Horizons

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Summer 2010

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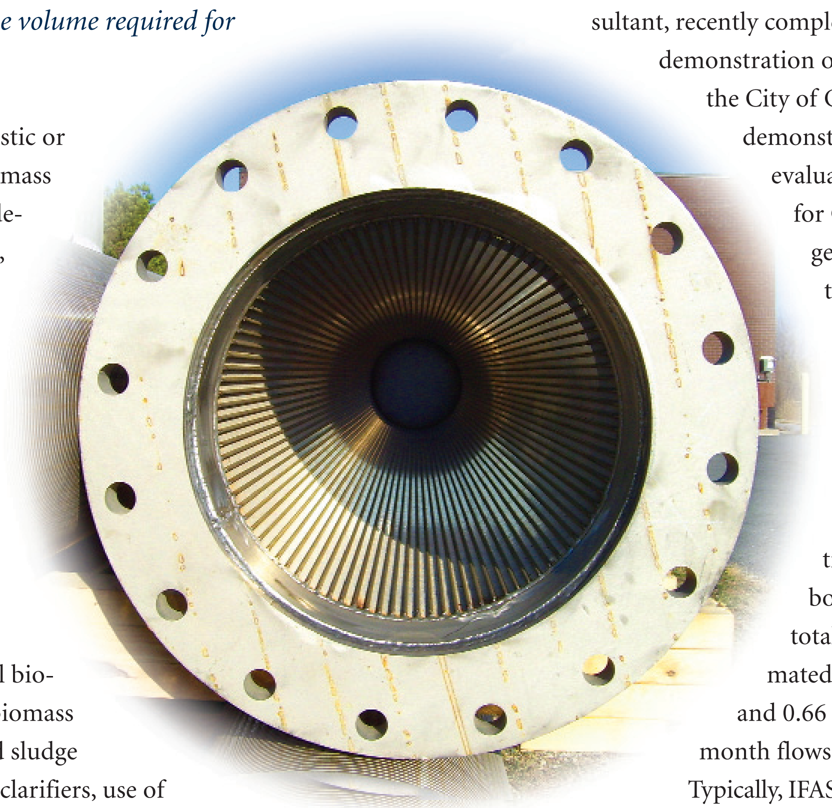
Inside

HAZEN AND SAWYER
Environmental Engineers & Scientists

Using Integrated Fixed Film Activated Sludge to Increase Capacity

By James Gellner, P.E., Senior Associate

Integrated fixed film activated sludge (IFAS) systems add fixed or free floating media to an activated sludge basin to encourage the growth of biomass and enhance the treatment process. IFAS systems are being implemented at an increasing number of wastewater treatment facilities to expand the capacity of the activated sludge system in the same tank volume. Hazen and Sawyer recently completed a demonstration of an IFAS system successful in achieving nitrification with less than 50 percent of the volume required for a conventional system.



IFAS media can be plastic or fabric. The amount of biomass that grows on the media depends on a host of factors, including loading, dissolved oxygen concentration, temperature, mixing energy, suspended phase biomass concentration, and solids retention time. The attached biomass combines with the suspended concentration to achieve much greater total biomass. Since the attached biomass is retained in the activated sludge basin, and not sent to the clarifiers, use of IFAS technology can increase the capacity of the activated sludge system in the same tank volume.

Although the benefits are significant, IFAS systems also come with several physical requirements that must be carefully considered in the design and operation of these systems:

- Mixing – adequate mixing must be provided to ensure that free floating media remains uniformly distributed.
- Turbulence / Sloughing Energy – The mixing energy provided by the aeration system is critical for sloughing of biomass and the creation of a thin biofilm.
- Aeration for nitrification systems – higher dissolved oxygen concentration (typically 3 to 4 mg/L) is required in the suspended phase to ensure that the biofilm is completely aerobic.
- Effluent screens – For free floating systems, effluent screens must be installed to contain media within the reactors.
- Foam removal / accumulation – Because of the need to retain free floating media within the IFAS cells, accumulation of foam is a common issue with IFAS systems.

Hazen and Sawyer, in conjunction with another consultant, recently completed a year-long, full-scale demonstration of the IFAS technology at the City of Greensboro, NC. The demonstration was part of an evaluation of process options for Greensboro to meet stringent nutrient limits at its two plants: the T.Z. Osborne Water Reclamation Facility (WRF), rated at 40 mgd, and North Buffalo Creek WRF, rated at 16 mgd. The watershed TMDL requires reductions in the discharge of both total phosphorus and total nitrogen by 2016; estimated limits are 5.3 mg/L TN and 0.66 mg/L TP at maximum month flows.

Typically, IFAS systems are pre-purchased or procured prior to final design. Often, sole source negotiations are used to procure the technology. During this project, specifications were developed to allow competitive bidding of IFAS systems in a traditional design-bid-build format. For the pilot demonstration, one activated sludge tank and one final clarifier was completely separated from the rest of the activated sludge system at the plant. Modifications were made to implement a 3.5-mgd capacity, full-scale IFAS demonstration pilot while taking advantage of the existing reactor zones and structures.

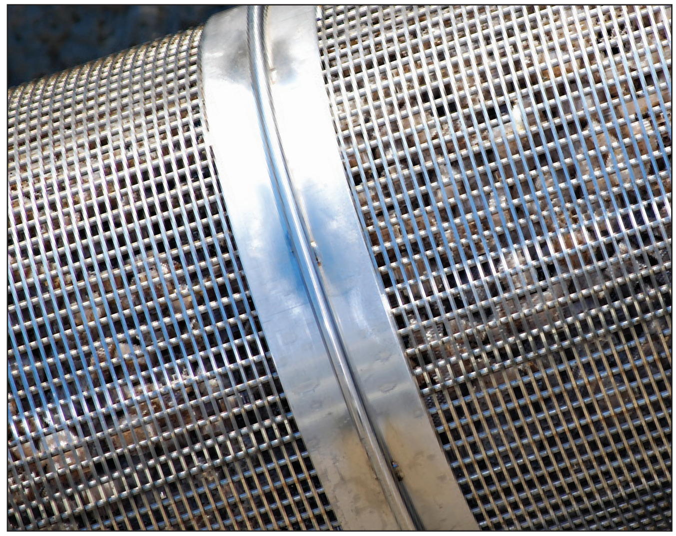
AnoxKaldnes was the selected supplier of the media and IFAS aeration system. Three separate IFAS cells were established in the pilot (Cells D, E, and F). AnoxKaldnes K3 media was placed in each IFAS cell to a fill fraction of 35%. The three cells provided a unique opportunity to examine biofilm performance under three distinctly different loading conditions.

The demonstration was operated for a period of one year, from April 2008 through April 2009. A significant sampling effort was implemented with the demonstration, wherein sampling and analysis of multiple parameters was performed by plant staff three times per week. In addition, weekly process profiles and additional analysis were performed by the team, and biomass accumulation on the media was also quantified weekly for each of the three IFAS cells in the demonstration basin.

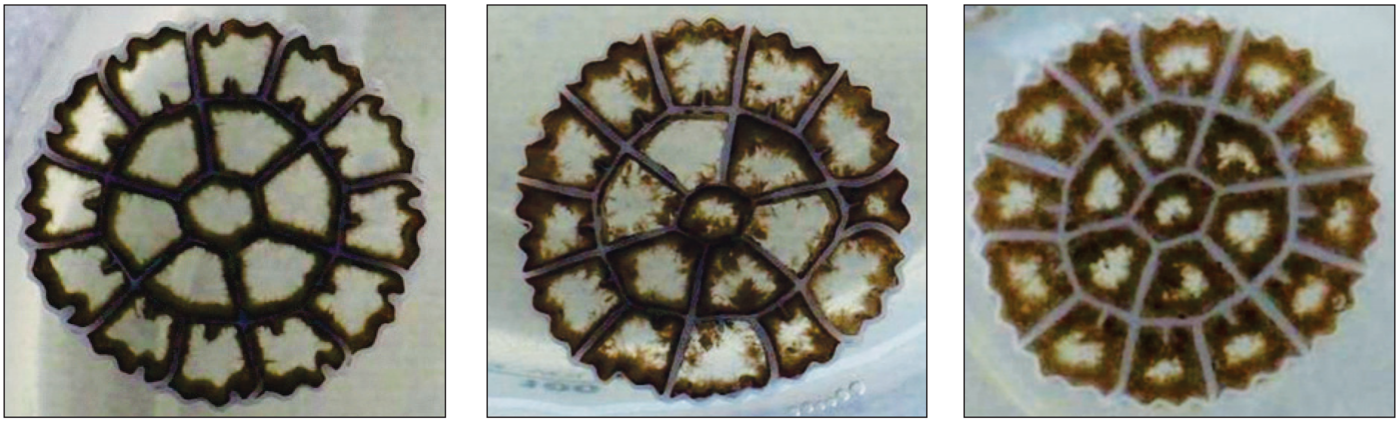
Key process findings and practical implementation considerations found during the pilot effort included:

Solids Inventory

The amount of biomass that can be maintained on the media has a significant impact on IFAS capacity and performance. An active attached biomass was observed throughout the demonstration period, but the nature and composition of the attached bio-



Free floating media for IFAS systems are retained by submerged wedgewire screens, increasing the capacity of the activated sludge system in the same tank volume.



IFAS systems rely on attached biomass for added capacity in similar tank volumes. Attached biomass from each IFAS cell (left to right downstream in the basin).

mass in each IFAS cell differed and changed over time. The quantity of attached growth is influenced by a number of operational and environmental conditions, including soluble biodegradable COD loading, MLSS concentration, temperature, and DO concentration. Attached growth responded quickly when loading conditions changed in the system. Generally, media biomass in the range of 5 to 15 g TSS/m^2 were easily created and maintained during the demonstration. Specific values for use during design were determined as a function of loading conditions.

Nitrification

In general, consistent nitrification was achieved in the three IFAS cells, corresponding to approximately 50% of the volume required in a conventional system and at higher loading rates. The fixed film biomass represented up to 50% of the total biomass in the system. The system achieved nitrification, even at temperatures of approximately 15 °C and total aerobic SRTs of approximately 5.5 days. Suspended phase biomass had an aerobic sludge age of as low as 3.6 days, and the attached biomass provided much of the nitrification activity during colder temperatures.

Aeration

The aeration requirements for IFAS systems must be considered both from a capital cost and long-term operating cost perspective. Suspended phase oxygen concentrations must be higher than typical (i.e. 3 to 4 mg/L) to remove any kinetic limitations associated with oxygen diffusion through the biofilm layers. The amount of air required is also influenced by the oxygen transfer efficiency of the aeration device used for the installation. During this pilot, higher air flows relative to conventional processes were observed. There was no evidence of higher than expected oxygen transfer efficiency relative to design values used for the test.

Foam

Because free floating media must be retained in the activated sludge tanks, natural foam traps are often created in IFAS systems. Typically, the only way to combat foam is to use defoamant sprays and or provide temporary wasting of surface foam from the system. During the pilot, plant operation and maintenance staff developed a vertical bar screen system that was mounted near the water surface that successfully retained media while passing foam. The screen had ¼-inch openings and was supported at top and bottom. A spray nozzle was directed at the bars, and the screen design was modified to allow for slanting toward the direction of flow.

Retention of IFAS Media / Hydraulics

Containment of IFAS media is normally accomplished through the use of submerged effluent cylindrical screens. Headloss above values recommended by the manufacturer was a significant issue at times during the pilot. When coupled with foaming events, the excessive headloss reduced the amount of air that could be supplied to the basins, especially when the foam was present.

Accumulation of Debris in IFAS Cells

During the operation of the IFAS demonstration, a significant amount of floatables and debris were noticed in the first IFAS cell. The cause of the buildup was recycled scum and bypass from influent screens. The observations of the pilot underscored the need to use caution in consideration of upstream screening. Screens should have openings less than 6 mm (the smaller the better), and conditions causing bypass of debris should be minimized.

The IFAS demonstration was extremely valuable, allowing the City and the design team to gain an understanding of full-scale design and operations issues associated with an IFAS system. The demonstration was successful in achieving nitrification with less than 50% of the aerobic volume required in a conventional system. The information gathered during the pilot will be used for a more detailed evaluation of full-scale costs of both the conventional and IFAS process options. ◣

DEP Building New System to Improve Reservoir Management

FOR IMMEDIATE RELEASE
February 24, 2010

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Environmental Protection Commissioner Cas Holloway today announced that work has begun on the Operations Support Tool (OST), a cutting-edge, $5.2 million computer system that will enable DEP's water supply operators to more accurately predict water storage levels in the City's reservoirs so that DEP can better manage the movement of water throughout the reservoir system, and ultimately, to the 9 million New Yorkers who rely on the City's drinking water every day. The initiative, the first of its kind in the world, will improve the City's water management systems by predicting events that could affect water quality much earlier than is possible now, and incorporating more data in the models used to determine water flows.

Cutting Edge Water Supply Computer Modeling System Will Be First of its Kind in the World

Understanding the volume and quality of the reservoirs and their feeding waters (rivers, streams, etc.) is critical to isolating and addressing cloudy water that can affect overall quality. When completed, the Operations Support Tool will enable DEP to divert or release water from its reservoirs at the best times to guarantee the highest quality water is delivered to New Yorkers and to protect downstream habitat. The system is expected to be complete by 2013 and will be phased in on a rolling basis. The consultant for the initiative is Hazen and Sawyer.

"The Operations Support Tool will help us make earlier and better decisions about moving water between and out of our reservoirs to ensure the delivery of the highest quality water possible to the 9 million New Yorkers who rely on our water supply," said Commissioner Holloway. "Proactively moving water not needed for supply can help cushion storm impacts that can affect downstream communities and improve the aquatic habit below our reservoirs."

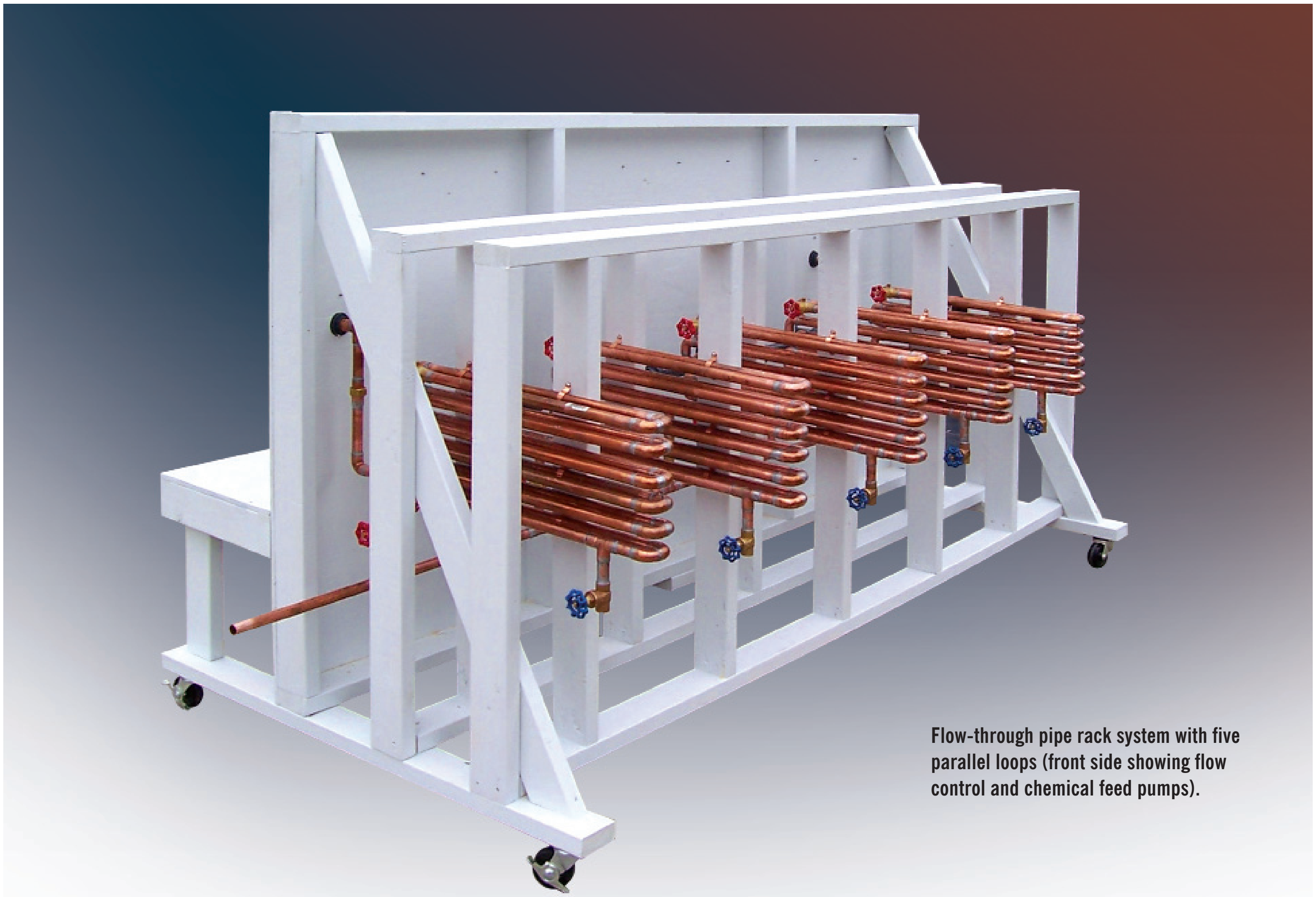
"We look forward to this collaboration with Commissioner Holloway and his team," said Jack Hayes, Ph.D., Director of the National Weather Service. "We help New York manage its regional water resources effectively by providing high-quality precipitation and stream flow forecasts. Implementation of the new Operations Support Tool holds great promise to strengthen this partnership."

The Operations Support Tool will link DEP's water quality and quantity models; assimilate near-real-time data on reservoir levels, stream flow into the reservoirs, snowpack and water quality in streams and reservoirs; and ingest National Weather Service forecasts. At the same time, it will apply the rules and laws that govern the water supply operations.

DEP manages the City's water supply, providing more than 1 billion gallons of water each day to more than 9 million residents, including 8 million in New York City, and residents of Ulster, Orange, Putnam and Westchester counties. Approximately 1,000 DEP employees live and work in the watershed communities.

Controlling Corrosion and Preserving Water Quality

By Becki Rosenfeldt, P.E., Senior Principal Engineer



Flow-through pipe rack system with five parallel loops (front side showing flow control and chemical feed pumps).

In an effort to comply with drinking water regulations such as the USEPA Stage 1 and Stage 2 D/DBP rule, an increasing number of drinking water providers are altering their treatment systems' processes, resulting in changes to finished water quality. Concurrent with changes in finished water quality has been an increase in lead corrosion in some drinking water systems. Hazen and Sawyer has taken a practical approach to evaluating the corrosive effects of finished water quality changes, performing targeted testing from desktop/bench-scale to flow-through pilot loop and full-scale studies to help utilities make educated decisions with regard to treatment process alterations and distribution materials.

Drinking water utilities today face a number of issues related to corrosion of distribution system materials including:

- Aging distribution infrastructure and premature failure of newer equipment due to the accelerated corrosion of materials.
- Compliance with Lead and Copper Rule revisions.
- Compliance with Stage 1 and Stage 2 Disinfectant/Disinfection By-product Rule.
- Declining water use for some utilities, leading to increasing detention times, water age, and opportunity for corrosion, which can negatively impact water quality.

Traditionally, the evaluation of corrosion has been done with the calculation of industry-accepted indices, performing pilot loop or coupon studies, or the evaluation of full-scale system samples.

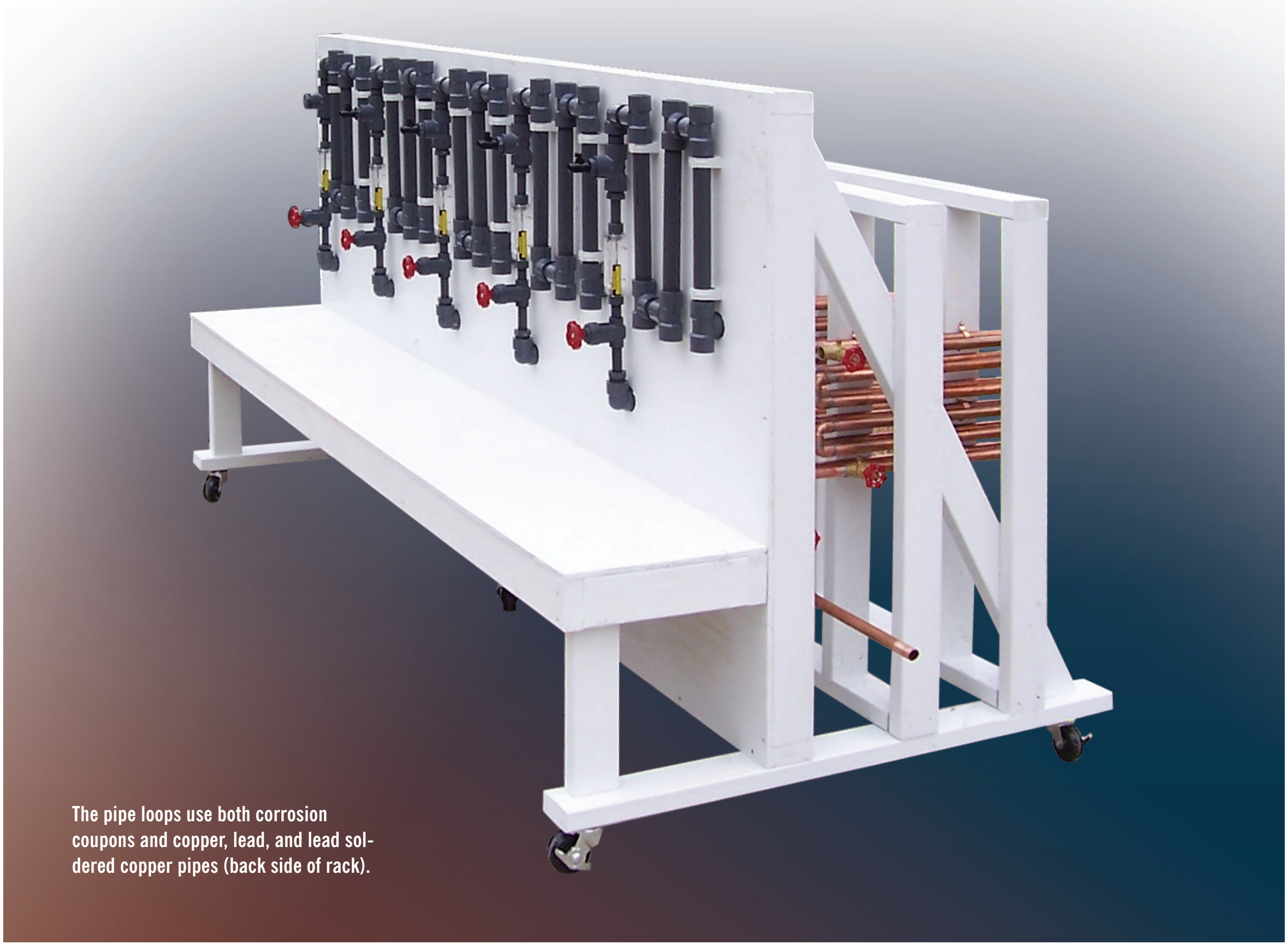
Hazen and Sawyer has demonstrated success using both desktop and pilot studies to evaluate the corrosive effects of finished water quality changes. Constructing customized pipe racks with several parallel loops allows us to test several corrosion control schemes or several different treated waters simultaneously (and/or allow for duplicates to increase data reliability). The test apparatus facilitates evaluation of both general corrosion rates and comparative first draw stagnation samples side-by-side, enabling us to study the effects of water quality changes on the corrosion of household plumbing (lead soldered copper pipe), as well as a full range of distribution system materials such as cast iron, steel, brass, and bronze.

Among other similar projects, Hazen and Sawyer is currently studying the use of an alternative corrosion inhibitor that may provide significant cost savings from both a reduced application of inhibitor and a reduction in caustic soda dose. An extensive pilot test using lead, steel, and copper coupons, as well as lead soldered copper pipe, is underway to evaluate the relative effectiveness of this inhibitor compared to the current use of phosphoric acid as an inhibitor.

Other recent work in this area includes:

- A detailed evaluation of the effects of converting to chloramine treatment on corrosion of lead, copper, and brass for New York City and for several smaller utilities.
- Assisting an upstate New York water system with corrosion issues that occurred after its wholesale supplier switched to chloramines and the main industrial user greatly decreased water demands.
- Addressing unique corrosion control issues on the cruise ships.
- Assisting a mid-Atlantic client with solving red water complaints.
- Examining the effect of switching coagulants to improve TOC removal on corrosion control for several utilities.

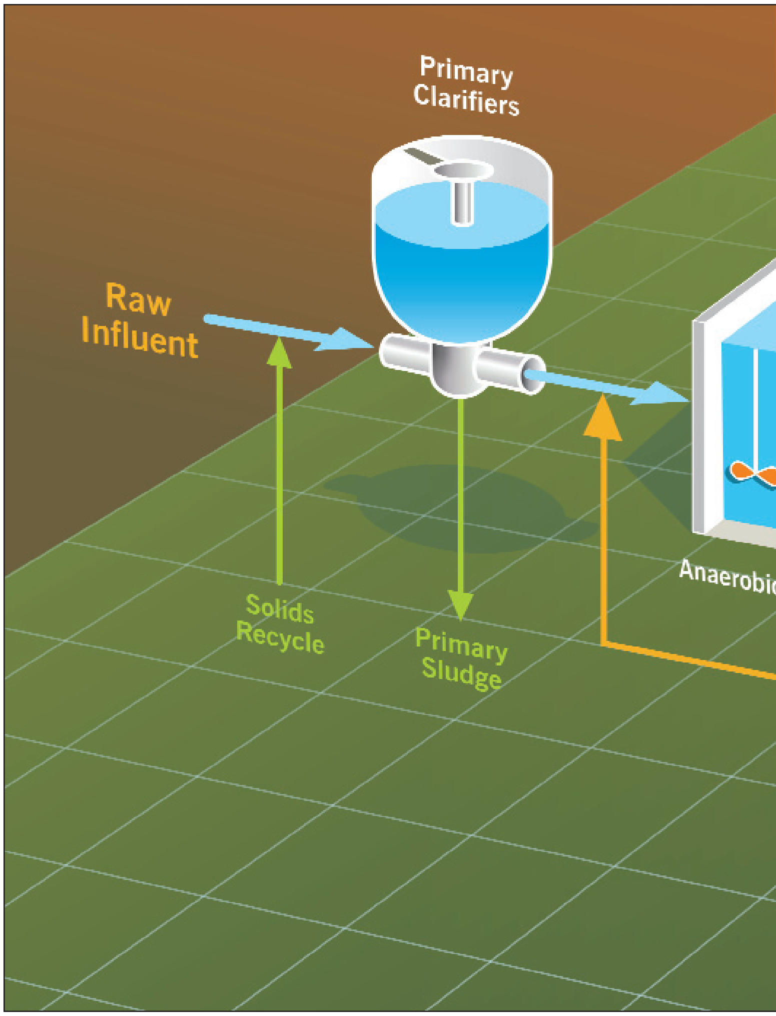
The USEPA recently declared corrosion as a "key area of research" in their effort to maintain high-quality drinking water throughout distribution systems. In addition to its impact on water quality, corrosion also represents a substantial economic expense for utilities today. By studying the effects of subtle water quality changes at a remote location, we can provide informed recommendations with regard to lead and copper corrosion and inhibitor or water quality changes that may be needed to comply with newer rules, reduce potential capital and operating expenses, and protect public health.



The pipe loops use both corrosion coupons and copper, lead, and lead soldered copper pipes (back side of rack).

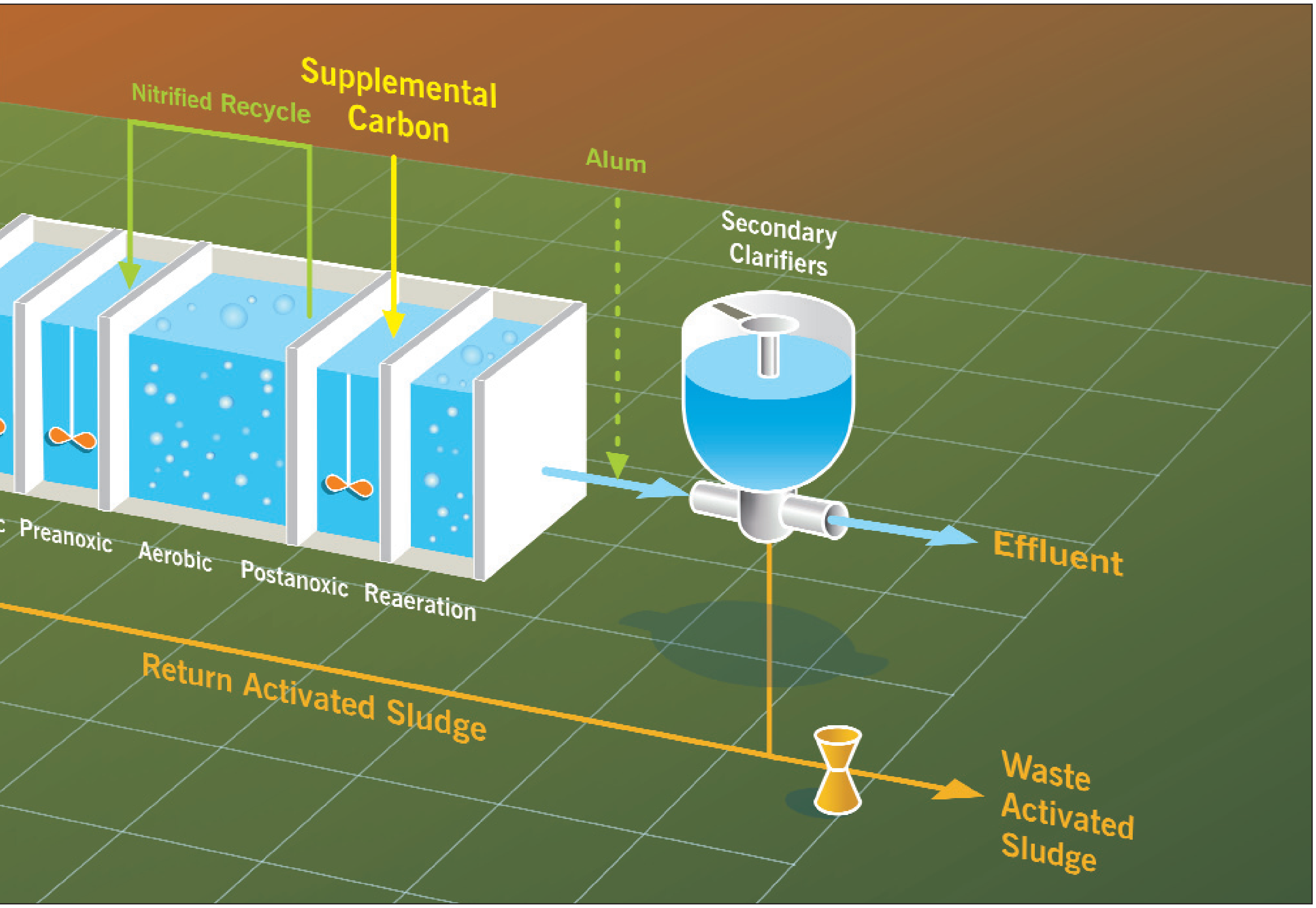
Finding Flexibility in Carbon Supplementation: Lessons from Four Plants

By Katya Bilyk, P.E., Associate
Theresa Bruton, P.E., Senior Principal Engineer
Joe Rohrbacher, P.E., Associate



An increasing number of wastewater treatment facilities are faced with the challenge of removing total nitrogen (TN) from their effluent to comply with concentration-based or annual mass limits on plant discharges to waterbodies. Supplemental carbon is often added to the post-anoxic zone and/or denitrification filters to reduce nitrate to meet these effluent TN objectives. Hazen and Sawyer has conducted pilot test programs to evaluate the efficacy of many alternative carbon sources, and performed field investigations and bench scale experiments as part of these pilots. Our findings can inform flexible facility design that accommodates a number of different supplemental carbon sources, offering Owners the opportunity to use market conditions to make cost-saving decisions.

The Neuse River Wastewater Treatment Plant is currently the largest wastewater treatment facility meeting "Limits of Technology" TN limits on the East Coast.



Five-stage BNR process. Nitrogen is removed from wastewater using a combination of aerobic (nitrification) and anoxic (denitrification) processes. Nitrogen removal facilities often employ ENR processes and/or denitrification filters to remove residual nitrate from the secondary process.

Nitrogen removal facilities often employ enhanced biological nutrient removal (ENR) processes, such as the 5-stage process shown in the figure above, and/or denitrification filters to remove residual nitrate from the secondary process. Denitrification requires a readily biodegradable carbon source, which is often limited in or exhausted prior to the post-anoxic zones or denitrification filter.

Methanol has historically been used for denitrification; however, recent cost volatility and safety concerns associated with methanol have led utilities to consider potentially safer, more sustainable carbon sources. Several carbon sources viewed as promising, more-sustainable replacements for methanol include glycerin-based products derived from biodiesel production, as well as several sugar-based waste products from the food and beverage industry. Glycerin products are available in both a refined, proprietary form and in a crude, potentially more variable form. Hazen and Sawyer has assisted many clients in full-scale testing of these alternative carbon products; findings from four of the most interesting pilots follow.

Neuse River Wastewater Treatment Plant (NRWWTP), 75 mgd, Raleigh, NC (glycerin)

The NRWWTP has an effluent TN limit of 2.5 mg/L and is currently the largest wastewater treatment facility meeting "Limits of Technology" TN limits on the East Coast. The plant has historically used methanol in its post-anoxic zone and denitrification filters, and was seeking a safer, cost-effective product. Many plants including the NRWWTP combine 5-stage BNR with denitrification filter technology and are looking for a single carbon source to satisfy both processes economically.

A 75% crude glycerin product was piloted in one of six bioreactors in June and July of 2008. Methanol continued to be fed to the remaining bioreactors, and one of these basins was used as a control to compare performance with the glycerin-fed bioreactor. The results of the full-scale test demonstrated that the mass of nitrate denitrified with the glycerin product was comparable to the mass of nitrate removed with methanol at an equivalent feed rate (1 gallon methanol = 1 gallon of glycerin). However, the properties of glycerin vary by manufacturer, so the

Optimization and a change in carbon source at the Henrico County Water Reclamation Facility has resulted in a chemical savings of $400,000 per year.

required feed rate of glycerin may be higher or lower than methanol. The full-scale testing also indicated that there was no acclimation period required for the biomass to fully utilize the glycerin product.

The glycerin product was also applied to the denitrification filters. Little if any denitrification occurred on the filters, which may be attributed to high dissolved oxygen (DO) concentrations in the filter influent. In addition, the filter run times between backwashes typically decreased as the glycerin feed rate increased. It is hypothesized that nearly all of the glycerin applied to the filters is being used aerobically, and the increased frequency of backwashes may be due to growth of aerobic bacteria. More research is needed to understand the effectiveness and operational impacts of glycerin and other alternative carbon source addition to denitrification filters.

Henrico County Water Reclamation Facility (HCWRF), 75 mgd, Petersburg, VA (corn syrup, glycerin)

The HCWRF has a current TN limit of 8 mg/L and a future TN limit of 5 mg/L. Hazen and Sawyer and the plant staff have worked together to identify a variety of optimization strategies that have improved the effectiveness and efficiency of nitrogen removal. One of those efforts involved using a safe and sustainable carbon source. For more than two years, Hazen and Sawyer assisted HCWRF in performing a full-scale pilot using corn syrup waste, and, more recently, we have piloted different glycerin products with success. During these full-scale pilots, Hazen and Sawyer optimized the product usage through detailed nutrient profiles that are a routine part of the pilot program but not often part of day-to-day operational data collection. This optimization and change in carbon source has resulted in a chemical savings of $400,000 per year. In addition to carbon source optimization, the blowers and DO in the zone upstream of the carbon addition point were optimized, resulting in a 20% electrical savings, or $300,000 per year, in power costs.

Parkway Wastewater Treatment Plant (PWWTP), 7.5 mgd, Laurel, MD (glycerin)

The Washington Suburban Sanitation Commission (WSSC) has performed full-scale testing of several alternative carbon sources at the PWWTP in an effort to meet a future TN limit of 3 mg/L. Hazen and Sawyer assisted the WSSC during pilot testing of three glycerin products by providing bench-scale testing and full-scale process profiling services. The results were utilized in Hazen and Sawyer's design of nutrient removal facilities including flexible carbon feed systems at the PWWTP.

Unicarb-DN was piloted in October 2007, and Brenntag and Virginia Biodiesel glycerin products were piloted in December 2007 and February 2008, respectively. The three products performed similarly and the full-scale pilot confirmed glycerin products were effective carbon sources for post-anoxic zone denitrification, although cold weather storage and pumping issues related to product viscosity need to be addressed. No acclimation

SDWRF carbon addition setup into mixing pump discharge.

period was required, as robust denitrification was observed within one day of adding these products.

Hazen and Sawyer performed bench scale testing on the Brenntag and Virginia Biodiesel products. The carbon feed ratios derived from the bench-scale tests were approximately 30% lower than the ratios observed in the field per equivalent amount of nitrate removed. This may be due to field conditions including substrate limitations, do impacts, and back-mixing. This underscores that care should be exercised when applying the results of denitrification batch testing to full-scale facilities or to other plants, as there is a risk of undersizing denitrification tankage and carbon feed facilities if bench-scale rates are applied to a full-scale process without adjustment for field conditions.

South Durham Water Reclamation Facility (SDWRF), 20 mgd, Durham, NC (glycerin)

The City of Durham, North Carolina, piloted several glycerin products to determine whether glycerin addition could assist the City in meeting an upcoming TN effluent standard of 3.0 mg/L. Hazen and Sawyer assisted the City in piloting the Brenntag glycerin product at the SDWRF from March 2009 through May 2009. Glycerin was added to the post-anoxic zone of the test basin, and nutrient profiles were performed in the test and control basins. The results from the first six weeks of pilot testing did not directly indicate any decrease in effluent nitrate concentrations between the test and control basins. This was attributed to reduced nitrification performance in, and high residual DO entering, the post-anoxic zone of the test basin, underscoring the importance of monitoring DO and ammonia in addition to nitrate and nitrite in and out of the post-anoxic zone in assessing denitrification performance. DO management is extremely important in wastewater treatment plants to avoid wasting supplemental carbon as well as aeration energy, both of which are significant operational expenditures at wastewater treatment facilities.

The feed rate was increased beginning the week of April 21st to overcome residual oxygen demand in the anoxic zone, and the test basin removed 1 to 2 mg/L more nitrate than the control once the feed rate was increased. Subsequent testing indicated that denitrification was successfully enhanced through glycerin addition. Construction of permanent supplemental carbon storage and feed facilities will allow the City to avoid more costly capital improvements.

Carbon Evaluation Methodology

Hazen and Sawyer has developed a methodology to evaluate the cost of various carbon sources on a cost-per-pound-of-nitrate-removed basis. This price comparison considers all applicable variables including solution strength, density, soluble biodegradable COD content, cost per gallon and anoxic yield. Costs were derived from current market pricing for the mid-Atlantic facilities discussed, and will have some variability from plant to plant. The cost analysis indicates that, in this region, glycerin products are currently most cost-competitive with methanol, while acetic acid and corn syrup tend to be more expensive.

Planning for Design

Providing flexible supplemental carbon facility design requires ensuring that materials of construction, pumps, piping, and appurtenant equipment are compatible with a variety of carbon sources. For example, 304 stainless steel storage tanks and piping are compatible with most supplemental carbon products except for acetic acid, where 316 stainless steel is recommended. Materials can be selected that reduce the cost and flexibility of the facility. Fiber-reinforced plastic and cross-linked polyethylene tanks are compatible with glycerin products, but would not be suitable for methanol and ethanol. Design of carbon storage and feed facilities must take into account the client's preferences for flexibility versus increased cost and complexity.

Using our own sampling teams and equipment, Hazen and Sawyer can evaluate and diagnose process performance within a one-day test period. For Owners facing economic pressures and tough nitrogen limits, knowing and understanding all the available treatment options can save capital costs now and operating costs long into the future.

Researching the Importance of Dissolved Organic Nitrogen in Wastewater Treatment

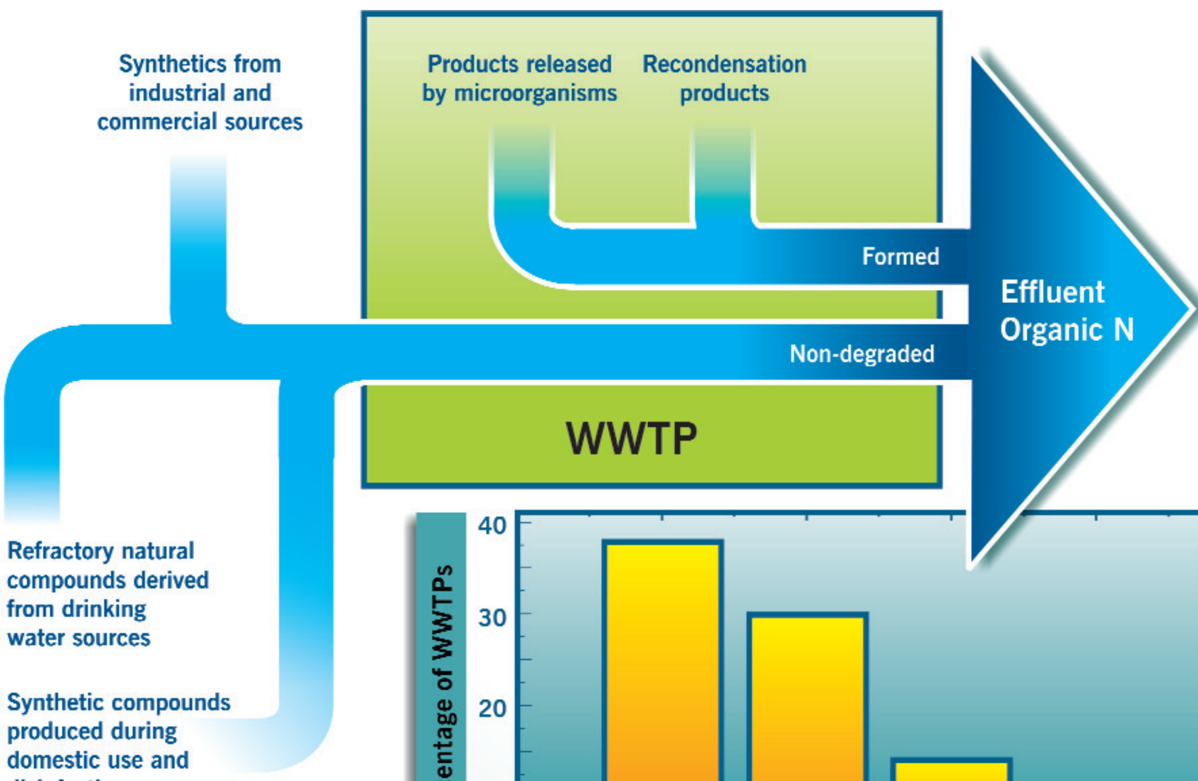
By Robert Sharp, Ph.D., P.E., Senior Consultant
Paul Pitt, Ph.D., P.E., Vice President

Wastewater treatment plants that utilize Biologic Nutrient Removal (BNR) have traditionally focused on the removal of inorganic nitrogen species (ammonia, nitrate, and nitrite) to meet their effluent nitrogen standards. However, as total nitrogen (TN) limits for many BNR plants become more stringent (< 6 mg/L TN), the importance of dissolved organic nitrogen (DON) has increased.

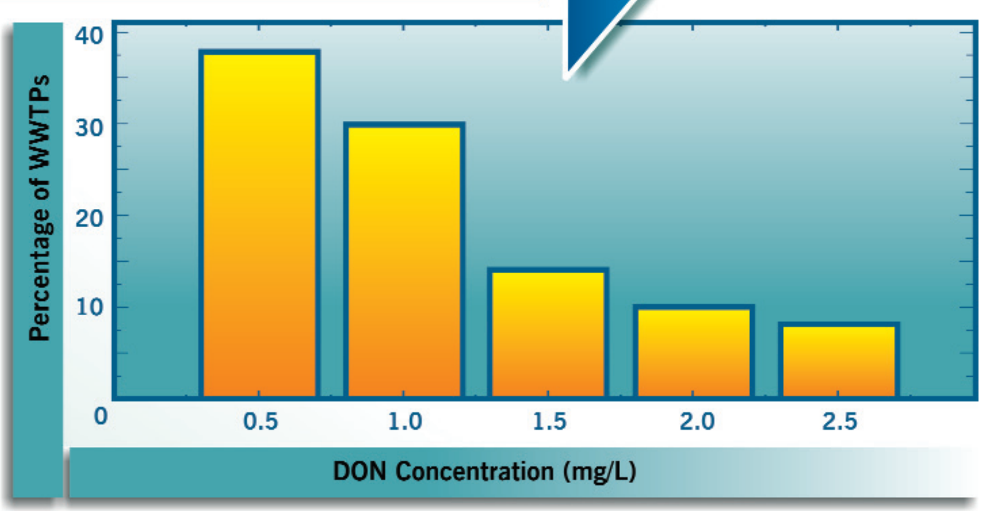
The DON content in a typical BNR plant effluent ranges from 0.5 to 2.5 mg/L. The concentration of DON in a plant effluent can be influenced by a number of variables, including influent wastewater characteristics, plant design and operation, and environmental factors. If a plant has a TN limit of 6 mg/L, the effluent DON could range from 10 to 40% of the total nitrogen, leaving the other 60% to be made of particulate organic nitrogen, ammonia, nitrate, and nitrite. As the effluent TN limit drops below 6 mg/L, the DON portion can quickly become the dominant nitrogen species found in the effluent. DON in BNR plants has been the focus of recent research sponsored by Hazen and Sawyer, and has gained the attention of the Water Environment Research Foundation (WERF), which has formed a committee to study DON as part of their Nutrients Knowledge Area. WERF, with the help of Hazen and Sawyer and others, has developed a DON Compendium that details the current state of DON research and resulting body of knowledge.

Characterization of Organic Nitrogen

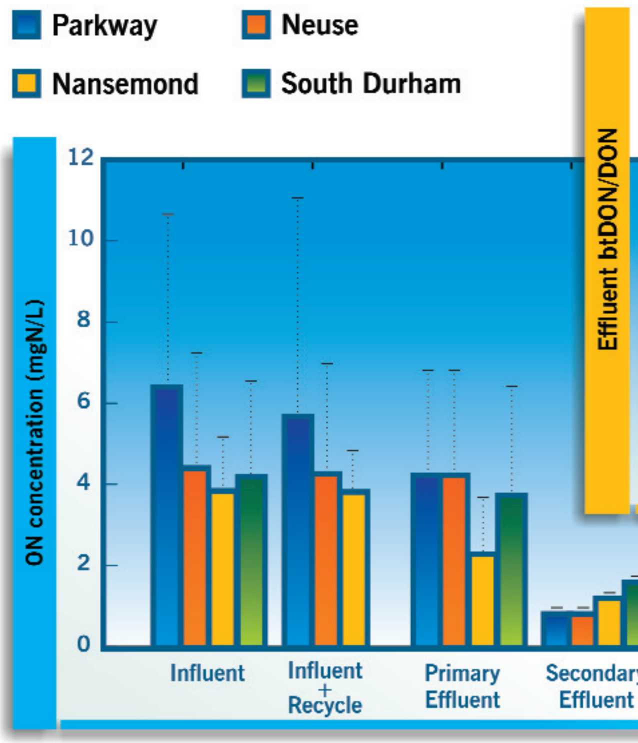
At BNR plants where organic nitrogen is a significant fraction of the total effluent nitrogen, measurement and characterization of organic nitrogen can lead to a better understanding of the mechanisms that govern its sources and fate, and offer insights on how it can be removed more effectively. DON research, including that sponsored by Hazen and Sawyer, has shown that there are a number of different types or characterizations of organic nitrogen that could impact the operational, performance, and regulatory aspects of BNR plants. These characterizations include:

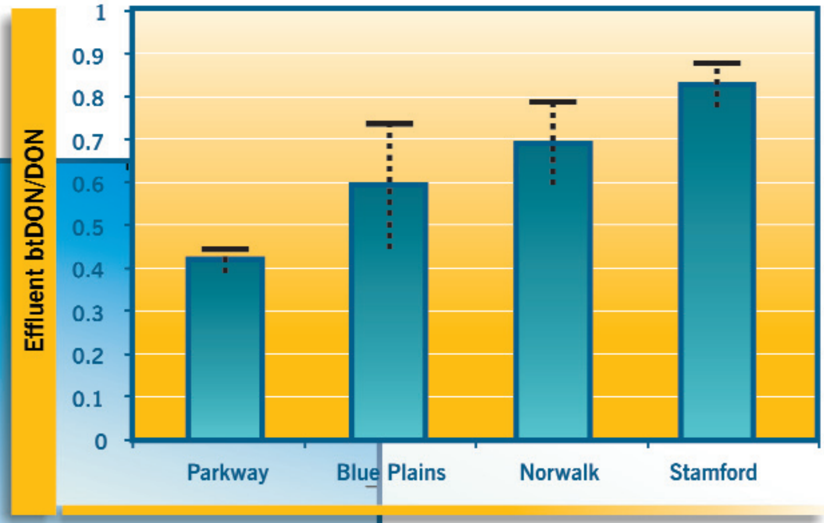


◀ Potential Sources of Effluent Dissolved Organic Nitrogen.



▼ Summary of Effluent Dissolved Organic Nitrogen Concentrations from 188 Wastewater Treatment Plants in Virginia and Maryland (Pagilla, 2007).





▲ **Fraction of Effluent DON that is Biodegradable (Sharp et. al., 2009).**

◀ **Fate of DON in Four Different BNR Plants (Sattayatewa et. al., 2009).**

1. Total Organic Nitrogen: TON or simply ON – all nitrogen contained in organic compounds found in wastewater (i.e. amino acids, peptides, and protein) and which can be either dissolved or contained in particulate or colloidal material.

2. Particulate Organic Nitrogen: PON – Organic nitrogen remaining on a 0.45-μm filter.

3. Dissolved organic nitrogen: DON – the organic nitrogen measured in the filtrate of a wastewater sample following filtration through a 0.45-μm filter, after filtration of the sample.

4. Filter floc DON: ffDON – DON remaining in a sample that has been flocculated with zinc sulfate and refiltered through a 0.45-μm filter – may also be referred to as “true” DON, since the colloidal fraction has been filtered out via the filter floc process.

5. Colloidal Organic Nitrogen: CON – the difference between the organic nitrogen remaining in the filtrate after filtration through a 1.2-μm filter, less the organic nitrogen remaining after filter flocculation ($CON = ON^{1.2} – ffDON$).

6. Biodegradable dissolved organic nitrogen: btDON – The DON removed using the btDON assay, which involves a long-term (10- to 30-day) bioassay similar to a BOD test, and activated sludge seed from the specific treatment plant.

7. Non-Biodegradable Dissolved Organic Nitrogen: rtDON – The DON remaining after the btDON assay.

8. Bioavailable DON: bDON – The effluent DON that can be used in surface waters due to bacteria activity and algae uptake of nitrogen – determined using various algal assays.

9. Recalcitrant DON: rDON – The effluent DON that is resistant to biological transformation and uptake by algae in surface waters.

Many of these definitions are based on assays (btDON, rtDON, bDON, and rDON) that are currently in development or have not been established as standard methods, but have been used in numerous research projects on the fate and characterization of effluent DON. As the database on these different types or fractions of organic nitrogen grows and develops, the importance of the effluent nitrogen fractionation at a given plant will become even more evident. For example, if it is shown that the majority of organic nitrogen in the effluent of a given plant is primarily in the particulate and colloidal form, plant operators may want to consider physical and chemical processes to reduce the organic nitrogen fraction. Conversely, if the organic nitrogen is shown to be mostly dissolved and biodegradable, changes to the biological process and plant operations may be warranted.

Current DON Research Findings

The research into DON and its importance in the wastewater industry has just begun. Studies funded by Hazen and Sawyer and handful of municipalities were the first to thoroughly characterize organic nitrogen in multiple treatment plants. This work was carried out by researchers at the Illinois Institute of Technology in Chicago and Manhattan College in New York City, and included the characterization and fractionation of organic nitrogen across 7 different treatment plants and the development of a modified bioassay to measure effluent biodegradable DON. The key findings of this research to date include:

1. CON is a less significant fraction of effluent TN if plants employ chemical addition for P removal.
2. DON can be produced in the biological process during heterotrophic activity in the primary anoxic zone of BNR/ENR plants. The DON may be a result of solubilization of particulate organic nitrogen in the wastewater or it may be excreted from the biomass as soluble microbial products (SMPs).
3. DON or CON removal is not significant across filtration and disinfection processes.
4. Variation in the influent DON does not translate to variations in the effluent DON.
5. The ffDON is a very good indicator of "true" dissolved organic nitrogen in a plant effluent, and correlates well with effluent biodegradable DON (btDON).
6. The amount of effluent DON that is biodegradable, as determined using a long-term bioassay, can vary greatly from plant to plant (20% – 90%), and appears to be influenced by temperature, solids retention time, and process configuration.

This work is currently being extended to include the step-feed Biologic Nutrient Removal process with and without carbon addition as part of the New York City Department of Environmental Protection's Applied Research Program.

Gaining a better understanding of the sources, fates, and characteristics of DON in BNR treatment plants provides valuable information for process optimization and control. For plants where DON makes up a significant fraction of the effluent total nitrogen, a better understanding of the characterization of DON fractions may provide valuable insights on how to improve overall nitrogen removal. This type of information may also help in the selection and design of process upgrades.

Experience at municipalities that discharge to the Long Island Sound and Chesapeake Bay suggests that the better we can quantify the biodegradable and bioavailable fractions of effluent DON, the more likely municipalities will be able to attain some level of regulatory credit or relief for inert or recalcitrant forms of DON that are currently being included in most discharge permits. As we standardize methods to measure both DON bioavailability and biodegradability, and develop a relationship between the two, we should better understand the true fate and importance of DON in both the treatment plant and the receiving water.

Hazen and Sawyer Publications on DON

1. Sattayatewa, C.; Pagilla, P.; Sharp, R.; Pitt, P. (2009) Fate of Organic Nitrogen in Four BNR Wastewater Treatment Plants, Water Environ. Research (accepted).
2. Sattayatewa, C.; Pagilla, K.; Pitt, P., Selock, K.; Bruton, T. (2009) Organic Nitrogen Transformations in a 4-stage Bardenpho Nitrogen Removal Plant and Bioavailability of Effluent DON, Water Research, 1-10.
3. C. Sattayatewa, N. Dubanowitz, K. Pagilla, R. Sharp, P. Pitt and T. Bruton. "DON and CON in Seven BNR Wastewater Treatment Plants' Processes and Effluents" In Proc. WEFTEC 2009, pp. 872-882. Orlando, FL.
4. Pagilla, K.; Sattayatewa, C.; Urgun-Demirtas, M.; Baek, S. (2009) Effect of Influent N Speciation on Organic Nitrogen Occurrence in Activated Sludge Process Effluents, International Water Association (IWA)-2nd Specialized Conference, Nutrient Management in Wastewater Treatment Processes.
5. Sattayatewa, C.; Pagilla, K. Sharp, R.; Pitt, P. (2009) Organic Carbon and Nitrogen Fate in Biological Nitrogen Removal Plants, IWA-2nd Specialized Krakow Conference, Nutrient Management in Wastewater Treatment Processes.
6. Sattayatewa, C.; Dubanowitz, N.; Pagilla, K.; Sharp, R.; Pitt, P.; White, C.; Bruton, T. (2009) DON and CON in Seven BNR Wastewater Treatment Plants' Processes and Effluents, Proceedings of the Water Environmental Federation, Nutrient Removal 2009, pp. 1110-1116.
7. Sharp, R.; Dubanowitz, N.; Sattayatewa, C.; Pagilla, K.; Murthy, S.; Pitt, P. (2009) Biodegradability of Effluent Dissolved Organic Nitrogen: Impacts of Treatment Technology, Process Variables, and Other Effluent Water Quality Parameters, Proceedings of the Water Environmental Federation, Nutrient Removal 2009, pp. 1117-1126.

The Role of Applied Research

by Ben Stanford, Ph.D., Director of Applied Research

As worldwide human populations continue to rise and clean water sources become more stressed from increased demand, we find ourselves faced with limited sources of high-quality water to meet the myriad needs of society. A combination of factors, including population growth, climate change, urbanization, and increased chemical production and use, all contribute to the number of contaminants entering our waterways.

Whether a utility is concerned with emerging contaminants or nutrient loading, disinfection strategies or water resource management, these issues are interrelated and together drive decision-making, from design and implementation to daily operations and maintenance.

Further complicating matters for operators and managers are the sometimes competing legislative and regulatory requirements. Take for example the "Chemical and Water Security Act of 2009" (H.R. 2868), which could make the use of chlorine gas for disinfection of potable water difficult for many utilities, together with the potential EPA regulation of perchlorate and chlorate, two contaminants formed during the decomposition of sodium hypochlorite solutions (often used instead of chlorine gas for water disinfection purposes). One regulatory action makes the use of chlorine gas difficult; the other complicates the use of hypochlorite, the most likely chlorine alternative. While neither is prohibitive, it takes careful planning and design on the part of engineers and managers to negotiate such issues and to provide a sustainable, effective treatment system.

With these and other issues such as EPA's six-year review, the third candidate contaminant list (CCL3) and third unregulated contaminant monitoring rule (UCMR3), and political and public pressure to address the concerns involving the presence of pharmaceutical, endocrine-disrupting, and other related but currently-unregulated compounds in drinking water supplies, there is an enormous need for focused, solution-based research efforts. This fundamental need lies at the core of Hazen and Sawyer's Applied Research Program, and is part of the nexus between water, wastewater, water reuse, and applied research efforts.

Our role in applied research is providing clients, scientists, and the broader water/wastewater/reuse community with the tools and information they need to implement process improvements, manage water resources wisely, keep abreast of pending regulatory requirements, communicate with the public, and minimize the economic and environmental impacts of the treatment process. Our efforts continually aim to improve efficiency, reduce energy inputs, and provide high-quality product water, whether for drinking water, wastewater discharge, or reuse. We constantly evaluate new technologies from a variety of perspectives, and pose challenges that test the limits of those technologies. Such rigorous testing informs recommendations about appropriate applications of a new technology, clearly reveals the cost/benefit ratio of the technology, and allows engineers to pair desired outcomes with the most appropriate tools.

"Applied research serves to provide leadership and guidance, pushing the cutting edge of science while remaining at the very center of practicality."

Applied research serves to provide leadership and guidance, pushing the cutting edge of science while remaining at the very center of practicality. As a platform for dialogue with regulators and utility managers, it provides meaningful opportunities for education and outreach. It also improves process design and implementation, and can lessen our impact on the environment and help us respond to the changes the environment may throw at us.

From developing models for reservoir management under climate change to minimizing ecosystem impacts of wastewater discharge, applied research can be used to develop and apply solutions to meet the needs of the water and wastewater sectors.

Cutting Edge Research Projects with Leading Foundations

Climate Change Research with the AWWA Research Foundation

Hazen and Sawyer will be playing a vital role in the Water Research Foundation's Climate Change Strategic Research Initiative, focused on evaluating the impacts of climate change on water supplies. The firm is undertaking two major research projects that will be instrumental in helping utilities anticipate, appraise, and manage potential climate risks.

- Developing an analytical framework that utilities can use to assess the impact of climate change and other long-term drivers on their systems, enabling them to make sound decisions during uncertain times.
- Simulating the impacts of alternative climate change scenarios on the municipal water demands of several North American water providers.

Ozone and Advanced Oxidation Processes Research with the WateReuse Foundation

Hazen and Sawyer is leading aspects of a research effort with the WateReuse Foundation examining the use of ozone and other advanced oxidation processes in water reuse and membrane applications.

- Providing key cost and operating scenarios for a study examining the efficacy of ozone in water reuse for trace contaminant destruction.
- Investigating the application of advanced oxidation technologies to reduce the organic fouling and overall energy usage of reverse osmosis membranes used during water treatment and water reuse.

For more information on these and other exciting research initiatives, visit www.hazenandsawyer.com