WATER ONLINE

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Disruptive Technology Makes Ozone A Better Treatment Option

Source: Mazzei Injector Company, LLC

Sidestream injection (SSI) systems are shaking up the water treatment industry, unseating industry-standard fine bubble diffusion (FBD) systems by delivering fast, high-efficiency ozone transfer with a small footprint. In fact, the high speed of ozone mixing and transfer is so fast in sidestream injection systems — just seconds rather than minutes — that bromate formation is minimized, allaying a long-time misconception about ozone injection.

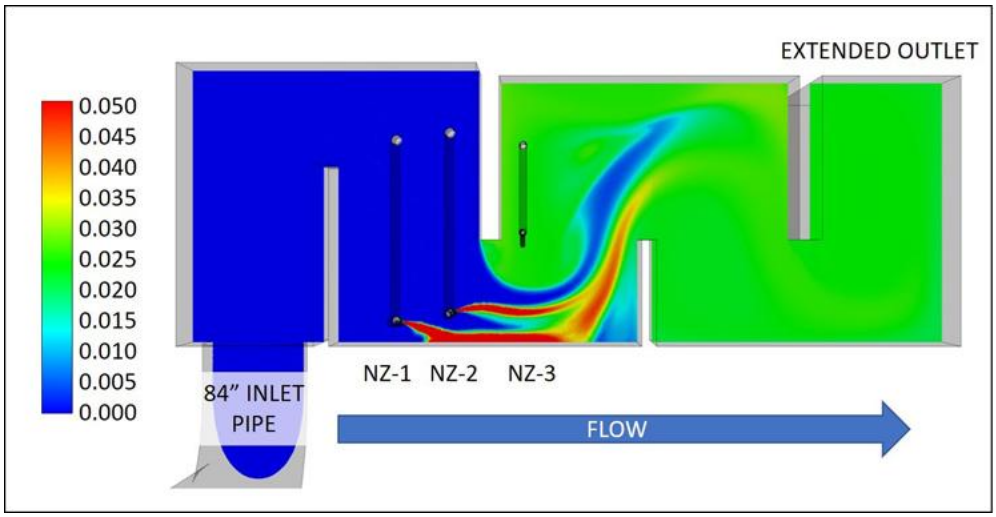
The simplicity, efficiency and ease of maintenance of sidestream injection systems is also building a strong following for the newer approach, particularly among public works officials eager to minimize operations and maintenance costs and reduce the need for employees to work in confined spaces.

In short, sidestream injection is proving itself a truly disruptive technology, making ozone a significantly better choice than ever in a wide range of disinfection, T&O (taste and odor) and water reuse applications.

Technologies Compared

Fine bubble diffuser systems pump relatively low concentrations of ozone at low-pressure, using the hydrostatic pressure of tall columns or deep basins — at least 18 feet — to ensure adequate transfer of ozone into solution. Contact time of 120 seconds is typical for disinfection with FBD systems.

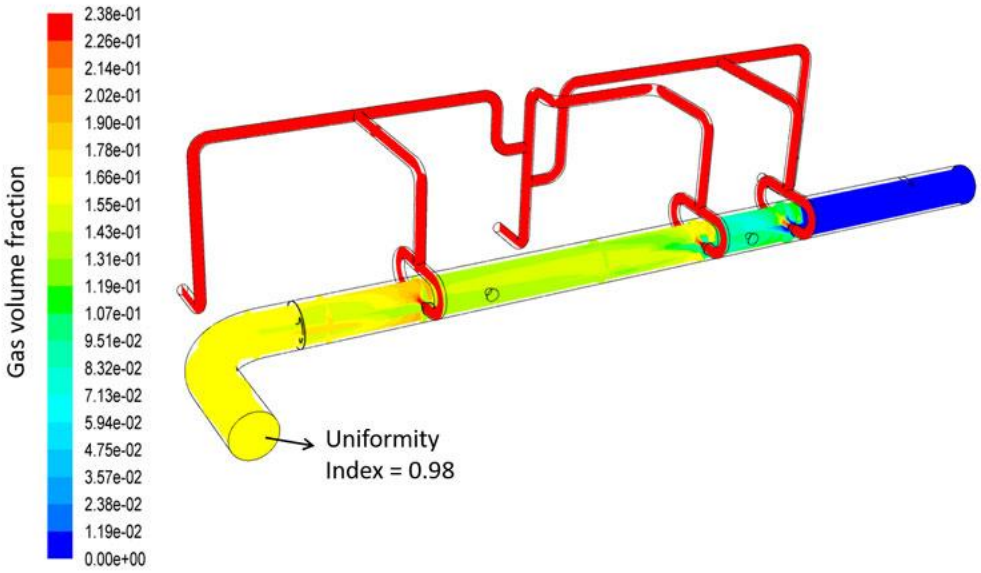
By contrast, sidestream injection can achieve transfer in as little as 3.7 seconds. Sidestream injection is accomplished through venturi injectors, which draw ozone into the water using a high pressure differential created by the sidestream flowing through a converging section into a diverging section. In addition to injecting ozone, the shear and turbulence created in a finely engineered venturi performs a significant amount of instantaneous mixing. In fact, a 2016 study by the Water Research Foundation noted that at lower gas to liquid ratios (less than 0.10), the majority of the ozone mass transfer in an SSI system actually occurs at the injector.



Ozone transfer from fine bubble diffusers requires large basins and longer contact time, and delivers moderate gas transfer and a uniformity index of about 95%.

From the injectors, the ozonated sidestream is reintroduced into the main flow through mixing nozzles in a basin or through an in-line Pipeline Flash Reactor (PFR). By directing the ozone-rich sidestream water through mixing nozzles that are sized, located, spaced and angled through the use of computational fluid dynamics (CFD) modeling, PFRs can deliver 95-percent or greater transfer in a matter of just a few feet downstream of the equipment. In fact, one water utility manager in Canada calculated that retrofitting a plant with an SSI system rather than an FBD basin expanded treatment capacity by 20 to 30 percent.

Mazzei Injector Company recently challenged its in-house CFD team — led by Dr. Sri Pathapati, who helped write the recently published ASCE book on applying CFD to design water and wastewater treatment systems — to redefine PFR technology to maintain the high ozone transfer efficiency but allow plants greater flow turndown capacity and more aggressive doses of ozone. The result of the team's work, the Mazzei PFR+, is a finely engineered flash reactor that incorporates carefully oriented mixing nozzles, specially placed flow conditioning vanes and a post-injection grid to maximize turbulence, mixing and transfer in a minimal footprint.



This computational fluid dynamics (CFD) model illustrates the highly efficient mixing and outstanding uniformity in a 3-foot-long, 30-inch-diameter Pipeline Flash Reactor.

Less Maintenance

From an expense perspective, one of the significant differences between fine bubble diffusers and sidestream injection systems is maintenance. Gaskets and seals in fine bubble diffusers are prone to breaks and blowouts. Membranes and diffusers can get fouled. Leaks and coarse bubbles from damaged or broken stones reduce transfer efficiency and total water contacting. Performing bubble pattern tests and inspecting the systems for damage requires shutdown and drainage of basins or contactors. FBD maintenance also often demands that operators work in confined spaces. One facility manager joked that the utility should issue each worker a bottle of pain reliever on FBD maintenance days to address the aches caused by hours of stooping and bending to inspect diffusion stones in a drained basin.

By contrast, venturi injectors and Pipeline Flash Reactors are easy to access and inspect while in operation, and any needed replacement is typically quick and convenient. There are no moving parts, no gaskets or membranes to replace, and minimal risk of fouling or calcification.

Creating sidestream flow requires a pump, which is easily accessible and straightforward to maintain or repair. Energy for the pumping system increases electricity costs on the SSI side of the equation, but plant managers familiar with both systems note that the added maintenance costs for FBD inspections and gasket/seal/diffuser repair quickly more than make up the difference.

A 2017 analysis by the American Water Works Association estimated that sidestream injection systems required 5 fewer days of facility downtime per year than fine bubble diffusers (2 days vs. 7) and 42 percent less annual operations and maintenance expenditure. Over the course of the projected 25-year life of a system, the differences alone added up to 125 fewer days of downtime and $142,000 less O&M cost for the SSI.

SSI systems have an added advantage for retrofits, where they can be designed and installed based on the existing flow patterns of the contactors without highly invasive construction.

A Pipeline Flash Reactor (PFR) delivers highly effective mixing in just a few feet of pipe, and can be designed to fit nearly any footprint or scale.

Dealing With Turndown

Every water treatment plant operator knows that there's rated system capacity and there's reality — turndown is a challenge in any real-world system as demands and performance targets fluctuate on a seasonal and even daily level.

Turndown is a major challenge for fine bubble diffuser systems. Since column or basin depth is crucial for maintaining hydrostatic pressure to ensure dissolution, reducing flow through the system requires operators to close contactors to maintain depth in those that are operating. That requires a close eye on flow and a significant amount of management. FBD technology depends heavily on gas holdup time, which is difficult to closely monitor as plant flow rates change.

SSI systems with PFRs offer an extra dimension of control because as mainline flow rate or ozone demand changes, dissolved ozone levels can be measured within moments just downstream of the flash reactor. As a result, ozone input can be adjusted almost instantaneously to ensure proper dosage. In a reaction basin, there is more hysteresis — it takes some time for the treated water to reach equilibrium after changes are made, and more time to see the result of the adjustments.

Sidestream injection systems can easily be retrofitted into existing contact basins. As this animation illustrates, precise placement and orientation of fouling-resistant nozzles delivers thorough mixing and contact without the need for diffusers.

SSI systems are more flexible when it comes to gas flow. When an ozone generator is being upgraded to increase ozone concentration, fine bubble diffusers can struggle to achieve adequate mixing with the smaller volume of gas needed to achieve the target concentration. Venturi injectors and mixing nozzles are effective at a much wider range of gas volumes.

The physics and chemistry illustrate the challenge. With an SSI system, flow can vary significantly with minimal impact on contact time. As long as water pressure in the system is maintained to optimize ozone transfer efficiency, flow is rarely an issue. However, dropping below rated volumes can be a serious problem in FBD systems.

Bromate Formation

Increased contact time is more than just a matter of efficiency — it's directly connected to the formation of bromate, a disinfection byproduct that is of major concern in many areas where feed water is high in bromine.

Time is a critical factor in the formation of bromate — given the same pH, temperature and other conditions, the longer bromine is in contact with ozone, the more bromate is produced. In fact, the curve describing bromate formation vs. time is a smooth, sweeping arc.

Many utilities with FBD plants also employ chemical treatment to control the formation of bromate, including ammonia, a chlorine-ammonia process, pH adjustments, or granulated activated carbon (GAC). However, there is no need to pre-treat the water in the SSI system. That represents significant savings in inputs and labor, and reduces the amount of chemical that must be stored and handled during a shift.

In the 2016 Water Research Foundation study comparing SSI and FBD systems in the same municipality, the SSI plant provided faster ozone contact and less bromate formation under similar ozone dose conditions. During two significant turndown trials — reducing flow from 25 gpm design capacity to 10 and 6 gpm — the FBD facilities produced 5.6 and 9.1 µg/L of bromate, respectively. As the authors noted, that increase in contact time "can be significant if bromate formation is a concern."

By contrast, the SSI system contributed less than 2.0 µg/L of bromate to the main flow under all conditions in the trial.

Disruptive Technology

In short, sidestream injection systems — with their efficiency, versatility, low maintenance demands and low bromate formation — are a disruptive technology that has made ozone a better choice than ever for drinking water and water reuse plants. Two decades ago, fine bubble diffusers may have put ozone into the spotlight. Today, sidestream injection systems are injecting ozone into the mainstream of the water treatment community.