Ozone 101

An article for the Texas Water Quality Association Quarterly
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In July of this year, I was honored by the Texas Water Quality Association with an invitation to speak at the annual meeting in Galveston. Working as a sales engineer for a manufacturer of ozone generators, I hear my share of tall tales concerning both the capabilities and limitations of ozone in water treatment. Consequently, the opportunity to set the record straight was most welcomed. In the following paragraphs, I have summarized the key points of my TWQA presentation.

The topics of my discussion included "How Ozone is Generated", "UV vs. CD Ozone Generation", "The Health Effects of Ozone", "The Benefits and Applications of Ozone Use", "Mass Transfer Basics", "Sizing Basics", "Aeration vs. Venturi Diffusion Methods" and "Installation Materials". To do justice to all this in-depth information, I have developed another seminar, which I look forward to presenting to you in the future.

As most of us are now aware, ozone is generated most commonly in one of two ways - by exposing an air stream to either ultraviolet light or to a high voltage electrical discharge. Oxygen molecules (O_2) are split into individual oxygen atoms (O_1). In this state, oxygen is very unstable so it joins with other oxygen molecules to form O_3, which is ozone.

Speaking first about ozone generation with ultraviolet light, ozone is produced when air (usually ambient) is passed over an ultraviolet lamp, which splits oxygen molecules in the air stream. Light is measured on a scale called an electromagnetic spectrum and its increments are referred to as nanometers. Ultraviolet ozone generators use a mostly 185 nanometer lamp because that wavelength happens to be the most efficient for producing ozone. However, the ozone produced by this "photo dissociation" of oxygen molecules is comparatively weak because the concentration of ozone available in the output gas is very low - commonly in the range of .01 - .1% by weight. At the same time, ultraviolet ozone generators do not require the feed gas air preparation that the other ozone equipment technology needs.

Ozone is also produced with a high voltage electrical discharge. Called "corona discharge" or "CD", it is the method most commonly used to generate usable amounts of ozone for most water treatment applications. The idea is to actually create a small, controlled lightning storm, which involves producing a constant, controlled spark (corona) across an air gap through which a prepared feed gas is passed. This feed gas may be air that has simply had most of its moisture removed or air with enhanced oxygen levels. The key to an efficient, reliable CD ozone generator is making sure that the feed gas is dried to a dew point of at least -60° F. This is important because as the electrical discharge splits the oxygen molecules, nitrogen molecules are also being split, forming several species of nitrogen oxides. They are normally benign, but if combined with moisture (ordinary humidity), these oxides form a very corrosive substance called nitric acid. Consequently, proper air preparation is critical, as is choosing a generator utilizing high quality materials in the construction of the reaction chamber and associated cabinetry.

The relative strength of corona discharge ozone expressed as a percentage of concentration by weight is commonly 0.5 - 1.7% for systems using dried air and 1.0 - 6.0% when an oxygen-enhanced feed gas is used. There are ozone generators available that will generate up to 20% concentration, but they are used in very high tech applications far outside the realm of normal water treatment.

A much simpler topic to understand is the health and safety of ozone gas. A properly installed and operated ozone system poses no health hazards. While ozone is a toxic gas and the established concentration limits must be adhered to, the odor threshold of .01 ppm is far below the safety limit of a .1 ppm exposure over an eight hour period. The first symptoms of excessive ozone exposure are headaches, eye, nose or throat irritation or a shortness of breath. These symptoms can be relieved by the simple application of fresh air. While no deaths have been reported from ozone, sound safety practices deserve attention. Again, the key to safety is remembering that the presence of ozone can be detected at very low levels - far below the safety threshold. The other good news is that ozone off-gas containment and destruction equipment for most water treatment applications is readily available and is usually a simple device containing either activated carbon or manganese dioxide.

Now that we've briefly discussed how ozone is generated and its health and safety aspects, let's outline the benefits and applications of ozone. Because ozone gas is so unstable (a property that gives ozone it's extraordinary oxidizing capabilities), it cannot be packaged or stored and must be generated on site. In most common water treatment applications, this means a simple wall-hung ozone generator combined with a compact air preparation unit and a venturi injector to safely get the ozone into the water. This means no drums to store, record, report or dispose of.

Also, ozone is a much more powerful oxidizer than chlorine. Based on EPA charts of surface water CT values (disinfectant residual and time constant), chlorine CT values are nearly 100 times greater than ozone, meaning that ozone acts much more quickly than chlorine. Ozone creates none of the trihalomethanes commonly associated with chlorine compounds and properly matched to the application, ozone will reduce most organic compounds to carbon dioxide, water and a little heat. Finally, as ozone sheds the atom of oxygen causing it's molecular instability during the oxidation process, it becomes oxygen again.

Looking at the benefits of ozone, it becomes clear where ozone can be used effectively. Bottled water, perishable goods (seafood, fruit, vegetables, etc.) and well water disinfection are examples of ideal ozone applications. The fact that ozone efficiently oxidizes the organics that cause taste, odor and color problems without leaving a high residual helps to simplify many water treatment trains. Ozone's ability to kill algae (planktons) with low doses makes it a popular treatment method for ponds and water features. The lack of residual also makes ozone perfect for pre- and post- treatment processes in wash-pad recycle systems where use of a chlorine compound would contribute to pH control or off gas problems. Additionally, ozone oxidizes and precipitates many metals and destroys some pesticides without leaving a trace. Finally, ozone functions as a preoxidizer of iron, manganese and sulfide compounds, allowing for their removal by simple direct filtration. Ozone acts quickly and easily, and the water quality resulting from its use is unmatched.

The next topic, "Mass Transfer", describes how ozone gas is dissolved in water. A science in itself, it is worthy of a separate presentation. In light of this, I will be brief by dividing the subject into four key points; each will apply to both venturi and bubble diffusion methods of mass transfer.

The first objective of any diffusion method is to create the smallest bubbles possible. The amount of ozone diffused into water depends on the surface area of the gas/water interaction. The smaller the bubble, the better the mass transfer because one cubic inch of tiny bubbles has much more surface area than a single, one cubic inch bubble.

The next point is the amount of pressure placed upon the bubbles and the surrounding water. Very simply stated, the higher the pressure the more a "squeeze" is put on the transfer, enhancing the process.

The third consideration is water temperature. Ozone loves cold water, so the higher the temperature the longer the contact time and residual required. Remember - it is difficult for water to absorb a gas when the water is trying to become a gas!

Last but certainly not least is the concentration of the ozone gas itself. Higher concentrations of ozone in the carrier gas will result in higher concentrations of ozone being absorbed. This the main reason for the success of corona discharge ozone generation equipment over ultraviolet types in water treatment applications.

A final topic for this publication is "Sizing Basics". The real issue here is that ozone is a chemical treatment just like other oxidizers, including chlorine, potassium permanganate, hydrogen peroxide, etc. Its extraordinary speed and power sets ozone apart from the other oxidizers, but there are rules to be followed in its application. Stoichiometric (chemical value) calculation charts and formulas are readily available for all common inorganic contaminants including but not limited to, iron, manganese, sulfide compounds. Simple formulas for flow and contaminant loading make ozone generator sizing easy. With contact times in the 2-6 minute range for common contaminants instead of the 20-30 minute times associated with chlorination, ozone systems are simpler, more compact and efficient than traditional treatments.

In summary, I hope I have been able to shed some light on what has become one of the fastest growing water treatment techniques available. As more industry professionals learn of the power, range and simplicity of ozone-based water treatment systems, they will be used in increasing numbers to resolve a variety of water treatment challenges. Thanks for your time and I look forward to providing you more specific information on ozone technology.

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