapped on the streets of the Village of Walton, flooding businesses and homes, especially Delaware Street and the ironically named Water Street.

When this high volume of stormwater runoff floods the streets, it sweeps up contaminants and carries them to the West Branch Delaware River that feeds into the Cannonsville Reservoir. The reservoir supplies 97 billion gallons of water to New York City's drinking water supply.

This project will return the floodplain to its natural state, and as a result it will reduce flooding and improve water quality.

Dutcher said, "We are going to remove the gravel creating a more natural floodplain elevation." This work will include removing and relocating a New York State Electric & Gas line to a deeper elevation and recycling the gravel and moving it outside of the floodplain.

During the walking tour, Dutcher pointed to a McDonald's golden arches sign several yards away. He said, "We are at the same height as the golden arches. This is how high the floodplain has grown over the years!"

iStockphoto.com

Eagles are often seen resting in the tree branches along river floodplains.

Dutcher took the group through a long muddy path surrounded by high shrubbery leading to the West Branch Delaware River. The team stood along the river's edge and continued to take photos of the resting eagle perched above the moving river.

The project includes restoring the floodplain's vegetation. The invasive plant species that the group has been walking through are going to be removed and grass is going to be planted.

He said where the team is standing along the river, a riparian buffer or hardwood forest is going to be created that will include a mix of native maples, ash and a mix of shrubs.

"Flood waters will drain from the town's streets, building rooftops and parking lots and filter through the restored vegetation and the riparian buffer before entering the river," said Dutcher.

The riparian buffer traps sediment and pollutants like harmful phosphorus and nitrogen particles from entering the river. This improves the quality of the water, maintain the river's temperature and fosters the creation of fish and aquatic habitats. The project will treat 2.8 acres of stormwater runoff.

Dutcher said, "This project is a big thing in Walton. It benefits the community in several ways."

The project will lessen the damages of flooding. When completed, the project will provide flood reductions for a 100-year storm event. This is a flood whose strength and water height is predicted to occur, on average, about once in 100 years. In addition, it will also be useful for lesser, 10-year storm events that occur on average once every decade. This project will also connect and drain the newly built green space in the center of Walton's Main Street.

Dutcher added that this project, which is expected to be completed by 2018, will also potentially give the land back to the community for other uses like athletic fields and park land.

That eagle never left the branch the entire time the team was walking the floodplain and it seemed to be keeping a steady eye on them. Some in the group saw it as nature's way of reminding them to keep focused on this project that has multiple benefits for locals, city dwellers and eagles who just happen to make Walton their home.

Dr. JoAnne Castagna is a Public Affairs Specialist and Writer for the U.S. Army Corps of Engineers, New York District. She can be reached at joanne.castagna@usace.army.mil. Follow her on Twitter at http://twitter.com/writer4usacenyc.

Restoring Oysters to Jamaica Bay –

DEP Joins with the Billion Oyster Project

by New York City Department of Environmental Protection, September 6, 2016

This past summer, the New York City DEP joined with the Billion Oyster Project to install nearly 50,000 oysters in Jamaica Bay, the largest single installation of breeding oysters in New York City. The New York/New Jersey Harbor was once blanketed by oysters, but due to over harvesting, dredging and pollution, they became functionally extinct decades ago. Oysters are widely recognized as a key component of a healthy marine ecosystem as they filter pollutants from the water, help to protect wetlands and shoreline from erosion and storm surge, and provide habitat for communities of fish and other aquatic organisms. The goal of this research project is to create a self-sustaining population of oysters, which will in turn improve water quality and protect critical wetlands.

The installation includes a central donor bed composed of the nearly 50,000 adult and spat-on-shell oysters as well as four smaller receiving beds composed of clam/oyster shell and broken porcelain. The porcelain was harvested from nearly 5,000 inefficient toilets that were recycled from the citywide water conservation program. Having reached reproductive maturity, it is anticipated that the adult oysters will spawn. The resulting fertilized eggs will grow as free-floating larvae in the water column until the young oysters attach themselves

Porcelain harvested from nearly 5,000 inefficient toilets is being used to create four smaller receiving beds composed of clam/oyster shell and broken porcelain.
Courtesy New York City Department of Environmental Protection

to the shells of the parent oysters on the donor bed or onto any one of the four receiver beds. With successful establishment and recruitment, the donor bed and the receiving beds are anticipated to show a measurable increase in oyster larvae attachment as well as an increase in the growth of mature oysters. The hope is that the oysters will become self-sustaining, spawning seasonally and providing new recruits.

Existing water quality monitoring at the site of the oyster beds will serve as a baseline for future comparison. This includes temperature, pH, salinity, conductivity, turbidity, dissolved oxygen and chlorophyll. Monitoring will continue for two years after the installation of the beds, in order to establish water quality benefits provided by the oysters. Measurements will also be taken to better understand the rate at which the oysters are removing nutrients from the water.

Prior DEP oyster reintroduction pilot studies showed adequate environmental conditions for oyster growth and survival within Jamaica Bay, including water quality within normal tolerances for the Eastern oyster. The results also indicated that the oysters had reproduced. In addition, an increase in biodiversity was observed, including many species using the pilot sites for breeding and feeding amongst the establishment of new plants. However, no recruitment of new oysters was observed. It is believed that the lack of recruitment is mainly due to the relatively small size of the pilot sites and the overall lack of oyster populations in and around Jamaica Bay and the New York/New Jersey Harbor.

The next step in restoring oysters in Jamaica Bay is to determine the effect of placing larger oyster beds in areas that could protect salt marshes from further erosion while improving water quality. It has been well documented that marshes and shorelines are eroding at an accelerated rate in Jamaica Bay due to a number of changes over time, including dredging and filling and climate change. Efforts are underway to restore some of the lost marshes. This study would test the effectiveness of living shorelines in the form of a relatively large oyster bed to slow erosive forces on these habitats.

In addition to our partners at the Billion Oyster Project, this research project has been made possible by a $1 million grant from the U.S. Department of Interior, which is administered by the National Fish and Wildlife Foundation. I'd also like to recognize DEP's team, including Angela Licata, John McLaughlin, Mikeal Parlow, David Lin, Qi Long (Jackie) Chen and Ben Huff. **The New York Times** ***ran a story on this project, available at http://www.nytimes.com/2016/09/05/nyregion/oyster-project-new-york-harbor.html?_r=0. Additional photos and video are available at https://www.flickr.com/photos/nycwater/sets/72157672119051880/.***

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See more photos on page 58.

continued from page 57

Installation Day for Nearly 50,000 Breeding Oysters in Jamaica Bay

Bags of oysters await preparation for their deployment.

Elements shown were used to build the oyster reef in Jamaica Bay.

Oysters are loaded into wire mesh cages.

Left and above: Oyster cages were deployed on September 1, 2016 in Jamaica Bay.

Oyster cages in position in Jamaica Bay were photographed October 4, 2016.

All photos courtesy of the New York City Department of Environmental Protection

Jamaica Bay stories continued on page 60

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Rev. 10/13/16

continued from page 58

Restoring Our Harbor, Reconnecting New Yorkers to the Water

The Billion Oyster Project (BOP) is an ecosystem restoration and education project aimed at restoring one billion live oysters to New York Harbor and engaging hundreds of thousands of school children through restoration-based STEM education programs. Students at New York Harbor School have been growing and restoring oysters in New York Harbor for the last six years. They have learned to SCUBA dive safely, raise oyster larvae, operate and maintain vessels, build and operate commercial-scaled oyster nurseries, design underwater monitoring equipment and conduct long-term authentic research projects all in the murky, contaminated, fast moving waters of one of the busiest ports in the country. Together and with the help of many partners these students have restored over nineteen million oysters. Fifty-four schools have partnered with the project to provide authentic, place-based science and math lessons through the lens of oyster restoration. Each year, thousands of students participate in these learning opportunities.

Results to Date	BOP by the Numbers
Oysters grown in NY Harbor	19.5 million
Reef area restored	1.05 acres
Pounds of shell recycled	300,000
Number of restaurants engaged	53
Schools engaged	54
High school students engaged	2,150
Middle school students engaged	875

Source: *https://www.billionoysterproject.org/about/*. Accessed on-line November 30, 2016.

Whale Spotted Near Lady Liberty

A whale spotted in New York Harbor November 17 near the Statue of Liberty serves as proof that DEP's remarkable efforts have made New York City's waterways the healthiest they have been in more than 100 years. And, November 19, a fisherman was surprised when a whale surfaced among the waves off Staten Island's South Shore. In recent years, at least seven species of whales, including humpbacks, have also been spotted in the New York Bight, an indent in the coastline that runs from Long Island to Cape May, NJ. The successful transformation of the City's harbor can largely be attributed to the billions of dollars DEP has invested in wastewater treatment – the pipes, pumps, tanks, equipment, and personnel – to keep our waters clean.

Source: NYCDEP Weekly Pipeline, November 22, 2016, Volume VII, Issue

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Breaching whale in New York waters

Resources

To advertise or to become a member, contact Rebecca Martin at 315-422-7811 ext. 5 or e-mail her at rebecca@nywea.org.

Visit www.nywea.org for information or see us on Facebook.

Operator Quiz Test No. 113 – Potpourri

The following questions are designed for trainees as they prepare to take the ABC wastewater operator test. It is also designed for existing operators to test their knowledge. Each issue of *Clear Waters* will have more questions from a different section of wastewater treatment. Good luck!

1. Which of the following digester conditions would have the most potential to result in low quality supernatant?:
   a. Feed sludge point is too close to the supernatant draw-off point
   b. Regular sludge withdrawal
   c. Digester gas monometer readings equaling the digester gas compressor controller set point
   d. Maintaining digester temperature of 98°F

2. Sludge conditioning in a centrifuge is regulated by all of the following except:
   a. Sludge feed rate
   b. Bowl speed
   c. Polymer dosing rate
   d. Conveyor belt speed

3. Step-Feed aeration is most accurately described as:
   a. A process using digested sludge to maintain nutrient balances
   b. A process that uses one tank for reaeration and for treating primary effluent
   c. A process that allows a slug of primary effluent to pass through a tank without mixing with other primary effluent entering the tank
   d. A process that adds primary effluent at several locations along the length of an aeration tank

4. Calculate the food to mass ratio with the following data:
   Aeration tank influent flow 2.0 MGD
   Aeration tank influent BOD 100 mg/l
   Aeration tank size 15'x30'x100'
   MLVSS 2,000 mg/l
   a. 0.3
   b. 0.6
   c. 0.15
   d. 0.08

5. A bar screen exhibits a large difference in upstream and downstream channel levels. This is most likely attributed to:
   a. High grit levels in the channel
   b. Blinding
   c. Lower than average water flows
   d. Higher than average water flows

6. Given the following information, calculate the total flow in gallons after 1-minute of flowing through this channel. Assume the channel is rectangular and full.
   Channel Width: 5.0'
   Channel Depth: 2.0'
   Velocity: 3.5 ft/sec
   a. 2,100 gal
   b. 292 gal
   c. 15,700 gal
   d. 17,520 gal

7. Detritus in wastewater can best be described as:
   a. Sludge
   b. Grit
   c. F.O.G
   d. Struvite

8. Which of the following statements is correct?:
   a. 1 HP-hour is equal to 0.746 kW-hour
   b. 1 cubic foot is equal to 8.34 gallons
   c. 100 ml is equal to 1 liter
   d. 1400 minutes is equal to 1 day

9. What is the detention time of a round secondary clarifier with a depth of 12 feet, a diameter of 130 feet and an influent flow of 11.25 MGD?:
   a. 1.5 hours
   b. 0.3 hours
   c. 2.5 hours
   d. 0.7 hours

10. The logarithm of the reciprocal of hydrogen ion activity can best be represented by:
    a. pH
    b. H^-
    c. H°
    d. PSI

Answers on page 62.

For those who have questions concerning operator certification requirements and scheduling, please contact Tanya May Jennings at 315-422-7811 ext. 4, tmj@nywea.org, or visit www.nywea.org/OpCert.

Winter 2016, Vol. 46, No. 4

Clear Waters

New York Water Environment Association, Inc.

ADVERTISERS	PAGE
AECOM	30
AFTEK	19
AIRVAC	44
Aqua-Aerobic Systems	48
Barton & Loguidice, D.P.C.	62
Bond, Schoeneck & King, PLLC	13
C&S Companies	13
CDM Smith	35
D & B Consulting Engineers & Architects	46
DN Tanks	27, 53
Eco-Rental Solutions LLC	60
Franklin Miller Inc.	25
GA Fleet	8
Gannett Fleming	60
GP Jager Inc.	20, 41, 59
Grace Industries	53
Greeley & Hansen	15
H2M architects + engineers	13
Harper Control Solutions Inc.	39
HDR	39
Holland Company, Inc.	21
IDEXX WATER Inc.	52
J. Andrew Lange Inc.	21
Koester Associates, Inc.	Inside Front Cover
Kusters Water	15
Lakeside Equipment Corporation	38
Mixing Systems, Inc.	Inside Back Cover
Mott Macdonald	45
O'Brien & Gere	21
Pumping Services	54
Siewert Equipment Co.	Back Cover
Smith & Loveless, Inc.	35
Statewide Aquastore, Inc.	60
Xylem Dewatering Solutions Inc.	46

Answers from page 61: 1 A, 2 D, 3 D, 4 A, 5 B, 6 C, 7 B, 8 A, 9 C, 10 A

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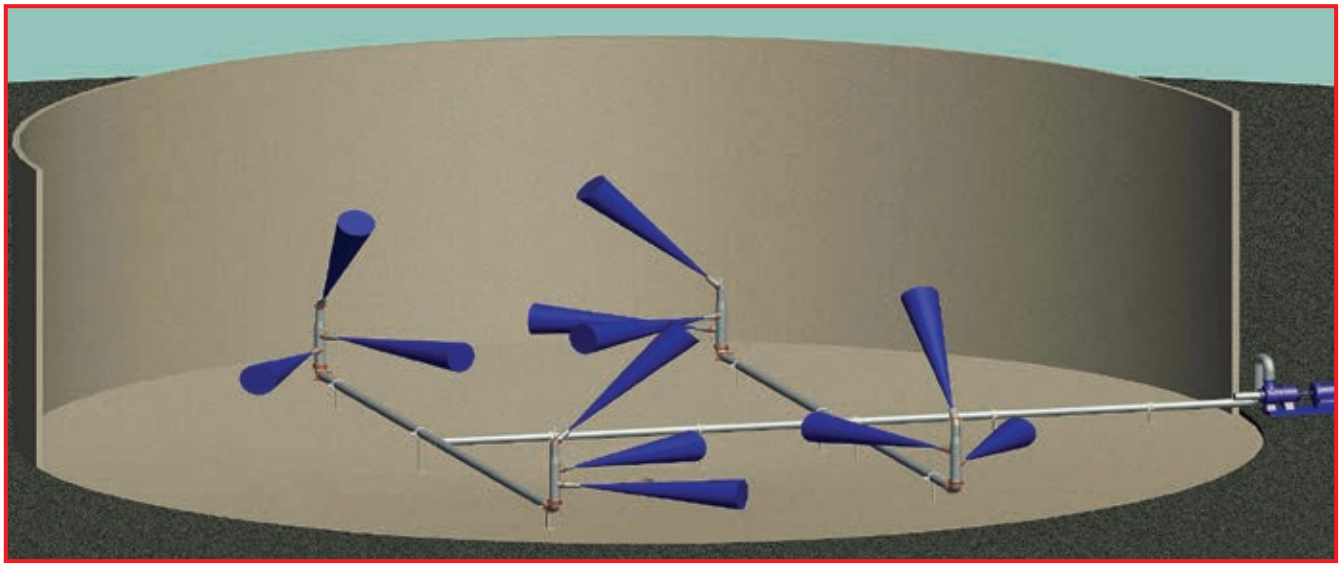

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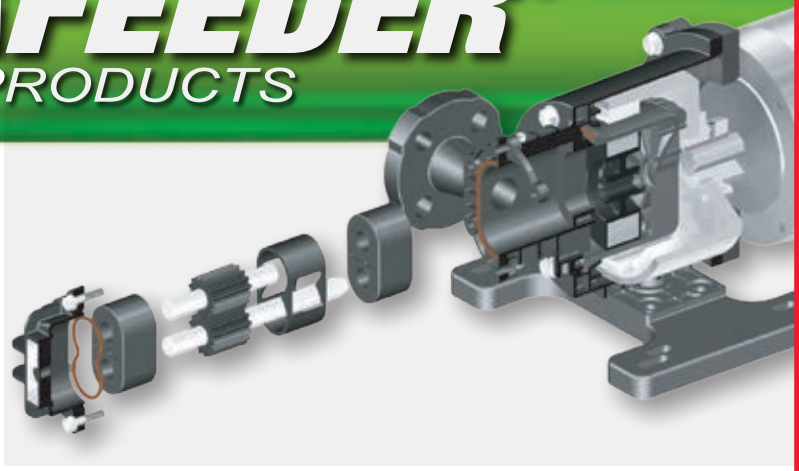

VanLare Wastewater Treatment Facility
Rochester, NY
Pulsafeeder Authorized Distributor: Siewert Equipment

Located on the southern shore of Lake Ontario, the Frank E. VanLare Waste Water Treatment Facility, Monroe County, N.Y., has a total treatment capacity of 660 mgd and is currently running around 100 mgd. The plant uses Non-metallic Eclipse pumps to pump 12.5% Sodium Hypochlorite, Chlorine, for disinfection before the final discharge of the wastewater. VanLare runs 24 hours a day, 365 days per year.

Benefits of Eclipse Pumps

- Leak free pumping ensures environment and worker safety
- Keep On Pumping kits (KOPkit®) offer drop-in replacements for wear parts
- Cost and frequency of maintenance is very low, less downtime and wasted chemicals

Eclipse for Chemical Dosing

VanLare originally installed peristaltic pumps for Sodium Hypochlorite and its Environmental Service team was in search of a better solution. Peristaltic hose life is unpredictable and inconsistent. These pumps are not leak free so worker safety was also concern because of inhalation and skin contact with the chemicals. After working with Siewert Equipment, they installed Non-metallic Eclipse pumps. Eclipse sealless design ensures zero emissions of hazardous or regulated chemicals. These pumps have superior chemical resistance. Service is quick and piping and electrical stay in place because of the front pull-out design.

In addition to pumping Sodium Hypochlorite, VanLare installed three Non-metallic Eclipse E25 pumps into the Ferric Chloride station. Ferric Chloride is used for phosphorus removal.

Pump Model	Quantity	Chemical Pumped	Application
E02	2	Sodium Hypochlorite	Scrubber odor control
E02	2	Sodium Hydroxide	Scrubber odor control
E05	5	Sodium Hypochlorite	Effluent disinfection
E05	4	Calcium Nitrate	Odor control
E25	3	Ferric Chloride	Feed to aeration system
E75	3	Sodium Hypochlorite	Odor control to sludge day tanks before centrifuge

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