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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.

Cover Image: Big Sur, California (Photo by Bob Stefko/Getty Images)

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.

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.

Taste and Odor

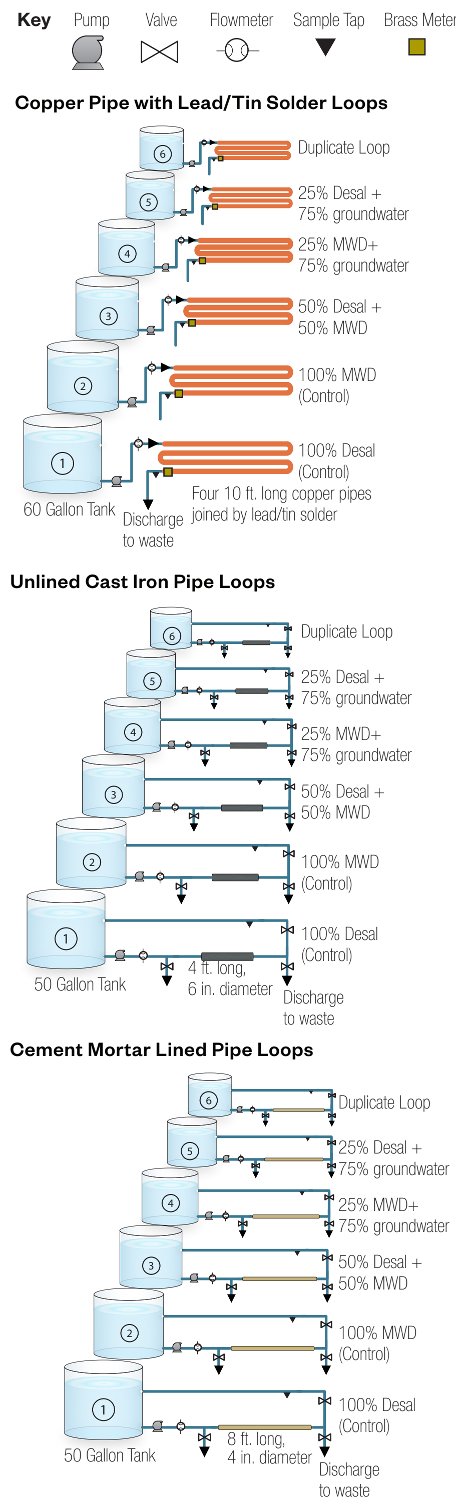
Often the first concern of a provider is identifying a source water that will be treatable and meet all Federal and State standards. Beyond that it is important to ensure that the finished water will be aesthetically acceptable to their customers. Taste and odor issues in drinking water are most commonly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

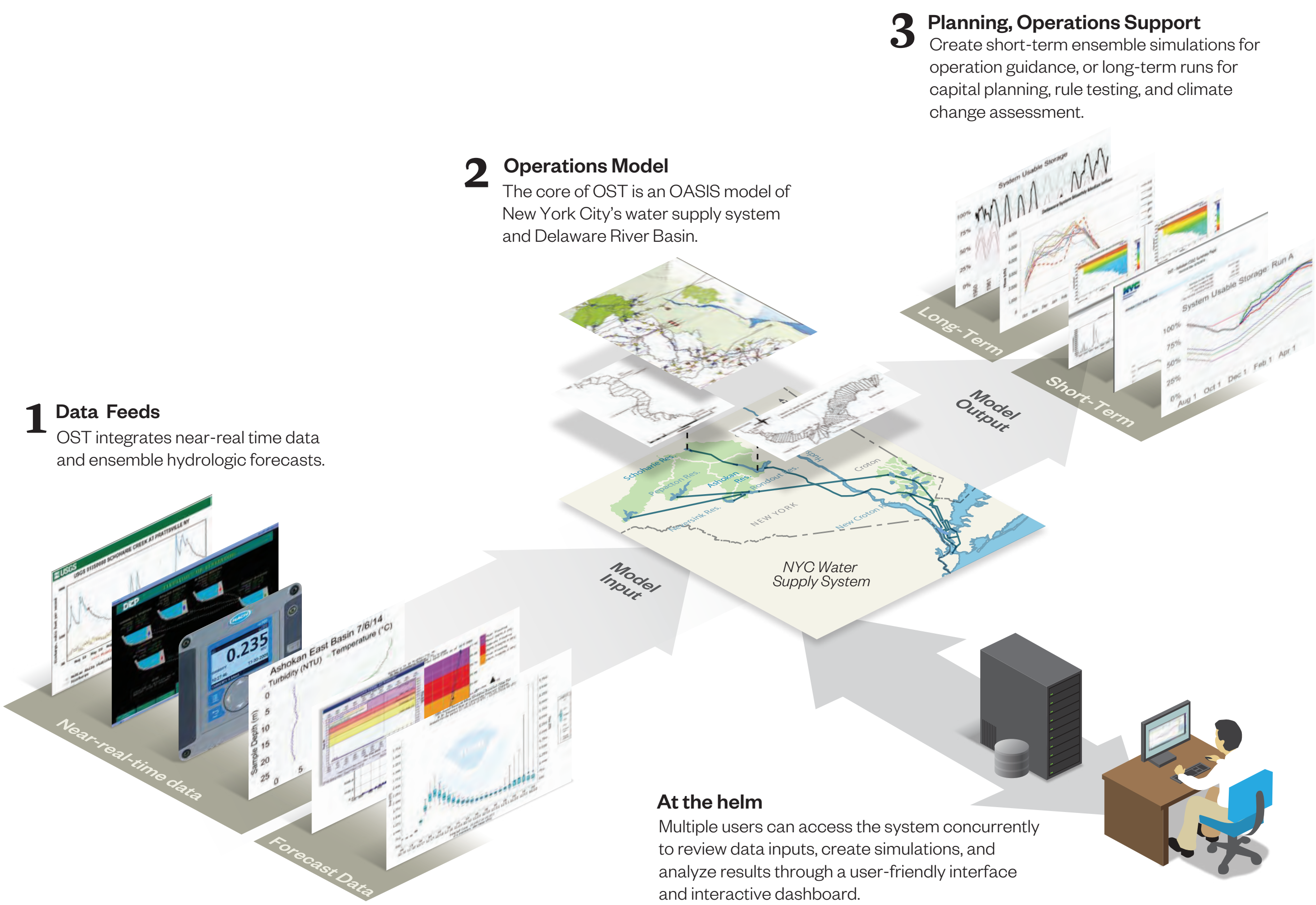
Disinfection byproduct formation

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.

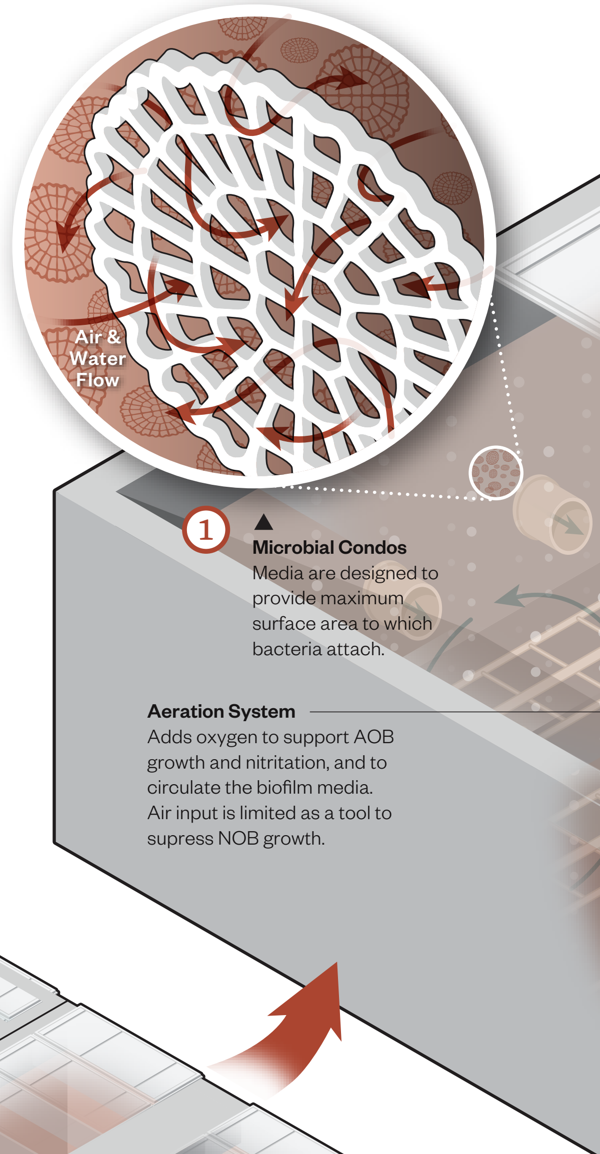
The sophisticated decision support system integrates near-real time data and ensemble inflow forecasts with reservoir system operating rules and simulation modeling, enabling system managers to conduct look-ahead simulations to support near-real time water supply decisions that reduce DBP precursors,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



Lessons Learned About Microbial Deammonification

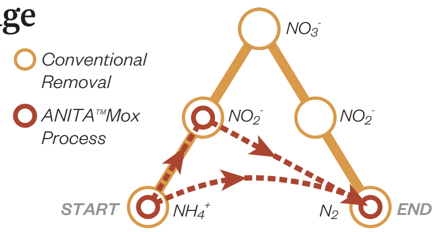
From Design, Startup and Operation of an ANITA™Mox System

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.



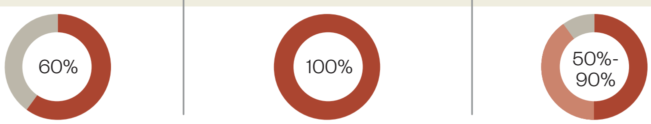
A "Natural" Shortcut Advantage

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.

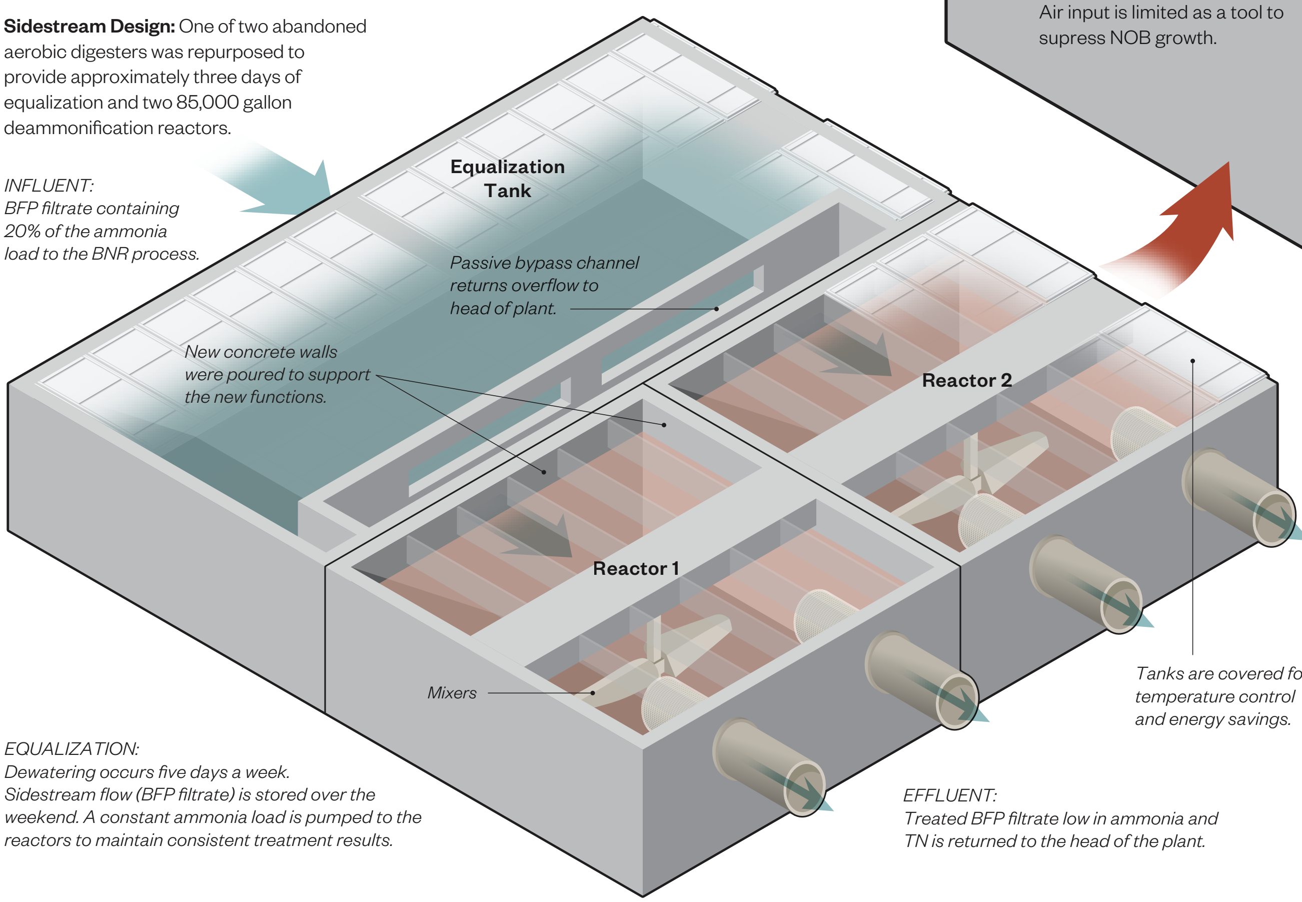


Theoretical savings in three key areas when using deammonification pathway for nitrogen removal are shown below.

Oxygen Requirement (lb O_2 / lb N)	Methanol Consumption* (lb / lb N)	Sludge Production (lb VSS / lb N)
4.6 to 1.9	3.0 to 0	0.5–1.0 to 0.1



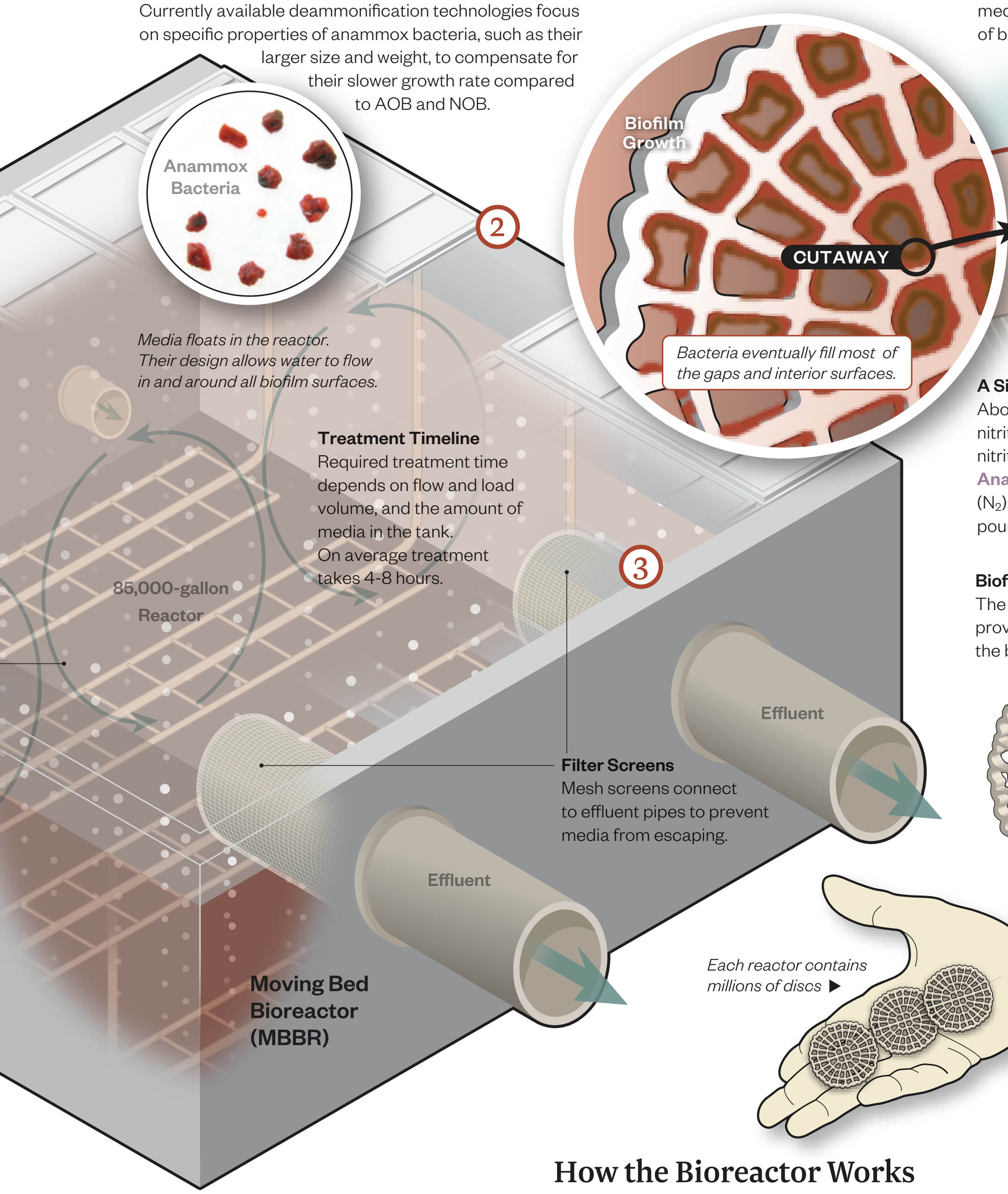
* Numbers vary for other carbon sources.

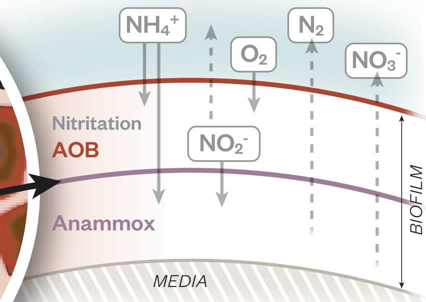


AUTHORS: KATYA BILYK, WENDELL KHUNJAR, GREG PACE, THOMAS WORLEY-MORSE, CHARLIE COCKER, RON TAYLOR, BOB GASPER, AND PAUL PITT

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.

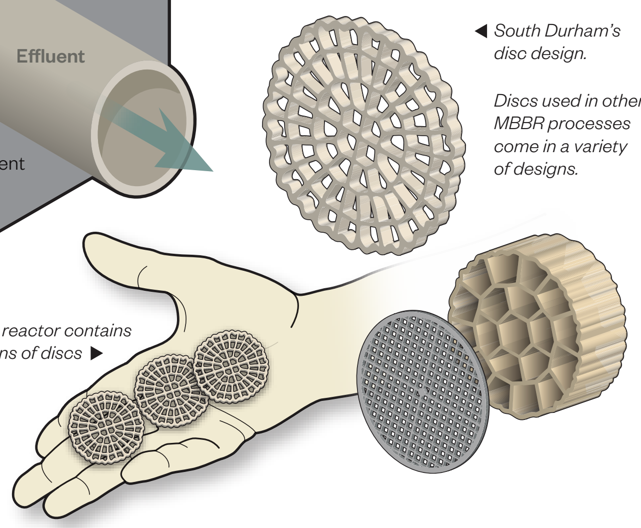
Biofilm Layers
AOB and anammox bacteria populate the media's surfaces, forming two distinct layers of biofilm, one **aerobic**, the other **anerobic**.





A Simultaneous Process
About 55 percent of the ammonia is oxidized to nitrite (NO_2^-) by **AOB** in the outer layer. The nitrite and remaining ammonia are converted by **Anammox** in the second layer to nitrogen gas (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.



How the Bioreactor Works

(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.

(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.

(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.

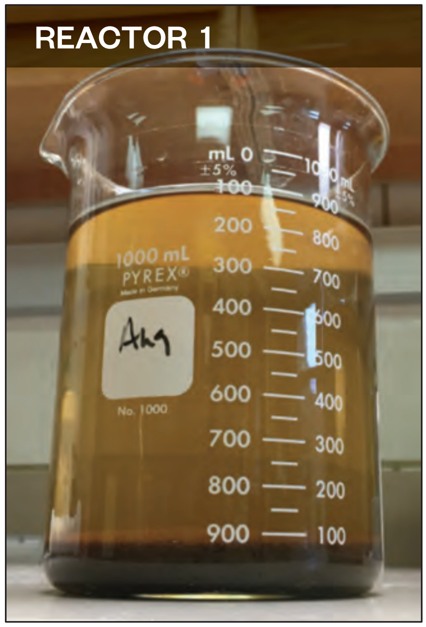
MONITORING NOBs
To help control growth of **Nitrite Oxidizing Bacteria (NOBs)** the SCADA system is programmed to calculate nitrate production as a function of ammonia removal and to issue a warning when this ratio rises above the stoichiometric 10%.

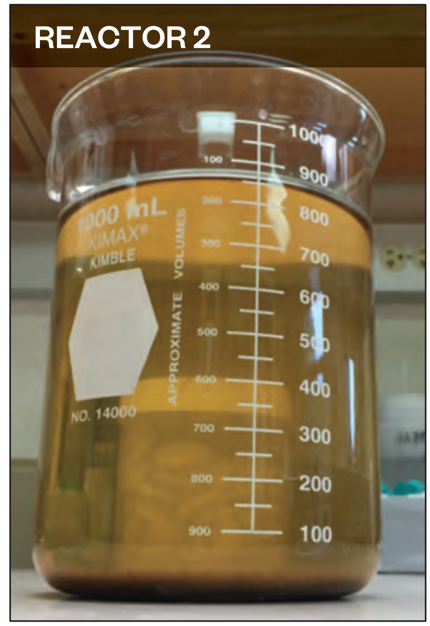
What We Learned

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..



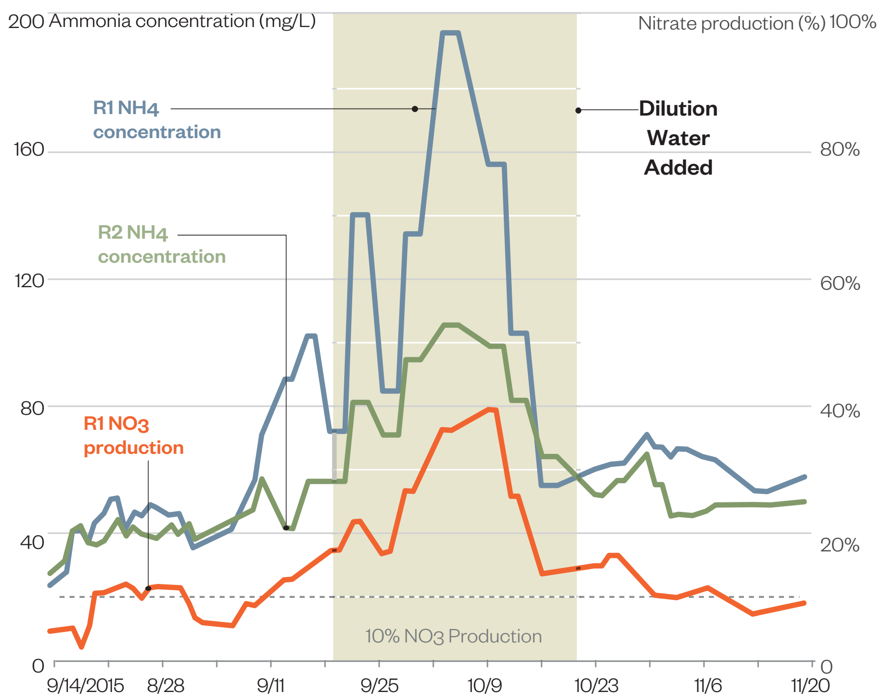


Nitrate Production Reduced by Adding Dilution Water

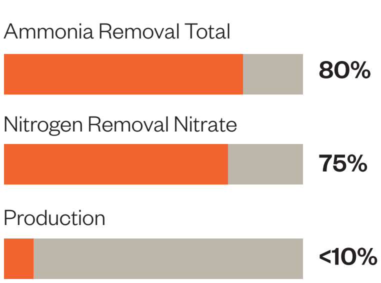
Dilution water was successfully used to decrease reactor Hydraulic Retention Time (HRT) and to wash out accumulated suspended growth. This restored ammonia and TIN removal to desired levels.

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

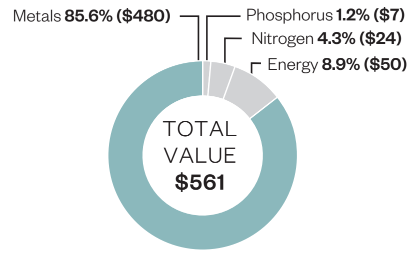
Over the next five decades, the amount of municipal residuals produced in North America is expected to increase by about 50% due to population increases. The current need to remove nutrients from wastewater effluents to low levels will only increase in the future, also contributing to increased residuals 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.

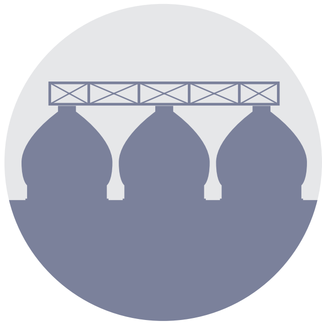
When responding to the drivers for residuals management, utilities and practitioners should view this significant increase in production

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