CAROLLO ENGINEERS VOLUME 3 2022

currents

CAN I TRUST THAT BLACK BOX?

Enhancing the Water Digital Twin Using Machine Learning

PLUS —

- Using biottta® for Nitrate and Arsenic Removal
- Water For People: Years of Giving Back
- New Atlanta and British Columbia Offices
- 2022 Bryant L. Bench Scholarship Award

THIS ISSUE'S **EDITORIAL**

NICK WEBBER, PE (nwebber@carollo.com)

Welcome to ***Currents*** 2022 Volume 3!

In this issue, we highlight Carollo's Blue Plan-it® (BPI) Decision Support System and advancements of the tool with machine learning integrations. Using BPI's Digital Twin WTP Operations Model empowered with machine learning, water utility engineers, managers, and operators can virtually experiment with their own systems using static and dynamic data. This improves the conventional water treatment analytics to drive actionable and improved outcomes.

Additionally, you'll read about two new offices we've opened this year, a biottta® pilot study on concurrent removal of nitrate and arsenic, our strong partnership with Water For People, and this year's Bryant Bench scholarship recipient!

Please reach out to me or the primary authors if you have any questions or comments. Enjoy!

IN THIS ISSUE

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TWO-STAGE, FIXED-BED BIOTREATMENT SYSTEM (biottta®) can Simultaneously Remove Nitrate and Arsenic

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Nitrate and arsenic often co-exist in groundwater sources. Physical-chemical processes typically used for removing these contaminants include reverse osmosis, electrodialysis reversal, ion exchange, and/or adsorption. These processes generate high-strength waste streams or residual solid wastes. When nitrate and arsenic co-exist, multiple unit processes may need to be implemented to produce safe drinking water. Since biological processes convert nitrate to innocuous nitrogen gas instead of concentrating the contaminant, combining biological nitrate removal with a physical-chemical process (e.g., coagulation/flocculation) may provide an efficient and cost-effective treatment alternative when these contaminants co-occur in water.

A 12-month pilot study was conducted for nitrate and arsenic removal at Desert Springs, Nevada, using the biottta® system, originally developed and optimized by Carollo over the last 24 years for nitrate removal. The pilot skid **(Figure 1)** consisted of a 1-ft diameter column (bioreactor) packed with granular activated carbon (GAC), followed by a second 1-ft diameter column (biofilter) packed with GAC and sand. The influent was supplemented with acetic and phosphoric acids for biological growth in the bioreactor. Iron-based coagulant, hydrogen peroxide, and aluminum chlorohydrate (ACH) were fed to the bioreactor effluent for arsenic removal, reoxygenation of the water, and turbidity removal, respectively. Nitrate and arsenic were monitored in real-time, using Hach's "Nitratax sc" sensor and Aqua Metrology Systems' in-line analyzer, respectively.

Under the optimized operating conditions, nitrate was removed from 29-35 mg/L N to <0.1 mg/L N. Arsenic was removed from 9-14 µg/L to <5 µg/L **(Figure 2)**. Turbidity in the filter effluent remained below 0.3 NTU for more than 95% of the sustained removal demonstration period.

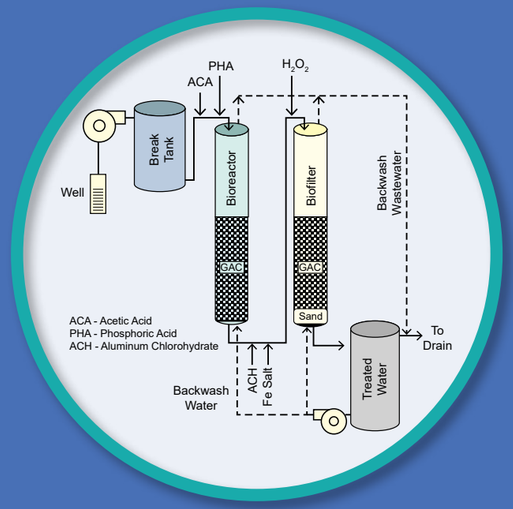

Figure 1 - Process Flow Diagram (Source - Water Science, 3[3]: e1292)

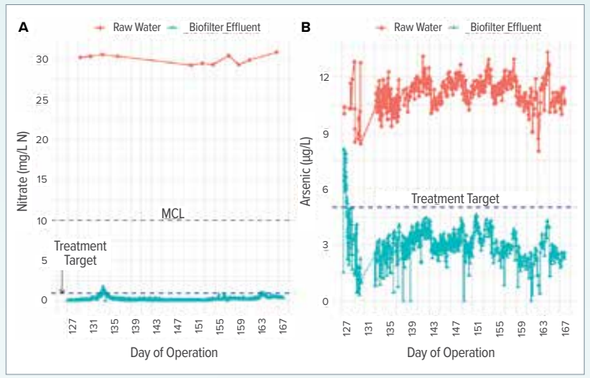

Figure 2 - Nitrate (A) and Arsenic (B) Concentrations in the Raw Water and Biofilter Effluent

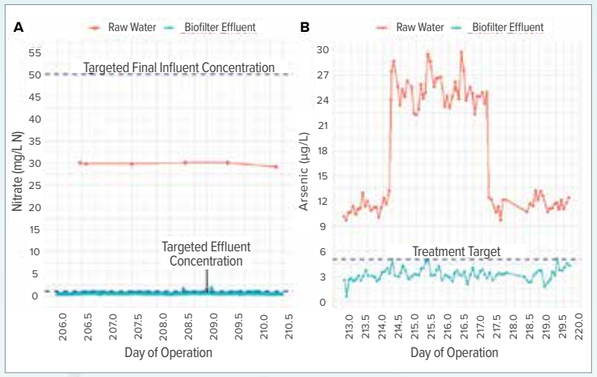

Figure 3 - Nitrate (A) and Arsenic (B) Removal during Raw Water Spiking Tests

System performance was minimally impacted during challenge testing, which included a 24-hour acetic or phosphoric acid feed failure, complete system shutdowns up to 36 days, and raw water nitrate or arsenic spiking. For example, when the influent nitrate concentration was step-increased to 50 mg/L N, nitrate in the biofilter effluent remained well below the treatment target of 1 mg/L N. **(Figure 3 [A])**. Similarly, spiking arsenic up to 30 µg/L did not affect arsenic removal across the biofilter **(Figure 3 [B])**. The raw water and biofilter effluent had similar disinfection byproduct formation potential (DBPFP), indicating that the enhanced biological activity in the system does not increase DBPFP.

Overall, pilot testing showed that biottta® can simultaneously remove nitrate and arsenic by combining biotic nitrate removal with abiotic arsenic removal mechanisms. For more details, check out AWWA Water Science (Water Science, 3(3): e1292), which can be downloaded for free.

CAN I TRUST THAT BLACK BOX?

Enhancing the Water Digital Twin Using Machine Learning

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CAN I TEACH MY DIGITAL TWIN TO LEARN? A SUCCESS STORY OF MACHINE LEARNING

The City of Houston and water authorities in the region have embarked on a multi-year project to construct a major expansion to the existing Northeast Water Purification Plant (NEWPP). This project will increase capacity from 80 mgd to 400 mgd. Using Carollo's Blue Plan-it® Decision Support System, a digital-twin type of operation model was developed for the NEWPP to assist the engineers, managers, and operators to virtually experiment with their facility to support operational decisions **(Figure 1)**.

Calibrated using full-scale, pilot-scale, and bench testing data, our digital-twin can track flow and mass balance, estimate solids production and chemical usage, simulate truck traffic associated with chemical and solids hauling, and assess power consumption. With several mechanistic-based water treatment analytics integrated, it can be used to assess concentration x time (CT) and predict disinfection byproduct formation for the plant's multi-disinfectant systems, including: ozone, chlorine dioxide, chlorine, and chloramine. It can simulate the impacts of chemical additions on water quality, tracking 15 corrosion and stability indices using standard algorithms similar to those used by the RTW model, Water Pro model, EPA WTP Model, etc. However, one challenging area of the water treatment modeling is how to estimate settled water turbidity and TOC when a combination of coagulation/flocculation chemicals (Aluminum Chloralhydrate [ACH], Coagulant Aid, Floc Aid, etc.) are added. No accurate mechanism model is available to simulate the performance of the flocculation and sedimentation process. Empirical models are often limited in their capabilities and accuracy, as shown in **Figure 2**.

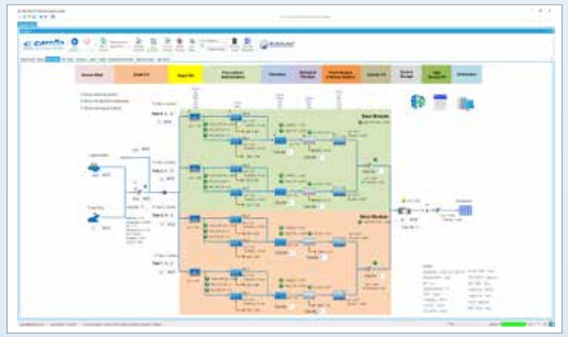

Figure 1 - Integrated with the latest machine learning and artificial intelligence analytics, Carollo's Blue Plan-it® WTP Operations Simulator helps water treatment plant managers and operators to increase productivity and reduce operational costs.

In the past, the plant staff relied on daily jar testing to determine the removal rate of turbidity and TOC under a given chemical dosing scheme. In recent years, zeta potential measurements were introduced, which seemed to have better correlation with chemical dosages. But it is still insufficient to support the development and calibration of a reliable and universally applicable model. A flexible operation support module is desired for the user to: **1)** Determine the settled water quality based on raw turbidity and TOC along with coagulant and polymer doses; **2)** Determine the chemical doses based on raw turbidity and TOC as well as the target settled water quality; and **3)** Determine the coagulant and polymers doses based on raw water quality and a zeta potential target.

In recent years, advanced data analytics and machine learning technologies have gained increased attention and applications in the water industry. Using common computational libraries, users can leverage machine learning to identify patterns of data and generate statistical models without explicit instructions. Fully integrated into the Blue Plan-it® Digital Twin models, several machine learning coding methods, such as random forest regressor or K-neighbors regressor, can now be easily applied to supplement our conventional water analytics.

CAN WE TRUST IT? THE ACCURACY OF MACHINE LEARNING MODEL

Four years of full-scale and jar test data for NEWPP were used for machine learning, with 80% of the data (2,666 data points) used to train the model and 20% of the data (644 data points) used to test the model accuracy. The data included, but are not limited to, raw water TOC, turbidity, and zeta potential; settled water TOC, turbidity and zeta potential; ACH dosage; flocculation aid dosage; coagulant aid dosage; time; and temperature. The machine learning algorithm can be used in three simulation modes: **1)** Chemical calculator mode to predict chemical dosages; **2)** Removal rate mode to predict

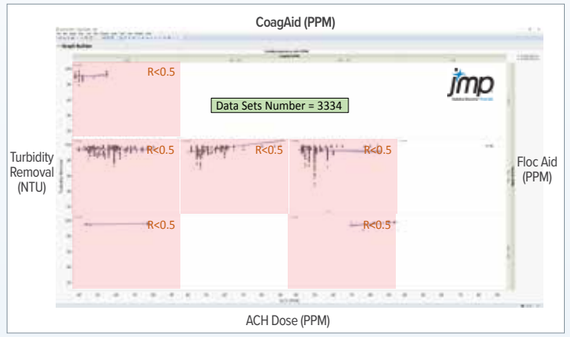

Figure 2 - A multizone correlation analysis of the historical data demonstrated that the chemical dosages have very poor correlation with settled water turbidity and TOC removal, with coefficient of determination (R^2) value of less than 0.5.

the settled water TOC and turbidity; and **3)** Zeta potential mode to predict the amount of chemicals that are needed to achieve a target zeta potential. When compared using the 20% testing data, the machine learning model accurately predicts settled water quality and chemical dosages with R^2 range from 0.93 to 0.99, significantly better than conventionally-fitted empirical models (**Figure 3**).

Once the accuracy of the model was successfully demonstrated, the machine learning module was integrated into the latest version of the NEWPP Operations Simulators. This innovation was well received by plant managers and operators. It is being actively used for training, troubleshooting, and operation and maintenance planning. The plant is collecting additional data day by day, which will be used to retrain the machine learning model. It is expected that the model accuracy will continue to improve over time.

WHAT ELSE CAN WE DO WITH IT? OTHER APPLICATIONS OF MACHINE LEARNING IN WATER TREATMENT

Instead of considering it as a black box, machine learning, when applied correctly, has been proven useful. It is especially a good solution when no known mechanisms or correlation is available to predict results and when adjustment of multiple factors (in the case above, dosages of multiple chemicals) ends up with multiple results (e.g., TOC, Turbidity,

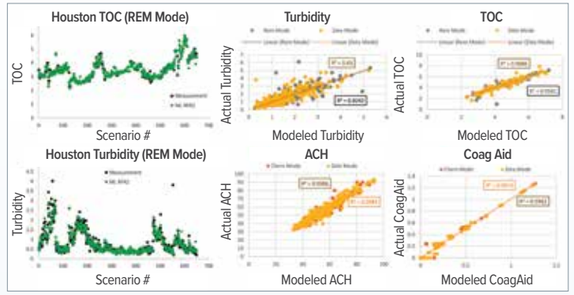

Figure 3 - Machine learning model predicts settled water TOC and turbidity, ACH doses, and coagulant aid doses accurately. (Measured data in black, machine learning predictions in green).

zeta potential, etc.). The next reasonable step to improve the NEWPP digital twin is to apply machine learning to model granular media filtration process. It is expected that this will improve the current empirical ways for estimating filtered water quality, filter backwash frequency, and unit filter run volume (UFRV). This will result in more accurate simulation of disinfectant decay and DBP formation using a hybrid data-driven mechanistic model.

Machine learning applications in the water industry can be far beyond what has been demonstrated above. It can also be used for modeling adsorption process performance to predict media replacement frequency for TOC or PFAS removal; membrane process modeling to predict membrane backwash, maintenance wash and CIP frequencies; and model predictive control of wastewater biological treatment.

Additionally, it can also be used to supplement the distribution system water quality modeling. Utilities often have years of data on chlorine residuals, THMs, and HAAs in the distribution system. Other data are also relevant, including water quality from each source in the system (bromide, UV254, pH, temperature, DOC, etc.), chlorine dosage at each injection point, and information required to estimate the water age and source contribution in the entire distribution system.

A machine learning model, which constantly receives and processes real time data and frequently gets retrained in an automated manner, could be instrumental to cope with such complexity and dynamic nature of the distribution system operation. Often times the issue is not lack of data, but lack of an established approach to turn the data into knowledge. To cope with this challenge, Carollo is working with utilities to establish a data pipeline for pulling in data semi- or fully-automatically from various sources (SCADA, Lab Information Management Systems (LIMS), data loggers, USGS website, etc.) to feed the digital twin. A strong data processing module is also being integrated into Blue Plan-it® to scrub, downsize, resample, and process the raw data into useful data that can feed the model.

At Carollo, we are committed to helping water utilities to improve operational effectiveness and enable better decision-making. With our machine-learning-powered digital twin, we are ready to partner with you in this exciting age of digital transformation in the water industry.

WATER FOR PEOPLE:
A Future Where Everyone has Safe, Reliable Water and Sanitation Services...Forever

For the 17th consecutive year, Water For People has received Charity Navigator's Four Star Rating – the highest possible score – which places them in the top 1% of all charities.

BRIANNA BARTON, PE, WORKPLACE GIVING COMMITTEE CAMPAIGN COORDINATOR (blbarton@carollo.com)

At Carollo, we work every day to provide clean water and sanitation for our local communities, but there are more than 2.1 billion people worldwide that lack access to clean, safe water and 4.5 billion people that lack access to improved sanitation. We can't reach everyone alone. **That's why we partner with Water For People**, an international nonprofit organization working to bring water, sanitation, and hygiene services to everyone in need , and to make sure those solutions last forever.

In 2006, Carollo's annual workplace giving campaign was created as a result of an employee-driven grassroots effort. There was a strong interest to support a good cause and help change lives. In typical engineering fashion, a lot of research went into potential nonprofit organizations to support. Water For People was selected as the recipient of our workplace giving program because their mission and values closely align with our own.

Carollo and its employees have donated over $775,000 to Water For People.

We support them in many ways, including:

- We are a corporate member of Water For People's Leadership Council.
- More than 40 office coordinators organize participation on some level from 100% of our offices.
- More than 110 employees are enrolled in automatic payroll contributions.
- We sponsor one employee annually to travel on a Water For People Impact Tour to spend a week observing their work first-hand in one of their nine target countries. Since 2017, we have sponsored six participants to India, Peru, Rwanda, and Guatemala.

For more information, visit **waterforpeople.org/carollo** or email **workplacegiving@carollo.com**.

"Water is all we do at Carollo, and this adds a special relevance to our relationship with Water For People. Our employees find it rewarding to know that our commitment to water doesn't just end with work but extends beyond through this partnership to have a broader impact. The annual campaigns always bring the company together in a meaningful way, allowing us all to feel part of something larger."

– B. Narayanan, Chief Executive Officer, Carollo Engineers, Inc.

Carollo Engineers Opens First Canada Office in

British Columbia

NEW SITE WILL SERVE WATER AND WASTEWATER CLIENTS IN THE VANCOUVER LOWER MAINLAND

In June, Carollo opened its first international location, in **Burnaby, British Columbia**, to better serve its water and wastewater clients in the Metro Vancouver area. The new office is located at the Metrotown Complex at 4720 Kingsway.

"With Carollo's singular focus on water, we bring proven solutions that will help Vancouver-area clients address impacts from climate change, integrate resource recovery, protect the First Nation's water resources, and enhance the community," said Eric Leveque, Carollo Canada Client Service Director.

Carollo provides water, wastewater, and stormwater services to public and private sector clients throughout Canada; the new Burnaby office is an opportunity to more efficiently foster and service those relationships with established clients while also building new connections.

Carollo is currently serving as Program Manager for Metro Vancouver's Northwest Langley Wastewater Treatment Plant Expansion, a project that will support regional growth, protect the environment, integrate tertiary treatment processes, and safeguard the plant against seismic and flood events.

Other notable projects include owner's advisory services for the Lake Country Wastewater Treatment Plant Phase 4 Upgrades (British Columbia), treatment process subject matter expertise for the Neptune Terminals Bulk Water Treatment Plant project (British Columbia), residuals treatment design and operational reviews for the new Peachland Water Treatment Plant (British Columbia), owner's advisory services for the Buffalo Pound Water Treatment Plant Improvements (Saskatchewan), and emergency response planning for the Regional Municipality of Peel (Ontario).

Opening of Carollo Office in Atlanta Metropolitan Region

To further develop applied research and collaboration of all things water on the East Coast, Carollo has opened its landmark 50th office location in the **Metro Atlanta** region. The office is located 30 minutes from downtown Atlanta at The Water Tower Innovation Center in Gwinnett County, Georgia.

Why The Water Tower? This 55,000-square-foot facility houses office and collaboration spaces, operator classroom and hands-on training areas, community meeting space, digital technology testing space, as well as experimental, analytical, and microbiology laboratories. Located within 100 yards of one of the most advanced water reclamation facilities on the Eastern Seaboard, a conveyance network brings process streams to the on-site pilot demonstration area to support bench-scale, full-scale, and pilot studies. This facility aligns with Carollo's focus on water, innovation, and sustainability.

The office currently has three staff members and growing. Prior to the office opening, contracts were won with two major clients: Gwinnett County and the City of Atlanta.

BRYANT L. BENCH SCHOLARSHIP

Carollo awarded its 7th Bryant L. Bench Scholarship to HIMANSHU SAIL during the prestigious Scholarship Recognition Event at AWWA's Annual Conference & Exposition (ACE) in June 2022.

The Bryant L. Bench Scholarship was launched in honor of Carollo's Water Practice Director, Bryant Bench, whose innovative treatment concepts helped improve drinking water quality across the country. Applicants for this scholarship must be pursuing a master's degree in a water engineering-related field. The scholarship is a one-time $10,000 award that students can use to complete or further their education in their chosen field.

Himanshu is pursuing his master's degree in Environmental and Water Resources Engineering at the University of Texas at Austin. He received his bachelor's degree in Chemical Engineering from the Institute of Chemical Technology, Mumbai. His research is focused on the biological treatment of produced water distillates for beneficial reuse. In addition to research, Himanshu also led UT Austin's team to win the Water Environment Association of Texas (WEAT) Student Design Competition 2022. In the future, he plans to become a Professional Engineer and leverage his skills to develop sustainable energy-efficient processes for water treatment.

Congratulations, Himanshu!

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