RESEARCH SPOTLIGHT

It Started in a Washtub

Advancing Desalination of Cooling Tower Blowdown

By Angelina Dinsmore, The Water Research Foundation

Have you ever heard the phrase, "blow off some steam?" When we blow off steam, we relieve some strong emotions. It feels good. It's a release. In the water and power sectors, cooling towers (CTs) blow off steam, too, and in doing so they are very efficient at cooling in power, industrial, manufacturing and commercial industries. The saline water left behind (that isn't blown off as steam) is called blowdown, and like our suppressed emotions, it's difficult to manage. During the evaporative cooling process, the fresh water evaporates, while the rest falls back into the supply tank, causing minerals and salts to upcycle in the CT supply water. To keep minerals—such as hardness and silica—from affecting the cooling efficiency and to maintain a proper water chemistry, the blowdown must be discharged into the sewer, while fresh water from the local drinking water system is added to augment what leaves as steam and blowdown. Treatment of this high-salinity blowdown is challenging, and water resource recovery facilities need a better, more sustainable process to prevent it from entering watersheds.

In 2019, Garver received a $150,000 Pitch to Pilot (P2P) grant from the U.S. Bureau of Reclamation's (BOR) Desalination and Water Purification Research Program to study an innovative process train that recovers the saline blowdown from commercial and industrial CTs. Over the past five years, the team developed a pilot-scale process train that has progressed to achieve greater than 99% total dissolved solids (TDS) reduction and continues to achieve zero liquid discharge (ZLD) for the 600-ton CT at Red

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Rocks Community College (RRCC). Garver's former Water and Energy Practice Lead, Eric Dole, led the charge and enlisted help from a variety of industry partners, including RRCC, Powell Water, Lyons Filter Company, Salt Miner, Endress + Hauser, Rockwell Automation, Flowrox, Blue White Industries, and Dr. Mike Mickley, among others. Together, they donated over $480,000 of in-kind equipment, instrumentation, labor, and knowledge.

Since WRF's last feature article on the P2P project, "Proving an Innovative Advanced Treatment Concept: Desalination Research on Cooling Tower Blowdown" in *Advances in Water Research* magazine, the research team has made great strides (Dole 2022). The same system that once achieved 54% recovery during the initial testing has, for the past two years, consistently achieved 97% recovery without any chemical pretreatment, which allowed their concentrate treatment system, called vacuum assisted electro-distillation (VAED), to treat the remaining 3%, thereby closing the ZLD loop.

In addition to their advancements in the world of desalination, Eric and his P2P project team also made a huge impact at the Water Quality Management Technology department at RRCC in Lakewood, CO. In 2019, Eric scoped out an empty trailer on RRCC's campus and decided it was time to transfer his patented VAED brine treatment prototype from a washtub in his garage to a bigger space. (This made his wife happy). With help from Jeremy Beard, a RRCC and Colorado School of Mines professor, as well as part-time process engineer at Garver, Eric utilized the empty trailer to host his prototype. Soon after, he noticed the campus' cooling tower up the hill—a source of salt pollution in the watershed.

"What do you think about repurposing the trailer and putting together an 'electrified' process train to desalinate the blowdown so it can be reused in the cooling tower?" Eric asked Jeremy.

"Well, what exactly were you thinking?" Jeremy replied.

And so, it began. The team designed and constructed an electro-coagulation (EC) + clarification (CLAR) + microfiltration (MF) + reverse osmosis (RO) system with a VAED concentrate treatment train. By working with Endress+Hauser and Rockwell Automation, global leaders in process instrumentation and control, Garver successfully designed, constructed, and operated this treatment train that was able to achieve ZLD treatment of the cooling tower blowdown. They transformed the not-so-good blow-down to high-quality treated water, without the chemical addition typically required in high recovery RO pre-treatment. As a result, the team created a model for an "electrified" ZLD treatment train for future desalination systems.

Working on the P2P project provided RRCC students with valuable piloting experience—an opportunity rarely offered to community college students. The project gave students real-world engineering design and construction

Washtub Version of Vacuum Assisted Electro-Distillation (aka Alpha Prototype)

experience and helped a few land their first job in the industry. Two of them, Jessica Johnson and Tyler LeClear, were hired by Garver. Tyler participated in the Bell Engineering program, a program that partners with community colleges nation-wide to support the completion of an undergraduate degree in an engineering field with project-based experience. Jessica Johnson reflected on the value of working on research projects as a young engineer.

"It allowed us to think outside the box," said Jessica. "Practicing trial and error helped us problem-solve in an unrestrictive way, as opposed to designing or operating a tried-and-true system that has more prescriptive approaches."

Jessica, among others, also shared what a positive experience it was to work with Eric. "Working with Eric was fun and freeing," she said. "He has the ability to roll with the punches and never fade in spirit, which was motivating when we ran into problems. Eric's ability to constantly search for solutions and take feedback from the team created a really fun working environment."

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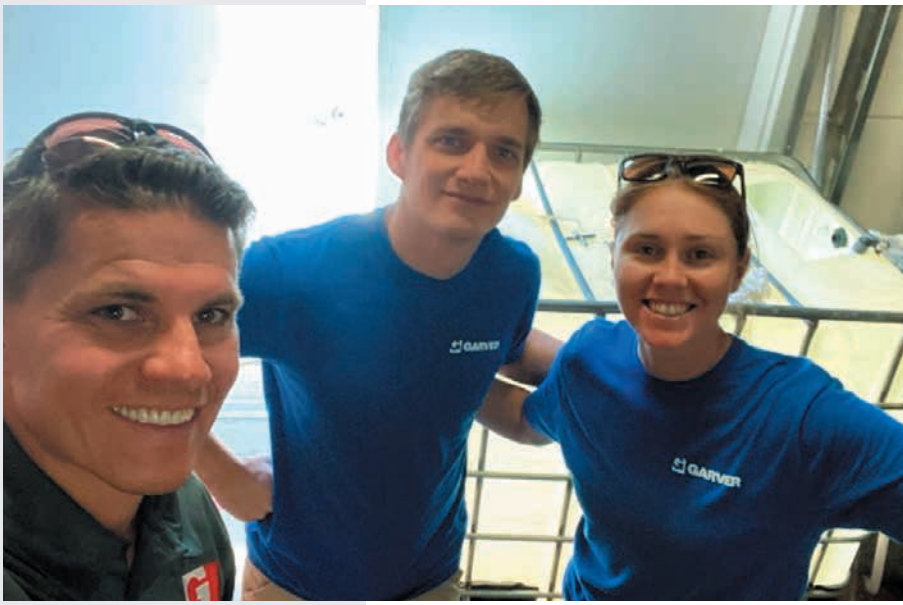
Eric also attributes much of his progress to "rolling with the punches." He shared that 'happy accidents' are what made the P2P project so successful. In fact, two years ago, after the field testing was concluded, Eric showed up to the trailer, only to find everything frozen. Cursing the unpredictable Colorado spring weather, he thought the project was done for. The team pivoted and began to focus on wrapping up the research report. Three months later, with barely any remaining budget, and potentially compromised RO membranes, Eric decided to initiate a failure mode analysis (FMA). He replumbed the pretreatment and slowly started sending more and more flow through the membranes until they could meet 60% of the specific flux (gfd/psi) during the previous field testing without leaking. After a brief permeate flush, the percent recovery returned to where it was before. Surprisingly, the system was good as new without any membrane preservation, three months of downtime, and no chemical pretreatment—only EC + CLAR + MF. The trailer has been in FMA mode for over two years now. Eric is using this surprise occurrence as an opportunity to dig deeper into how the membranes have remained intact with so little care and is readying a hypothesis for future testing.



Eric Dole, Tyler LeClear, and Jessica Johnson (left to right).

Utilizing Electrocoagulation

Although certain project wins stemmed from trial and error, the overall success of the work came from a high level of planning, preparation, and

orchestration. The project involved an innovative combination of electrolytic processes—EC and VAED. EC has been around for 100 years; however, not until the past 20 years have commercialized units entered the market, thanks to Scott Powell of Powell Water Systems.

Eric was first introduced to EC as he knows it in 2012 by Scott. He discovered he and Scott were working on the same thing, though Eric didn't initially categorize VAED as traditional EC, not to mention Powell Water had been selling commercialized systems for decades, and Eric's was still in a Lowe's washtub in his garage.

"Does EC stand for 'everything covered?'" he joked to Scott. "Because it sure does take care of a lot."

Scott's typical response is "no" as there are certain ions the technology will not remove such as salt; however, it does an impressive job with removing many other reverse osmosis membrane-fouling contaminants.

Electrolytic processes are being increasingly considered and used, making the work very timely, according to Dr. Mike Mickley of Mickley & Associates LLC. He praised Eric's efficiency when addressing various challenges with creative solutions during the test phase. A desalination expert for nearly 60 years, Mike remarked that for the level of complexity, the pilot was planned, carried out, and communicated "unusually well." Mike and Eric have known each other for about eight years, and initially met due to common interests, including electrocoagulation. Mike served as a sounding board for Eric on various project aspects and reviewed his data and writing, saying that the report drafting and reviewing was always efficiently managed and conducted.

The VAED system is a unique combination of vacuum distillation, ohmic heating, and electrocoagulation, in a single, multiple effect evaporative crystallizer. The higher the salinity, the more effective the VAED process is at distilling the brine due to ohmic heating. This can result in substantial capital and operational savings. For more information on the commercialization journey of VAED, follow Salt Miner LLC, who has licensed the technology. They are currently working on a proposal to build a 2,500 gallon per day system for a commercial ion exchange water softening at a food manufacturer in Minnesota.

The Passion Behind the Project

One can safely argue that Eric found his niche as an engineer. Growing up in Wilmington, DE, Eric showed an interest in the environment from an early

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Dole giving a tour to representatives from NAWI, NREL, DOE, and Lawrence Berkeley National Labs

age. He was the kid in the neighborhood wanting to celebrate Earth Day by picking up trash and planting trees. On Career Day in 7th grade, Eric was star-struck by the DuPont environmental engineer that spoke to his class.

"I thought he was fantastic," Eric recalled. "I was okay at math and science—I knew I'd have to work hard at it, but I knew that's what I wanted to do."

Posing for a picture and shaking the gentleman's hand, Eric was featured in the next school newsletter with the caption "Future Environmental Engineer, Eric Dole…." Fast forward to 1999, Eric graduated from Arizona State University with a bachelor's degree in civil engineering with an environmental emphasis. As a full-circle memento, his mother gifted him a framed cut-out of the article to remember the driving force of his studies.

With the COVID-19 pandemic starting right at the project's genesis, Eric thought it would be difficult to get any instrumentation or donations. However, it turned out to be the opposite. Thanks to an army of industry subject matter experts—Powell Water Systems, Endress+Hauser, Rockwell Automation, Salt Miner, and Harrington Industrial Plastics, to name a few—Eric formed the perfect team who allowed the project to take off and flourish.

"I certainly did not do it alone," said Eric. "It took a team. A team that I am extremely proud of, especially the students that worked on it. Jessica and Tyler acted like MacGyver from the 80's action series on TV by shoestring fixes with whatever scrap material was available on site. We had a champagne research concept on a Schlitz budget, so this helped stretch our research dollars."

WRF is proud to feature Eric—a passionate engineer who built his dream team to advance the science of water. Published in April 2024, the full research project is available on BOR's website.

*Since publishing this article, Eric is no longer with Garver and has joined Kimley Horn and Associates, Inc. as the Water Energy and Practice Builder in Denver, CO. To contact Eric Dole, please find him on **LinkedIn**.*

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