Ozone Dose

By Paul Overbeck

Achieving accurate sizing for applications with consistent or variable source water

Do you feel sizing an ozonation system is easy? While sizing and ozone generator selection is easy for many applications that have a consistent source water, it is not a simple process for all source waters or treatment objectives.

Consistent Source Water Sizing

Consistent feedwaters are typically from groundwater not under the influence of surface water and from water sources that employ significant pretreatment processes. These water sources will have level ozone demands and are sized by flow using the flowing ozone generator sizing equation:

Ozone generator output in pounds per day (ppd) = water flow (gal per minute) x applied ozone dose in mg/L x 0.012

Where 0.012 = 8.3453 lb/gal H_2O x 1,440 minutes/day x 1 mg/L

Note 1: 18.39 gal per hour (gph) = 1 ppd

In bottled water, the treatment objective is disinfection and taste and odor control. This can be met with a 0.1 to 0.2 ozone residual entering the bottle after 2 to 4 minutes detention time.

Bottled Water Examples

A bottled water plant designed to bottle 20,000 gal per day (gpd) purified water from reverse osmosis (RO) treatment operating eight hours per day, assuming a 1.0 mg/L ozone dose, would require a 0.5 parts per billion (ppb) (9 gph) ozone generator.

A bottled water plant designed to bottle 20,000 gpd natural spring water operating eight hours per day, assuming a 1.6 mg/L ozone dose, would require a 0.8 ppb (15 gph) ozone generator.

Most ozone generator manufacturers offer standard systems rated at 10, 20 or 30 gph. Therefore, in this and all cases, the generator size decision is dependent on the source water. You will need a 10-gph unit on RO permeate or a 20-gph unit on spring water. If a bottled water business offers both purified and spring water to its customers and operates two consecutive eight-hour shifts, it needs to purchase at least a 15-gph ozone generator. If it wants to operate both bottling lines over the eight-hour period, a 30-gph system would allow for up to 25% expansion.

Water Quality and Ozone Demand

The suggested 1 mg/L dose on RO permeate and 1.6 mg/L dose for spring water in these examples is based on the premise that there is more ozone demand in spring or groundwater than in RO permeate that has already removed the majority of dissolved ionic and organic material with which ozone may react. In the real world you would use the source water analysis to help you estimate the ozone demand based on measured oxidizable substances including iron, manganese, sulfide ion/H_2S, total organic carbon (TOC) and microorganism load in the treated or untreated source water.

There are generally accepted ozone reaction doses for these materials that an ozone generator supplier can assist with.

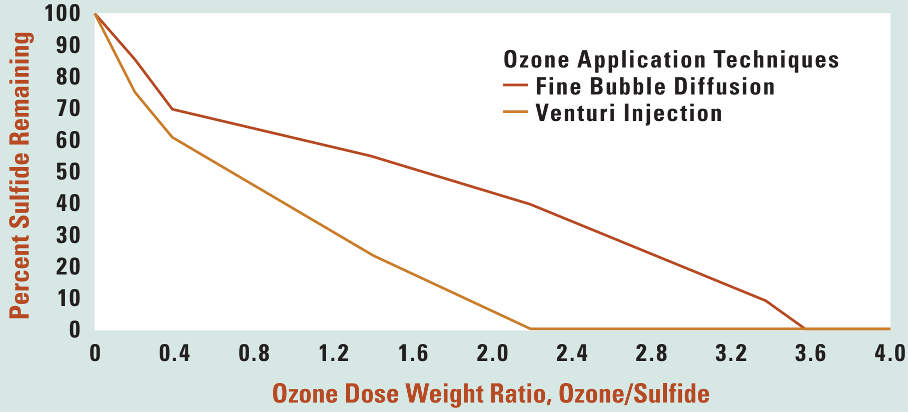
A good example is sulfide ion/H_2S. The Stoichiometric dose is 4 mg/L ozone for 1 mg/L sulfide ion with the overall reaction:

$$S^{2-} + 4O_3 \rightarrow SO_4^{2-} + 4O_2$$

In the real world, the oxygen in the gas stream will participate in the ozone oxidation process, requiring less ozone than the chemical reaction predicts. The actual amount of ozone needed from

Sizing

Figure 1: Sulfide Removal Versus Ozone Dose Ratio
Oxygen-Fed Ozone Generator



air-fed and enriched oxygen sources (cylinder or PSA onsite O_2 concentrator) can be seriously impacted by the gas-to-liquid mass transfer system. Oxygen-fed ozone generators are currently the most common system designs for low capital and operating costs.

Figure 1 shows pilot study data for the Orlando (Fla.) Utility Commission (OUC) water treatment facilities comparing ozone dose requirements using fine bubble diffusion and inline venture injection.

The rapid mass transfer of both oxygen and ozone at the high-energy mixing zone within the injector showed significant benefits, resulting in smaller ozone generators to treat the groundwater. The OUC and Toho Water Authority in neighboring Kissimmee, Fla., have added ozone to all their treatment facilities. A greater than 50% difference (2.2 versus 3.6 mg/L O_3) in oxygen-ozone requirements can mean several hundred thousand dollars in capital equipment, not to mention operating costs on a 20-million-gal-per-day municipal drinking water system.

Variable Source Water Sizing

Surface water, groundwater under the influence of surface water, industrially contaminated groundwater and both industrial and municipal wastewater will show high seasonal or operational variability in monitored quality parameters and ozone demand.

Spring snow melt, summer downpours, algae blooms and autumnal turnover deliver larger organic load variations to drinking water treatment plants and ultimately to commercial-industrial customers. Municipal treatment plants with flocculation/sedimentation/filtration systems may have operational upsets during difficult seasonal conditions. They can deliver safe drinking water meeting all governmental standards but the ozone demand from elevated TOC levels can use up all the ozone in the bottled water ozone system sized with no safety factor, resulting in low or no residual going into the bottle.

In recent years we have been hearing more and more about endocrine disrupting compounds (EDCs), personal pharmaceutical care products (PPCPs) and other emerging contaminants of concern. These are natural or synthetic chemicals or pharmaceuticals making their way into our source waters. They make their way at low levels through industrial discharge and municipal wastewater treatment processes. Because analytical systems can measure at lower and lower levels, the public hears larger and more disturbing numbers. It sounds much more significant when a reporter says that a particular chemical was measured at 800 parts per trillion rather than 0.8 ppb, even when the regulated drinking water standard is 3 ppb.

One of the standards set by the U.S. Environmental Protection Agency (EPA) is for the presence of a substance in drinking water, called a maximum contamination level (MCL). EPA has set an MCL for atrazine of 3 ppb. In agricultural areas, atrazine can exceed this level, requiring specialized treatment. In these cases, a system is sized to meet the variable demand plus additional ozone for reaction with the specific contaminant. Bench studies can be made to determine reaction rates and dose response to achieve treatment objectives. The photo shows color change during a bench study on atrazine reduction.

The analytical results in Figure 2 show ozone-based advanced oxidation processes (O_3 AOP).

The bench scale test data justified a pilot study that determined dose requirements for variable conditions of the particular source water.

Research has shown that ozone and ozone AOP (O_3/H_2O_2) are also effective at reducing an alphabet soup of EDCs and other organic contaminants whether currently regulated or unregulated. Water Research Foundation-funded studies by the International Ozone Assn. (IOA) member Dr. Shane Snyder, then with Southern Nevada Water Authority, identified significant benefits reducing estrogenicity of municipally treated effluent by approximately 60% at a typical wastewater ozone disinfection dose of 5 to 8 mg/L. We will continue to hear about the level of EDCs and PPCPs as health effects are determined. Then specific regulation will occur. *wqp*

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