BEYOND EXPECTATIONS

VOL. 1 NO. 24 PAGES 244
MARCH - APRIL 2022, Rs. 100

SMART WATER & WASTE WORLD

BE SMART WITH WATER

www.smartwww.in

FINEST

GLOBAL
CASE STUDIES

ANNUAL DIGITAL EDITION

FINEST 50 CASE STUDIES

INJECTION SYSTEMS, OZONE GENERATORS, UTILITY, WTP

ORLANDO UTILITIES COMMISSION SWITCHES TO SIDESTREAM INJECTION FOR OZONE EFFICIENCY

By Dr. Srikanth Pathapati

Since 1997, the Orlando Utilities Commission (OUC) has been ozonating well water for odor control through the removal of hydrogen sulfide, steadily upgrading its systems in step with technological improvements. In recent years, OUC has replaced older air-fed ozone generators and Fine Bubble Diffuser (FBD) ozonation systems in three of its water treatment plants with newer, oxygen-fed ozone generators Feeding Side Stream (SSI) venturi injection/pipeline contacting systems. The upgrades have resulted in significant improvements in mass transfer efficiency, reductions in operations and maintenance costs, improved turndown capabilities, and the ability to automate ozonation rates for even greater efficiency.

The Orlando Utilities Commission (OUC) is the second-largest municipal utility in the U.S. state of Florida and the 14th largest in the United States, providing electricity, water, and chilled water to more than 240,000 customers through eight water plants and a 2,736 km (1,700-mi) distribution network. The utility conducted a comparison of its old and new ozonation systems at its OUC Conway and OUC Southwest water treatment plants and presented the results to the Florida Section of the American Water Works Association in 2021, earning the conference's award for the best technical paper.

The use of ozone to disinfect drinking water dates back to 1907-1908. At nearly the same time Jersey City, New Jersey, adopted the U.S.'s first chlorine disinfection system, an ozone disinfection system was installed in Nice, France. European ratepayers objected to the odor of chlorine in their water, driving the adoption of ozone on the continent while American utilities installed chlorination instead. For most of the century, the capital and operational costs of ozone generation, coupled with occupational safety measures for operators, were high hurdles for American utilities. However, as ozone generator technology advanced in recent decades, those hurdles lowered, and an increasing number of American water treatment plants adopted ozone for its powerful oxidation, efficiency, and efficacy on taste-and-

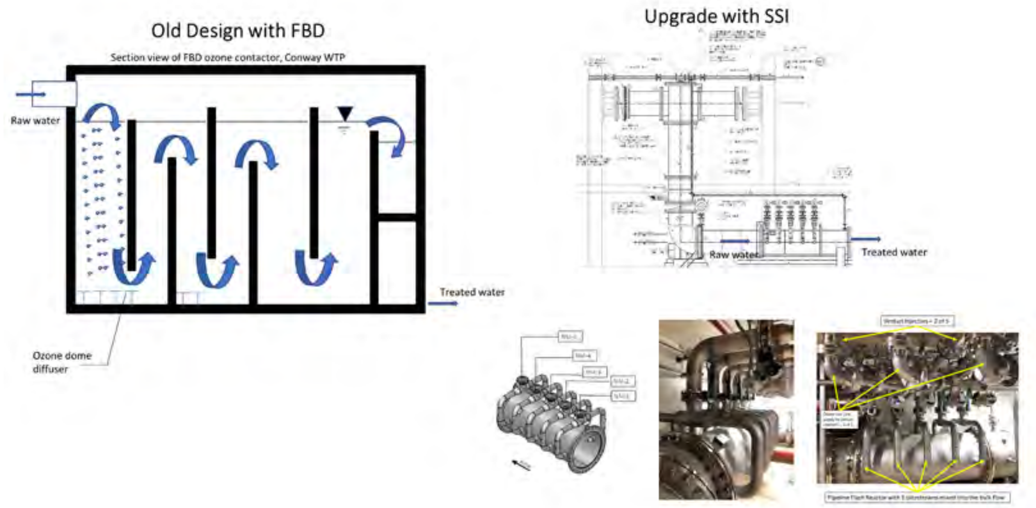
The large American municipality measured significant improvements in ozonation efficiency by replacing fine bubble diffusers with sidestream venturi pipeline injection.

Five venturi injectors ozonate a sidestream flow and mix the treated water into the main flow in a Pipeline Flash Reactor (PFR) at OUC Southwest WTP.

odor compounds, complex organics, and pathogens. Ozone is also less sensitive than chlorine to temperature and pH, making it a more robust option for oxidation and disinfection.

Advances in ozone generators have also spurred changes in mixing systems. Fine bubble diffuser systems require an optimal diffuser gas flow of just 0.12 scfm/ft^2 — higher gas flows would cause significant short-circuiting in basins. Such passive mixing technologies were common in conjunction with baffled contacting basins in the days when air-fed ozone generators could only produce low concentrations of gas. As new generations of ozone generators became capable of producing ozone concentrations as high as 10% from Liquid Oxygen (LOX), venturi sidestream injection systems became a highly efficient alternative to FBD.

Sidestream injection systems divert 3 to 10% of the total flow into a venturi injector, which uses the energy of the flowing water via the Venturi effect to create a vacuum that draws in ozone, shears the bubbles, and creates turbulence that mixes the gas into the stream. The ozonated sidestream is returned to the main flow via a Pipeline Flash Reactor (PFR). The reactor is a length of pipeline that features precisely located and angled mass transfer nozzles for thorough mixing. For high applied doses, the mixing action of the PFR is sometimes augmented by a static mixer and—in the case of the OUC systems—a Westfall 2800 wafer-style static mixer plate. In the OUC plants, just 3.7 meters (12 feet) of the pipeline—barely over 2.1 meters (7 feet) of PFR and 1.5 (5 feet) of the



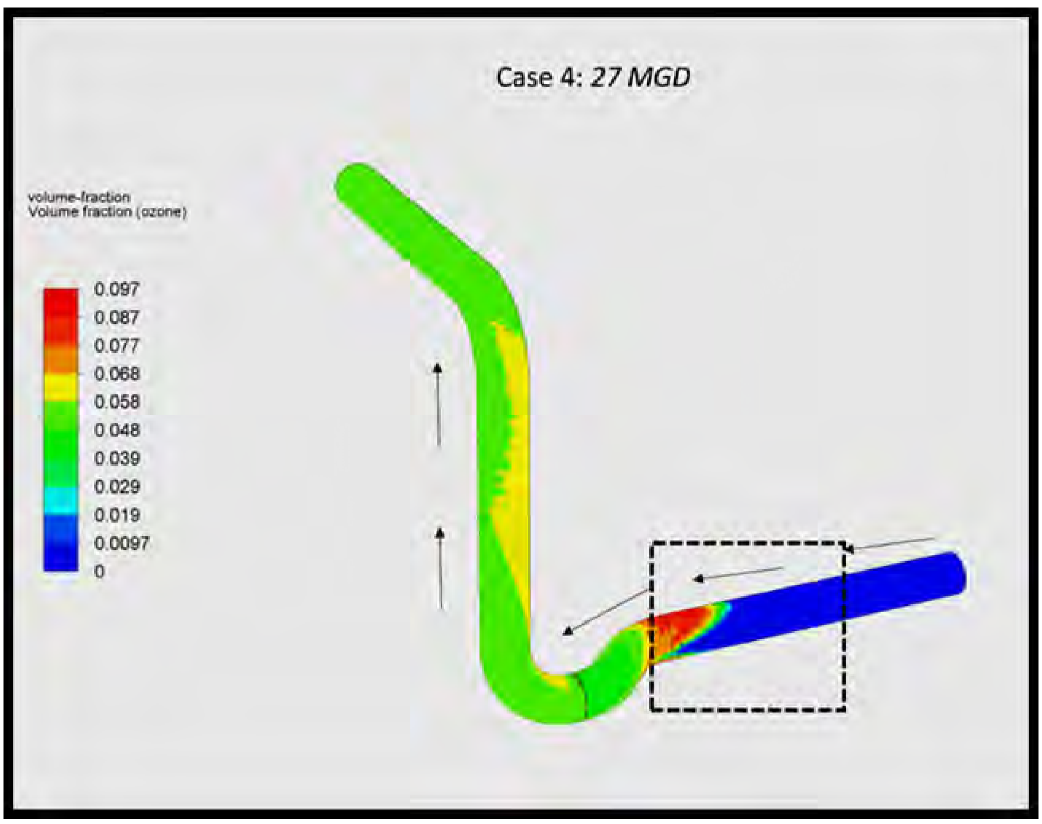
Upgrades at the OUC Conway WTP replaced fine bubble diffusers with a 5-venturi side stream injection system.

static mixer—replace a 7-meter (21-foot) deep contacting basin while achieving a significantly higher mass transfer efficiency.

In fact, SSI ozone contractors have been demonstrated to deliver velocity gradient values of three to eight times higher than FBD systems, and a coefficient of variation (COV) of 5 to 10%, compared to COV of 20 to 45% with FBD systems.

In 2020, Mazzei Injector Company executives conducted a deep dive into industry data collected by the International Ozone Association's Pan-American Group, as well as the company's application engineering files, to explore trends in ozone systems over the past several decades. They found that the OUC's path is consistent with the widespread adoption of high-efficiency ozone generators and side stream injection systems.

OUC Southwest's air-fed ozone system was upgraded with three 1,260 PPD LOX-fed generators in 2010, raising its design capacity from 30 to 40 MGD (136,383 to 181,844 cu m/d). In 2015, the plant's three-train FBD system, which contained 1,656 diffusion stones, was replaced by five small venturi injectors feeding into a single 36-inch (0.9 m) PFR and wafer static mixer plate. Existing over/under baffle basins that served as dissolution chambers for the FBD system now function as reaction chambers.



This CFD analysis illustrates nearly instant mixing at the pipeline flash reactor, followed by a wafer-style plate mixer.

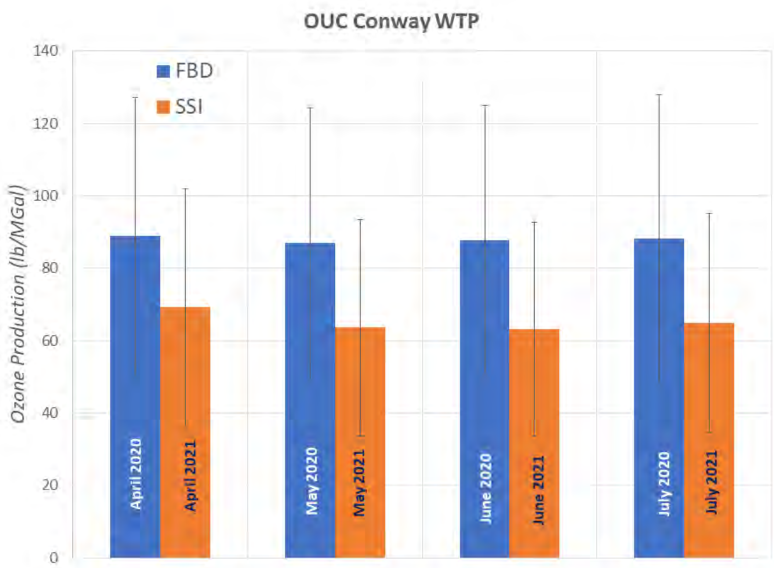
OUC Conway has a design capacity of 26.75 MGD (121,608 cu m/d). Like OUC Southwest, its air-fed ozone generators were upgraded to a LOX-fed system and its FBD dissolution system was replaced by a five-injector SSI system feeding a PFR followed by a static mixer.

The five-injector design in both facilities allows operators to optimize pump energy costs by turning on or off injectors in response to changes in flow through the plant while applying a consistent dose of 12.0 mg/l ozone to maintain target concentrations of 10% by weight.

Among the benefits of SSI is the near-plug-flow behavior of the system. Mazzei Injector Company used ANSYS Fluent (v. 19.2) Computational Fluid Dynamics (CFD) software for multiphase, turbulent flow to model the OUC upgrades. Design engineers at CDM Smith, who developed both the FBD system and the SSI system that replaced it, also conducted a conceptual design of five years of data for all seven OUC plants, followed by an analysis of an additional year of data to confirm the five-year study. CFD modeling determined >95% uniformity and coefficient of variation (COV) of <5% at the ozone sampling locations.

Modeling results were supported by performance testing of the SSI system at OUC Southwest, which measured ozone concentrations of 11.9 to 12.3% wt., a COV of 5 to 7%, and average mass transfer efficiency of 98.7%. By contrast, the COV of dissolved ozone in the plant's FBD system (detailed in a 2000 paper by Schulz and Bellamy in Ozone: science and engineering) was 21 to 25%. Similarly, a performance test using two analyzers downstream of the PFR and static mixer at OUC Conway recorded weighted mass transfer efficiency of 96.9% and 97.2%.

The ability to sample immediately downstream of the PFR/mixer for almost



Comparison of monthly ozone production per million gallons of treated water for OUC Conway WTP, before and after upgrade to SSI from FBD.

instantaneous readings of ozone residual levels, coupled with high transfer efficiency and thorough mixing, make SSI well-suited for monitoring ozone residual levels through Oxidative Reduction Potential (ORP) sensors. In turn, those sensors can be wired into SCADA/PLC systems to control ozone dosing. By contrast, the sampling port in FBD systems is located well downstream in the contact basin, so instrument readings reflect a 20-to-30-minute delay after changes in dosage, as well as slow-downs in response time during low flows.

In those conditions, the use of ORP sensors for controlling dose is not viable. In fact, OUC operators had given up on ORP monitoring of their FBD systems because incomplete mixing resulted in unstable readings.

Greater efficiency in SSI systems also contributes to reduced energy usage, less material waste, and lower operation cost. The lower COV in the SSI system is easily explained by the extraordinary mixing energy in the PFR/static mixer system—4,800 to 5,300 sec-1 vs. 232 sec-1 for the FBD system.

The total reactor volume and longer contact time required for the passive FBD dissolution system limit the amount of transfer that can occur. Higher doses and a need to compensate for a longer lag time in identifying demand result in significantly larger capital costs.

To enable process control of hydrogen sulfide oxidation and hedge against periodic low residual levels, OUC operators overdosed their FBD systems. A comparison by CDM Smith of five years of FBD system data with 2018 SSI data revealed a 28.23% reduction in ozone dosage in the side stream system, a result of its greater mass transfer efficiency. Comparing daily LOX consumption between an FBD system in May 2020 and an SSI system in May 2021 showed a reduction of 28.30% in LOX (measured as scfm/mg). An OUC comparison between an FBD system in 2020 and an SSI system in 2021 treating water from the same two wells at the OUC Conway WTP measured a 30.1% reduction in ozone production for the SSI treatment.

Operations and maintenance costs are dramatically reduced by upgrading from FBD to SSI. FBD systems require regular shutdown and confined space entry for gasket replacement and diffuser maintenance, as well as labor-intensive, manual checks of each diffuser. A cost analysis for a 14 MGD (63,645 cu m/d) water treatment plant in Kitchener, Ontario, Canada revealed an annual difference of 7 downtime days for FBD maintenance vs. 2 days of downtime to maintain the SSI system, and an O&M cost difference of $13,300 per year for fine bubble diffusers vs. $7,600 per year for the sidestream injector system. Over the 25-year lifetime of the system, the difference was stark—175 down days and $332,500 in costs for the FBD system vs. 50 maintenance days and $190,000 for SSI. A similarly detailed analysis is underway for the OUC plants.

Modernizing its ozone generators and upgrading mixing systems from fine bubble diffusers to side stream injection/PFR resulted in demonstrable savings for the Orlando Utilities Commission in energy, maintenance, and downtime. The switch permitted the utility to reinstate ORP monitoring and use the results to automatically manage ozone dosage control, reducing ozone demand by nearly one-third. Treatment efficacy, system efficiency, and cost savings make a compelling case for the benefits of side stream injection in ozone systems for water treatment plants.

About the Author

__Dr. Srikanth Pathapati__ is Director of R&D at __Mazzei Injector Company__ and has 15

years of experience in physical testing, design optimization, and multiphase CFD modeling. The American Society of Civil Engineers (ASCE) recognized Sri for his work in computational fluid dynamics with the 2013 Rudolph Hering Medal for "the most valuable contribution to the field of environmental engineering.", as well as the 2020 ASCE State-of-the-Art of Civil Engineering award for his contributions to the ASCE-EWRI Primer on Computational Fluid Dynamics. He received his Doctorate in Environmental Engineering from the University of Florida, and his Bachelor of Engineering in Electrical Engineering from the University of Madras, India.