To maintain and improve US water and wastewater infrastructure, the US EPA estimates that $473 billion is needed for water and $271 billion is needed for wastewater infrastructure. With this growing funding deficit, water and wastewater utilities will need to find innovative solutions to treat water to higher quality for at a lower cost per gallon. My research focuses on integrating statistical and machine learning into process monitoring, control, and optimization at water and wastewater treatment facilities—bringing value to existing assets and an improved understanding of complex physical, chemical, and biological unit processes.

***Current research***

*Fault detection and diagnosis* in water and wastewater treatment is imperative to fully treating water in a cost-effective manner. Currently, upper and lower limits on individual process variables are used to determine if a process is in- or out-of-control. However, this approach ignores the relationships between all monitored process variables and does not detect a process failure until the system has already been affected. The use of dimension reduction methods, like principal component analysis (PCA), can help detect out-of-control conditions holistically. Modification of PCA to account for the non-normal behavior of wastewater treatment processes was implemented for a 7,000 gallon per day sequencing-batch membrane bioreactor and demonstrated the ability of modified PCA to detect a variety of faults (e.g., pump failure, clogging, microbiological shifts) in biological and membrane-base systems sooner than the existing fault detection method.

*Forecasting* water quality variables for full-scale water and wastewater treatment facilities is a simple approach to improve control but is usually limited by a lack of a dynamic process model. Utilizing online monitoring data from the City of Boulder’s (Colorado) wastewater treatment facility, a simple statistical model (diurnal model combined with multiple linear regression) was shown to forecast ammonia equal to or better than a machine learning approach (recurrent neural networks). The integration of the data-driven forecasting model into the existing feedback, cascade control strategy initiates treatment prior to ammonia exceeding the feedback threshold and reduced treatment when ammonia is anticipated to be below the threshold. Ultimately, this work reduces the mechanical stress on the aeration system, reduces peak effluent ammonia concentrations, and reduces peak energy demand by proactively treating wastewater. Additionally, this solution placed 1st in the Water Environment Federation/Water Research Foundation 2019 Innovation Challenge.

*Soft-sensors* refer to the use of data and analysis methods to predict the value of an expensive or hard-to-measure variables, in lieu of a physical sensor to measure a variable directly. For the Metro Wastewater Reclamation District in Denver, CO, the conversion to a novel disinfection system led to difficulties predicting the decay of the disinfectant (peracetic acid) throughout the basin. Online water quality data from upstream treatment processes was merged with laboratory measurements to determine total disinfection and *E. coli* removal using artificial neural networks. This work assisted in demonstrating to the state regulatory agency the efficacy of treatment and establishing treatment requirements.

***Future research***

Real-time monitoring and control of water treatment systems will be imperative to meeting future water demand globally. To ensure treated water is pathogen-free, utilities need to demonstrate the removal of a variety of compounds and microorganisms. My future work will focus on identifying surrogate parameters and developing soft-sensors for these hard-to-measure variables utilizing novel and traditional sensing technology at bench and pilot scale.