



# Hazen

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# HORIZONS

water environment solutions

SUMMER 2016

# Engineering Trust in Drinking Water Supplies



Zariah Garner, age 9 of Flint, rests on a stack of water as national guard members and civilians carry cases to vehicles on January 23, 2016 in Flint, Michigan. Water was handed out to citizens after a federal state of emergency was declared over the city's contaminated water supply. (Photo by Brett Carlsen/Getty Images)

Extended drought and population increases in the western and southern United States have many providers struggling to meet demands for potable water. To augment supply, many are adding new raw water sources such as groundwater, ocean desalination, or direct or indirect potable reuse to their supply portfolio, while some switch their primary water source altogether. Blending new sources with existing ones, or even subtly changing the characteristics of the water in a distribution system, adds several layers of complexity to drinking water management.

Improper planning for the introduction of new or newly blended water sources into existing, aging distribution systems can have dire consequences,

as seen recently in Flint, Michigan. For many years, the City of Flint distributed water as a wholesale customer of Detroit Water and Sewerage District. In 2013, the financially-struggling City ended this contract and changed raw water sources, treating and distributing Flint River water at its own facility. Soon after the switch, water quality excursions began and quickly increased in severity, from off-color and taste-and-odor events to violations of disinfection byproduct maximum contaminant limits and increases in cases of reported Legionnaire's disease. Simultaneously, large differences in finished water chloride, hardness, and pH paved the way for corrosion of pipe materials, most notably leaching of iron and lead. Flint also eliminated feed of ortho-phosphate-based corrosion

control inhibitor to the finished water, further exacerbating water chemistry issues and ultimately resulting in very high lead levels at places in the Flint distribution system.

The tragic situation and further public mishandling of the relevant information has reverberated throughout the water industry, eroding public trust and complicating communication of what it truly means to be providing "safe" water to the public. Guaranteeing any water source meets quality requirements at the tap requires a comprehensive understanding that begins at the source and extends throughout the entire distribution system.

## Alternative Source Analysis

A significant factor in any alternative source analysis is the treatability of the raw water. The process begins with a focused sampling campaign to assess a suite of targeted water quality parameters that should stretch over a year - on a monthly

or bi-monthly basis - to capture seasonal changes. If the sampling period does not also capture extreme events such as flooding or drought, these should be simulated.

The goal of the sampling campaign is to identify treatment processes (and

their capital and operating costs) that would produce a finished water that meets all applicable federal and state regulations and is aesthetically pleasing. When blending new water into an existing supply, this analysis is further complicated by the myriad of potential blending options and ratios.



## Taste and Odor

Often the first concern of a provider is identifying a source water that will be treatable and meet all Federal and State standards. Beyond that it is important to ensure that the finished water will be aesthetically acceptable to their customers. Taste and odor issues in drinking water are most

To address future water demand (and limit effluent surface water discharge), Tampa Bay Water is evaluating potable reuse alternatives. One potential alternative is to blend reclaimed water within the existing 25-mgd seawater desalination facility.

Two related treatment options are under consideration - the first would introduce a reclaimed water source upstream of the desalination process, where it would reduce the salinity of the feed to the seawater reverse osmosis process to improve the efficiency of the high pressure pumping equipment.

In the second alternative, after undergoing advanced treatment, the reclaimed water would be blended with the product water from the existing desalination process and stabilized before introduction into the distribution system. As with the consideration of any new water supply, both alternatives will require careful evaluation, operation, and monitoring to ensure stable water quality and to avoid any impacts to the distribution system.

commonly caused by MIB and geosmin associated with algal growth, but can also be due to many other factors such as hardness, salinity, and other organic compounds. Ensuring that the finished water has the proper stability mitigates the risk of lead and copper release, while also preventing colored water complaints due to iron corrosion

in the distribution system. While conventional drinking water treatment plants can potentially prevent or remove some of these components, sporadic extreme weather events coupled with partial removal capabilities at the treatment plant may lead to taste and odor episodes or other aesthetic issues in the finished water.



The town of Newmarket (NH) chose to incorporate supply from a new groundwater well to supplement existing wells that no longer meet average daily demand or peak use periods. In order to ensure public confidence in the design of the project, the Town implemented an aggressive outreach program to notify consumers and determine whether the new product would be aesthetically acceptable.

The program included a flavor profile analysis to assess the potential blends of the new well, notification to the consumers of the potential impacts of the new constituents, and even a public forum for consumers to participate in a blind taste test of the new distribution system well water.

## Corrosion/Stability

Proven health hazards, such as lead poisoning, can occur via corrosion of lead service lines and household plumbing. Many water quality factors affect corrosion, including the chemical characteristics of the water

(e.g., pH, alkalinity, hardness, salts) the physical properties of the water (e.g., temperature, gases, particles), and treatment chemicals. Corrosion is often controlled by adjusting the pH and alkalinity or by adding a corrosion

inhibitor. Prior to major modifications in the full-scale treatment process, the corrosivity and stability of the alternate water should be analyzed through models and/or pilot-scale testing.



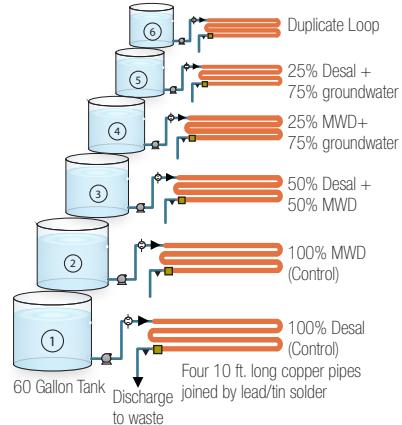
West Basin Municipal Water District - provider of wholesale water service to 17 cities and approximately one million people in southwest Los Angeles County (CA) - established a goal of serving 10 percent of the local water supply with desalinated ocean water by the year 2020.

To support their efforts, we conducted a four-month pipe loop study to evaluate corrosion-related impacts of stabilized desalinated water and blends with other local sources on different pipe and household plumbing materials in pilot-scale pipe loops.

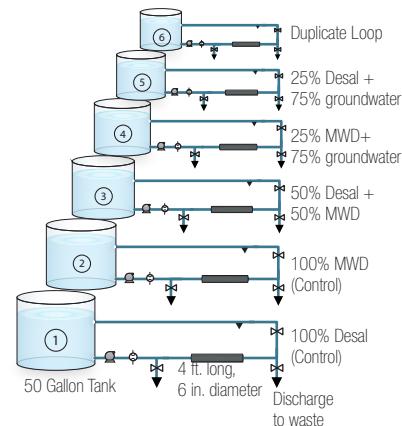
The results of the bench tests indicated that the introduction of desalinated ocean water (with appropriate calcium, alkalinity, and pH levels, and stabilized chloramine residual) into a range of typical and representative distribution system and household materials is not expected to cause negative impacts on water quality, corrosion, or disinfection.



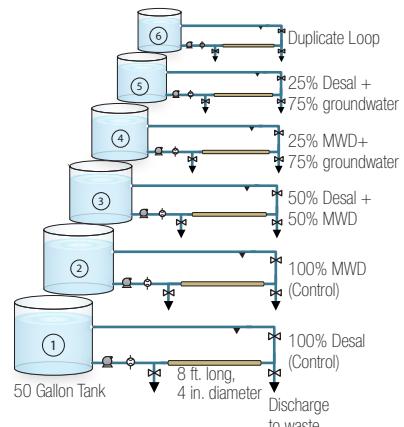
**Copper Pipe with Lead/Tin Solder Loops**



**Unlined Cast Iron Pipe Loops**



**Cement Mortar Lined Pipe Loops**



## Disinfection byproduct formation

Disinfection byproducts (DBPs) are water contaminants that result from reactions that can occur between chemical disinfectants and compounds that naturally occur in source water, most frequently natural organic matter (NOM). Formation of DBPs after drinking water treatment is greatly affected by source water

quality. Source waters containing high levels of DBP precursors may lead to undesirably high levels of DBP formation during treatment.

Drinking water treatment plants using surface water as their source are obliged to achieve a certain NOM (i.e., total organic carbon) removal based on the alkalinity. NOM removal can be

achieved by coagulation flocculation, biological filtration, activated carbon treatment, MIEX®, and UF/RO. Reducing total organic content through source water selection/blending may allow for more efficient downstream treatment processes, reducing formation of DBPs through several mechanisms.

New York City's Operation Support Tool (OST) enables managers to prioritize diversions from sources with the best water quality across multiple reservoirs, multiple intake levels/locations within a given reservoir, or both.

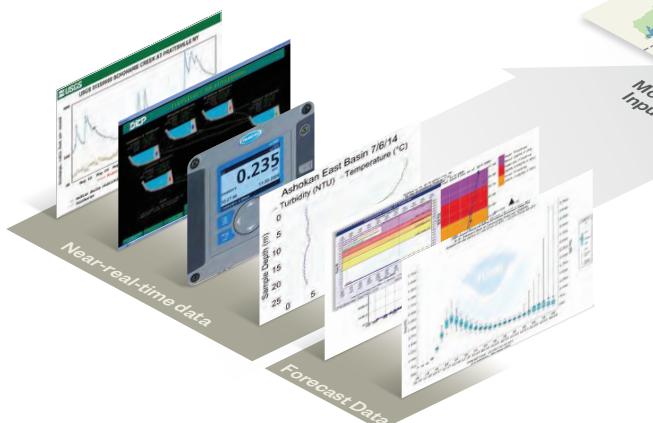
The sophisticated decision support system integrates near-real time data and ensemble inflow forecasts with reservoir system operating rules and simulation modeling, enabling system managers to conduct look-ahead simulations to support near-real time water supply decisions that reduce DBP precursors, improve treatability, and/or reduce treatment costs.

## 2 Operations Model

The core of OST is an OASIS model of New York City's water supply system and Delaware River Basin.

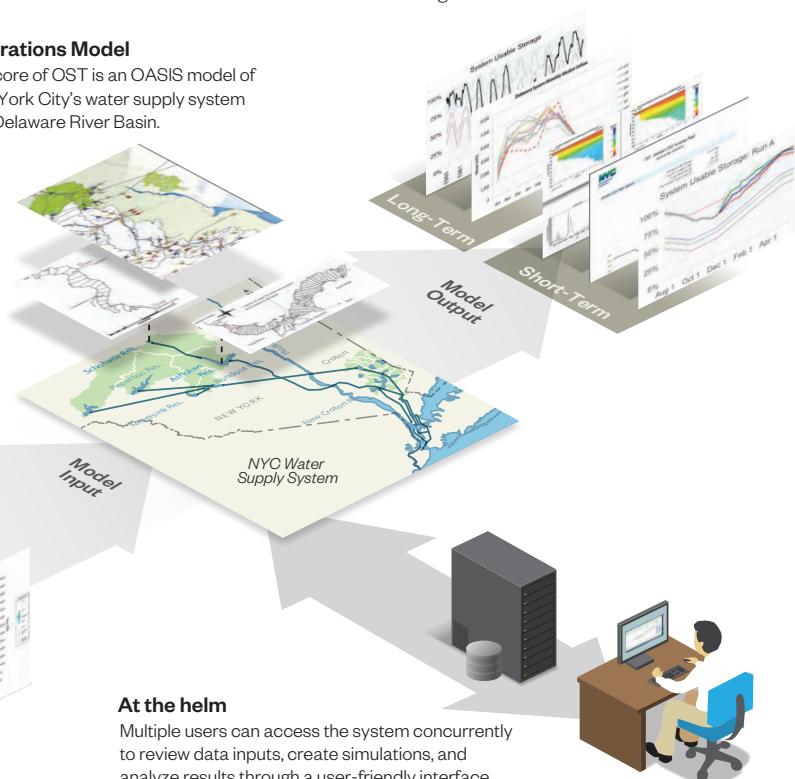
### 1 Data Feeds

OST integrates near-real time data and ensemble hydrologic forecasts.



## 3 Planning, Operations Support

Create short-term ensemble simulations for operation guidance, or long-term runs for capital planning, rule testing, and climate change assessment.



### At the helm

Multiple users can access the system concurrently to review data inputs, create simulations, and analyze results through a user-friendly interface and interactive dashboard.

# Lessons Learned About Microbial Deammonification

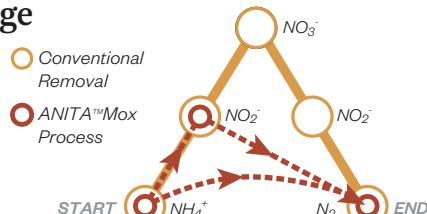
## From Design, Startup and Operation of an ANITA™ Mox System

The one-stage ANITA™Mox process is an energy-efficient deammonification process for removing nitrogen from sidestreams. In sidestream applications, such as that deployed at the South Durham Water Reclamation Facility (WRF), this process has been removing about 80 percent of the influent ammonia and 70 percent of the influent total nitrogen (TN). The process utilizes ammonia oxidizing bacteria (AOB) and anammox bacteria grown on plastic media with no supplemental carbon required.

### A “Natural” Shortcut Advantage

The ANITA™Mox Process exploits a natural microbial shortcut to conventional nitrogen removal in wastewater. The process provides efficient nitrogen removal with significant energy and cost savings.

**Theoretical savings** in three key areas when using deammonification pathway for nitrogen removal are shown below.



Oxygen Requirement  
(lb O<sub>2</sub>/lb N)

4.6 to 1.9

60%

Methanol Consumption\*  
(lb / lb N)

3.0 to 0

100%

Sludge Production  
(lb VSS/lb N)

0.5-1.0 to 0.1

50%-90%

\*Numbers vary for other carbon sources.

**Sidestream Design:** One of two abandoned aerobic digesters was repurposed to provide approximately three days of equalization and two 85,000 gallon deammonification reactors.

**INFLUENT:**  
BFP filtrate containing 20% of the ammonia load to the BNR process.

New concrete walls were poured to support the new functions.

Equalization Tank

Passive bypass channel returns overflow to head of plant.

Reactor 1

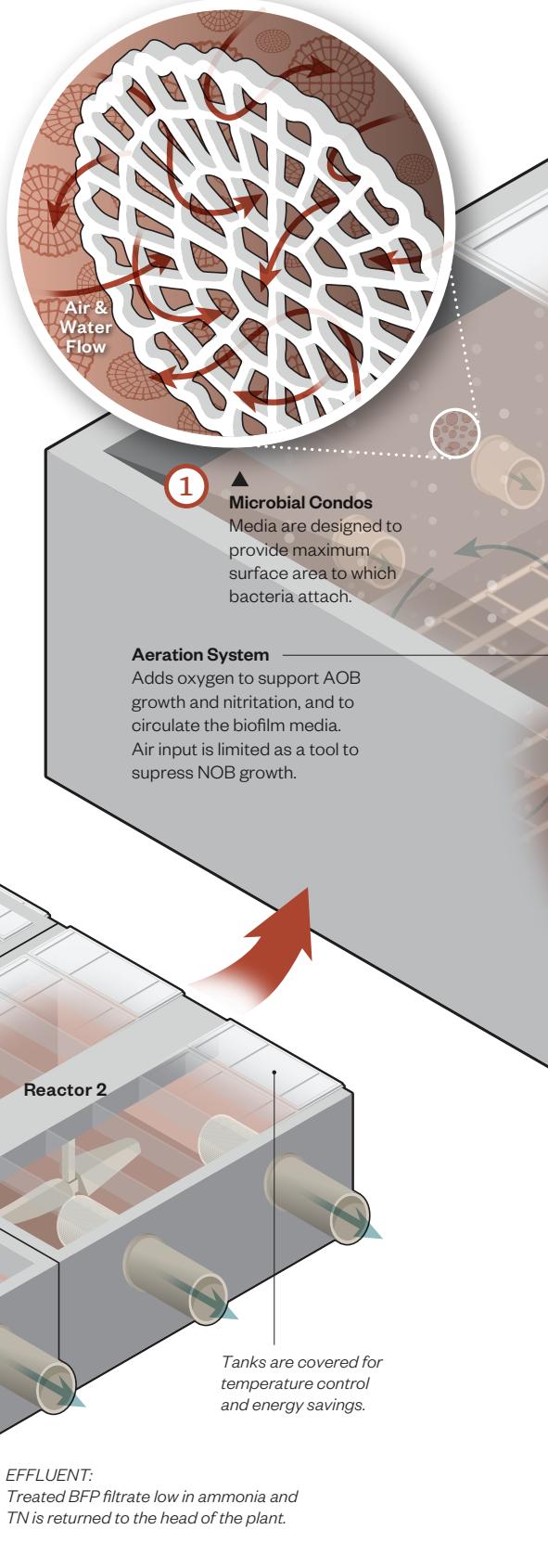
Reactor 2

**EQUALIZATION:**  
Dewatering occurs five days a week.  
Sidestream flow (BFP filtrate) is stored over the weekend. A constant ammonia load is pumped to the reactors to maintain consistent treatment results.

Mixers

Tanks are covered for temperature control and energy savings.

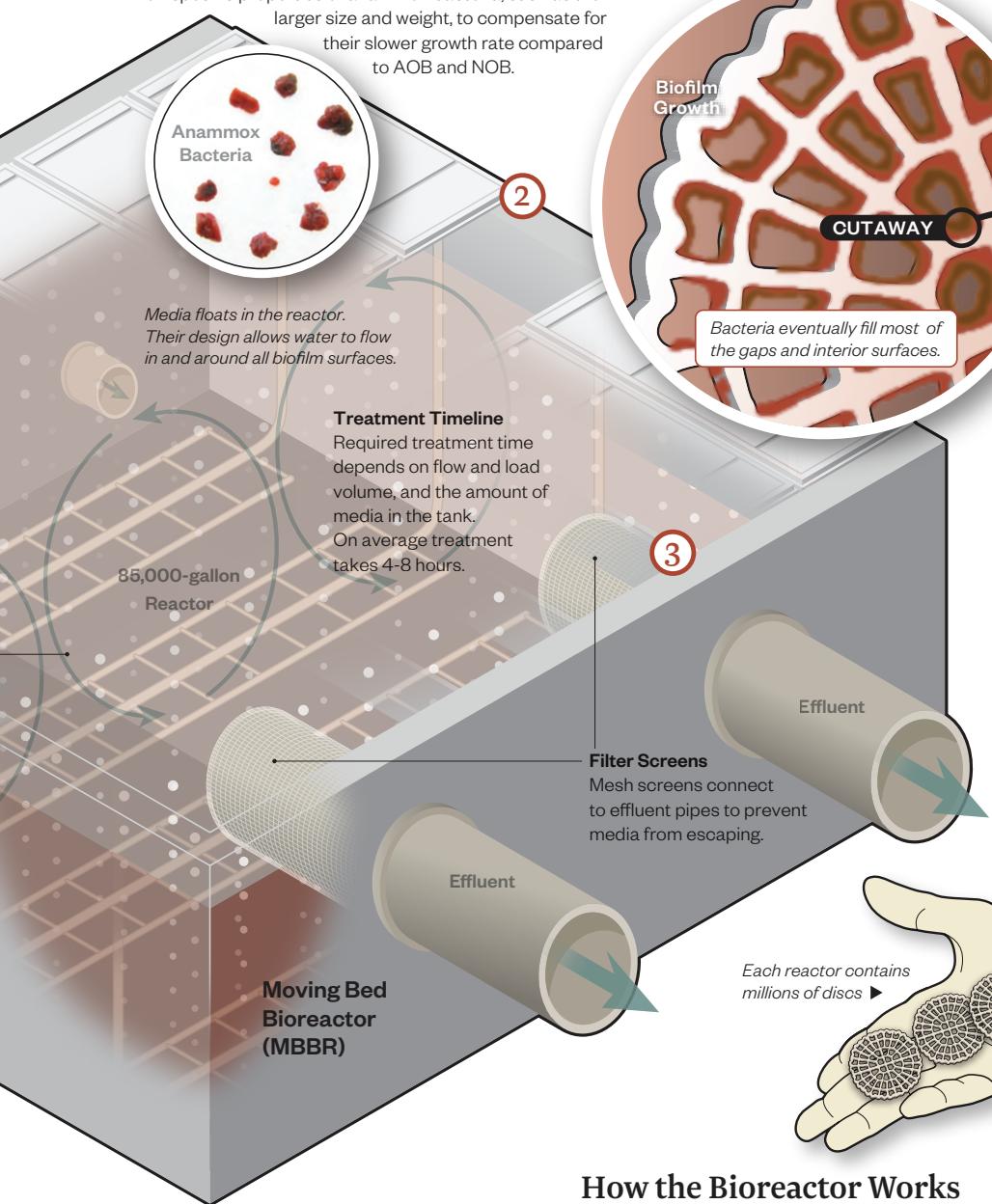
**EFFLUENT:**  
Treated BFP filtrate low in ammonia and TN is returned to the head of the plant.



AUTHORS: KATYA BILYK, WENDELL KHUNJAR, GREG PACE, THOMAS WORLEY-MORSE, CHARLIE COCKER, RON TAYLOR, BOB GASPER, AND PAUL PITTS

## Bodacious Bacteria

ANITA™Mox utilizes AOB and anammox bacteria. Currently available deammonification technologies focus on specific properties of anammox bacteria, such as their larger size and weight, to compensate for their slower growth rate compared to AOB and NOB.



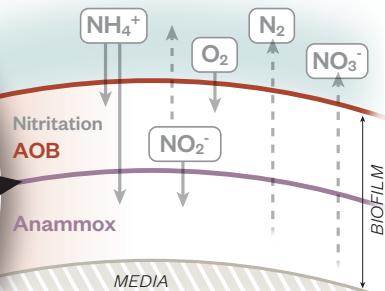
**1** Equalized BFP filtrate enters reactors. Biofilm attached to plastic media carriers in the reactor provide surface area to which the AOB and anammox bacteria attach. Other bacteria can attach as well so it's important to create an environment that favors AOB and anammox growth and suppresses competitors. An aeration system provides oxygen for the AOB.

## How the Bioreactor Works

**2** AOB and anammox bacteria occur naturally in wastewater. These ammonia-eating microbes coat the media and colonize into an inner/outer biofilm system. Anaerobic anammox bacteria on inner layer and aerobic AOB on outer layer. Both consume ammonia, and Anammox converts ammonia and nitrite (oxidized ammonia from AOBs) into nitrogen gas.

## Biofilm Layers

AOB and anammox bacteria populate the media's surfaces, forming two distinct layers of biofilm, one **aerobic**, the other **anaerobic**.



## A Simultaneous Process

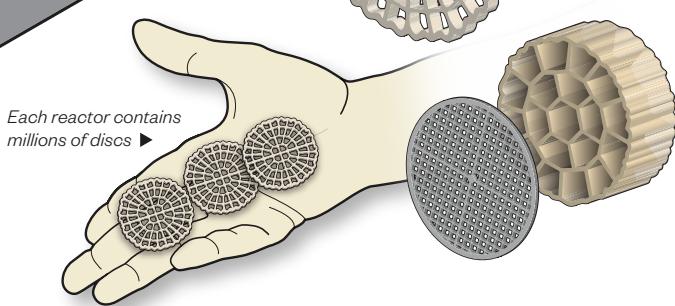
About 55 percent of the ammonia is oxidized to nitrite ( $\text{NO}_2^-$ ) by **AOB** in the outer layer. The nitrite and remaining ammonia are converted by **Anammox** in the second layer to nitrogen gas ( $\text{N}_2$ ). The process produces about 10% nitrate per pound of nitrogen removed.

## Biofilm Media

The discs are made of virgin polyethylene that provides highly-effective surface areas on which the biofilm grows.

◀ South Durham's disc design.

Discs used in other MBBR processes come in a variety of designs.



**3** Reactor HRT depends on the influent flow rate. Treated effluent passes through mesh screens that prevent media from escaping. Treated effluent is returned to the head of the plant to pass through mainstream treatment. Some facilities send return stream to the BNR process to enhance nitrification with AOBs, which can be helpful in cold weather.

## MONITORING NOBs

To help control growth of **Nitrite Oxidizing Bacteria (NOBs)** the SCADA system is programmed to calculate nitrate production as a function of ammonia removal and to issue a warning when this ratio rises above the stoichiometric 10%.

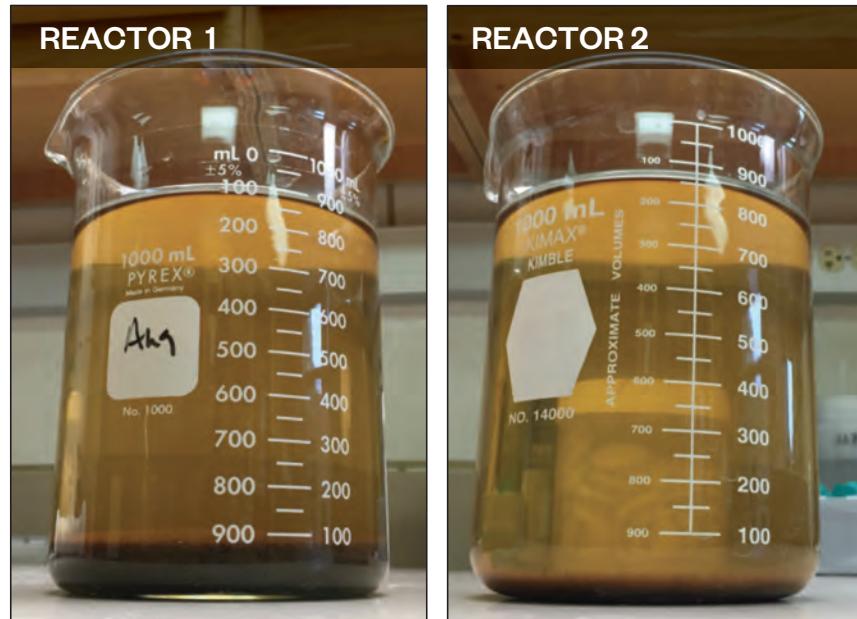


# What We Learned

## Limit Number of Reactors to Minimize Operational Complexity

During startup, small differences in process control led to different microbial populations and differences in nitrogen removal between the reactors. Reactor 1 developed higher nitrate concentrations than Reactor 2, although nitrate levels were elevated in both reactors for a period of time. NOB had to be suppressed to restore target ammonia and TIN removals. In future designs, it is recommended that the number of reactors be limited to no more than two to minimize operational complexity.

*We sampled for TSS and found high concentrations in both reactors, with Reactor 1 having twice the MLSS of Reactor 2.*



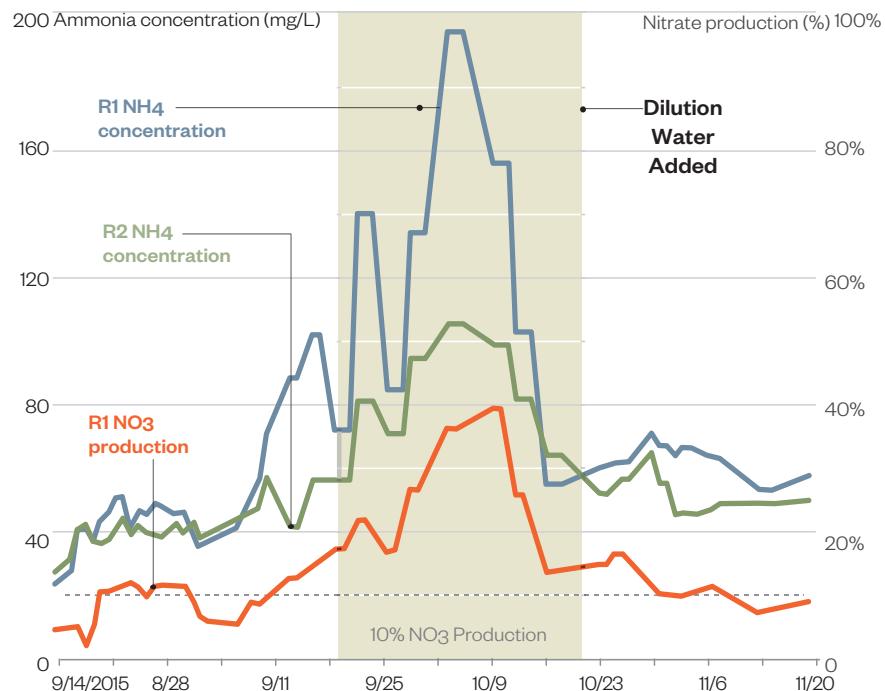
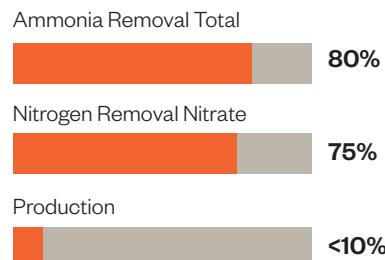
## Nitrate Production Reduced by Adding Dilution Water

Dilution water was successfully used to decrease reactor Hydraulic Retention Time (HRT) and to wash out accumulated suspended growth. This restored ammonia and TIN removal to desired levels.

**Nitrate production dropped shortly after the addition of dilution water.**

DATE	R1 MLSS (mg/L)	R2 MLSS (mg/L)
10/1/15	2,250	1,100
10/15/15	1,600	305
10/21/15	670	185
10/28/15	296	254

### Current Performance



## Measuring TSS is a Good Proxy for NOB Activity

Measuring Total Suspended Solids (TSS) in the reactors served as a proxy for NOB growth potential and can be used to monitor NOB growth in MBBR sidestream deammonification systems. NOBs had accumulated in suspended phase. This was discovered when filtering samples became difficult.

# SOLIDS STATE

## The Present and Future of Residuals Treatment

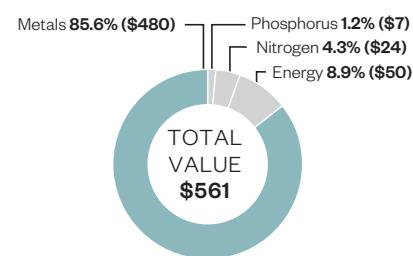
Over the next five decades, the amount of municipal residuals produced in North America is expected to increase by about 50% due to population increases. The current need to remove nutrients from wastewater effluents to low levels will only increase in the future, also contributing to increased residuals production. Greater pressure on natural resources such as water, nutrients, energy, and metals will also contribute to the need to maximize the resources present in wastewater.

While the main driver for managing this material will continue to be federal and state regulations, other drivers include public perception of the material, availability of disposal or beneficial outlets, energy demand for management, and the overall cost of treatment from production to end use. The current residual management practice focuses on inactivation of pathogens (residuals now called biosolids), some form of energy recovery, and producing stabilized material for partial recycling to the environment with little economic value.

When responding to the drivers for residuals management, utilities and practitioners should view this significant increase in production

### VALUE OF CHEMICALS IN BIOSOLIDS

Value per dry ton of residuals



SOURCE: Environmental Science & Technology

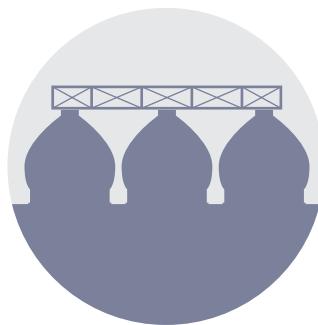


### LAND APPLICATION/NUTRIENTS

**Present:** Wastewater utilities nationwide produce residuals of varying quality depending on cost and state and federal regulations. In Cary (NC), the facility produces a final dried product that meets the requirements for a Class A Exceptional Quality product, which is generally more marketable than Class B.

**Future:** Further improvements to the quality of released biosolids material will be required as public awareness grows. We can also expect to achieve greater efficiency in producing these higher quality products, further offsetting the cost of treatment.

**Value:** -\$\$\$\$



### ENERGY

**Present:** Gwinnett County implemented a combined heat and power system at the F. Wayne Hill Water Resources Center that provides up to 40% of the plant's energy needs. A fats, oils, and grease and high strength waste receiving station injects waste streams rich in readily-digestible volatile solids directly into the anaerobic digesters, increasing gas production.

**Future:** Technologies for converting residuals to crude oil such as pyrolysis or hydrothermal liquefaction are being developed with a good chance of success in the near future. These technologies do not require high capital investment and require smaller footprint.

**Value:** \$\$\$

**Dr. Mohammad Abu-Orf** is a globally acknowledged biosolids processing expert, with more than 24 years of municipal and industrial experience in the areas of dewatering, stabilization, and energy recovery. He has been involved in directing biosolids master planning and biosolids management plans for wastewater treatment plants ranging in size from 5 to 350 mgd. He also has five patents and more than 120 peer-review publications to his credit.



as an opportunity rather than a problem. The recent paradigm shift to consider waste material such as residuals as a resource is a key to their sustainable management. From a resource perspective, some published literature has indicated that the value of a dry ton of residuals is about \$650, where ~5% of this value comes from the value of existing nutrients, 8% is from the energy content as compared to coal, and the remaining value is from the presence of heavy and precious metals. From an economic standpoint, the most valuable resources in the residuals are not being explored since the focus thus

far has been on recovering nutrients and energy value, representing an untapped potential revenue stream. Generally, at present, the cost of processing residuals is higher than the amount of resources contained in the material. Thus, developing technologies for cost-effectively recovering these resources will become an increasingly critical factor to ensure economic sustainability.

Processing and managing residuals will remain a challenge in the future with no single or standard solution. The pressures and drivers are expected to shift or change in

the future with more pressure on preserving the Earth's resources and sustainable practices requiring adapting to these pressures and drivers. Economic sustainability and resource scarcity will dictate the resources we need to recover from residuals and help establish new technologies. In the future, we expect to see a place for most existing technologies with a gradual shift to more nontraditional technologies such as Super Critical Water Oxidation and Hydrothermal Liquefaction.



## PHOSPHORUS

**Present:** One of only two working phosphorus recovery systems in the country, the Nansemond Treatment Plant implemented the Ostara Pearl® process, which removes phosphorus and ammonia from the sidestream – producing a fertilizer that is sold commercially – and saves the facility \$450,000 annually in reduced chemical and sludge disposal costs.

**Future:** More facilities will recover phosphorus through struvite precipitation, not only reducing the operating costs associated with cleaning struvite-clogged pipes, but also producing a marketable product that is becoming more costly to mine. Greater adoption should in turn drive down capital costs as well.

**Value:** \$\$\$\$



## METALS

**Present:** The most valuable resource in the residuals, heavy and precious metals, is not currently widely recovered due to the costs involved, but it is gaining some attention from practitioners and utilities. We are currently leading research to determine optimal methodologies to recover rare earth elements from wastewater (see next page for more).

**Future:** Most of the metals considered toxic to ecosystem organisms and regulated in land-applied biosolids also have significant potential economic value. Future technologies could borrow from the mining industry, with an opportunity to use similar methods of recovery on residuals incineration ash.

**Value:** \$\$\$\$\$

# Rare Earth Elements in Wastewater

Advancements in electronics, energy systems, and transportation technologies are increasing the demand for redoxstable metals with unique electrochemical properties, collectively termed “rare earth elements” (REEs). As with nutrients, we see an increased presence of these REEs in our lives, our wastes, and our environment, representing new opportunities for recovery of resources. REE recovery from wastes can offset development of natural REE reserves while also protecting our ecosystems.

We are currently co-leading (along with CH2M and Bucknell University) a Water Environment & Reuse Foundation (WE&RF) research study to quantify the potential for REE recovery and commoditization from municipal wastewater. We designed and implemented a comprehensive sampling campaign from 31 Water Resource Recovery Facilities (WRRFs) throughout the United States and Canada, which is currently underway.

Once sampling is complete, we will rank available extraction/separation methods according to their suitability for use in both liquid wastewater and biosolids. Factors to be used in ranking are expected to include yield, product purity, relative cost, process complexity and flexibility, capital equipment, consumables, O&M considerations, and compatibility with recovery of other resources. The outcomes of this work should yield a much broader quantitative assessment of the prevalence of REEs entering North American WRRFs than currently exists, allowing

WE&RF and utilities to quantify the potential costs and value associated with large-scale recovery and prioritize research efforts toward optimal separation strategies.

## RARE EARTH ELEMENTS

□ Light REE      ■ Heavy REE

Hydrogen	1 H	Helium																		2 He
	1 H	2 He	3 Li	4 Be	5 B	6 C	7 N	8 O	9 F	10 Ne	11 Na	12 Mg	13 Al	14 Si	15 P	16 S	17 Cl	18 Ar	19 K	20 Ca
22.660	24.020	25.985	26.982	28.085	29.983	30.973	31.972	32.970	33.969	34.968	35.967	36.966	37.965	38.964	39.963	40.962	41.961	42.960	43.959	44.958
40.960	41.959	42.958	43.957	44.956	45.955	46.954	47.953	48.952	49.951	50.950	51.949	52.948	53.947	54.946	55.945	56.944	57.943	58.942	59.941	60.940
59.940	60.939	61.938	62.937	63.936	64.935	65.934	66.933	67.932	68.931	69.930	70.929	71.928	72.927	73.926	74.925	75.924	76.923	77.922	78.921	79.920
79.920	80.919	81.918	82.917	83.916	84.915	85.914	86.913	87.912	88.911	89.910	90.909	91.908	92.907	93.906	94.905	95.904	96.903	97.902	98.901	99.900
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399.900	400.900	401.900	402.900	403.900	404.900	405.900	406.900	407.900	408.900	409.900	410.900	411.900	412.900	413.900	414.900	415.900	416.900	417.900	418.900	419.900
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439.900	440.900	441.900	442.900	443.900	444.900	445.900	446.900	447.900	448.900	449.900	450.900	451.900	452.900	453.900	454.900	455.900	456.900	457.900	458.900	459.900
459.900	460.900	461.900	462.900	463.900	464.900	465.900	466.900	467.900	468.900	469.900	470.900	471.900	472.900	473.900	474.900	475.900	476.900	477.900	478.900	479.900
479.900	480.900	481.900	482.900	483.900	484.900	485.900	486.900	487.900	488.900	489.900	490.900	491.900	492.900	493.900	494.900	495.900	496.900	497.900	498.900	499.900
499.900	500.900	501.900	502.900	503.900	504.900	505.900	506.900	507.900	508.900	509.900	510.900	511.900	512.900	513.900	514.900	515.900	516.900	517.900	518.900	519.900
519.900	520.900	521.900	522.900	523.900	524.900	525.900	526.900	527.900	528.900	529.900	530.900	531.900	532.900	533.900	534.900	535.900	536.900	537.900	538.900	539.900
539.900	540.900	541.900	542.900	543.900	544.900	545.900	546.900	547.900	548.900	549.900	550.900	551.900	552.900	553.900	554.900	555.900	556.900	557.900	558.900	559.900
559.900	560.900	561.900	562.900	563.900	564.900	565.900	566.900	567.900	568.900	569.900	570.900	571.900	572.900	573.900	574.900	575.900	576.900	577.900	578.900	579.900
579.900	580.900	581.900	582.900	583.900	584.900	585.900	586.900	587.900	588.900	589.900	590.900	591.900	592.900	593.900	594.900	595.900	596.900	597.900	598.900	599.900
599.900	600.900	601.900	602.900	603.900	604.900	605.900	606.900	607.900	608.900	609.900	610.900	611.900	612.900	613.900	614.900	615.900	616.900	617.900	618.900	619.900
619.900	620.900	621.900	622.900	623.900	624.900	625.900	626.900	627.900	628.900	629.900	630.900	631.900	632.900	633.900	634.900	635.900	636.900	637.900	638.900	639.900
639.900	640.900	641.900	642.900	643.900	644.900	645.900	646.900	647.900	648.900	649.900	650.900	651.900	652.900	653.900	654.900	655.900	656.900	657.900	658.900	659.900
659.900	660.900	661.900	662.900	663.900	664.900	665.900	666.900	667.900	668.900	669.900	670.900	671.900	672.900	673.900	674.900	675.900	676.900	677.900	678.900	679.900
679.900	680.900	681.900	682.900	683.900	684.900	685.900	686.900	687.900	688.900	689.900	690.900	691.900	692.900	693.900	694.900	695.900	696.900	697.900	698.900	699.900
699.900	700.900	701.900	702.900	703.900	704.900	705.900	706.900	707.900	708.900	709.900	710.900	711.900	712.900	713.900	714.900	715.900	716.900	717.900	718.900	719.900
719.900	720.900	721.900	722.900	723.900	724.900	725.900	726.900	727.900	728.900	729.900	730.900	731.900	732.900	733.900	734.900	735.900	736.900	737.900	738.900	739.900
739.900	740.900	741.900	742.900	743.900	744.900	745.900	746.900	747.900	748.900	749.900	750.900	751.900	752.900	753.900	754.900	755.900	756.900	757.900	758.900	759.900
759.900	760.900	761.900	762.900	763.900	764.900	765.900	766.900	767.900	768.900	769.900	770.900	771.900	772.900	773.900	774.900	775.900	776.900	777.900	778.900	779.900
779.900	780.900	781.900	782.900	783.900	784.900	785.900	786.900	787.900	788.900	789.900	790.900	791.900	792.900	793.900	794.900	795.900	796.900	797.900	798.900	799.900
799.900	800.900	801.900	802.900	803.900	804.900	805.900	806.900	807.900	808.900	809.900	810.900	811.900	812.900	813.900	814.900	815.900	816.900	817.900	818.900	819.900
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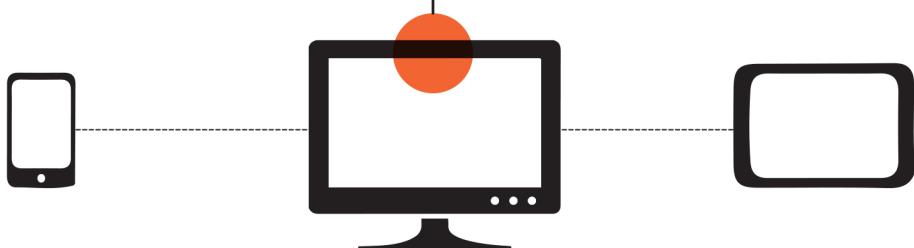
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