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Today's Ozone Applications

Disinfection Safety via Water Analysis

Ozone in Small Systems

ACE 07 Toronto: A Huge Success

Ozone in Small Mutual Water Systems

Figure 4. Ozone disinfection is very scalable—two ozone generation systems can produce up to 400 grams of ozone per hour and service up to 1,600 homes

Figure 3. This integrated ozone contacting system was utilized for the small mutual water system described in the case study

By Bob Smith-McCollum

Mutual water systems have been part of the American landscape for more than a century. By definition, mutual water companies (MWCs) are organized by or for water users in a given district to secure an ample water supply at reasonable rates. The first MWCs were formed by farmers and ranchers to provide sufficient water for their crops and livestock. As early as the late 1800s, MWCs were formed to provide potable water for growing communities outside of larger cities.

Today, MWCs are often formed to provide potable water to small groups of homes in semi-rural or rural areas. Membership in MWCs is typically limited to landowners situated within defined boundaries. The membership transfers with the sale of the property to the new owner. Monthly and special assessments are levied to provide, maintain or improve the water services.

Critical challenges

Developers face several challenges in sourcing water for new homes and communities. Many are not able to tap into the existing municipal water supply from neighboring cities due to the high cost of laying pipe to reach the nearest city water source. Furthermore, good surface water sources are becoming scarce. Most easy-to-access water sources have been secured and are legally controlled by large cities.

A variety of alternative water sources are available:

- Drilling wells into the local water table
- Capturing rain and snow in small, local reservoirs or cisterns
- Desalination of sea water in coastal and island locations
- Reusing treated waste water
- Condensing water from the air in humid environments

These alternative water sources present important challenges for purification and disinfection. High levels of metals, salts and total dissolved solids may yield unpalatable taste and odor. Waterborne salts and metals may also clog plumbing and stain fixtures. Alternative water sources may be at higher risk for contamination from bacteria, cysts and viruses. To complicate matters, quality standards for small communities are under increasing regulatory pressure to meet the same standards as big cities.

Ozone solutions

The use of ozone in municipal water systems is well documented. In fact, the first commercial application of ozone occurred in a water treatment plant in Nice, France in 1906. In the United States, ozone was presented at the 1939 New York World's Fair as the future of water treatment. Ozone was first used to disinfect drinking water in the US in Whiting, Indiana in 1940.[1]

Ozone is a naturally occurring compound in which three atoms of oxygen are combined to form the ozone molecule (O_3). Elemental oxygen most commonly exists as two oxygen atoms (O_2). Ozone is formed when energy from ultraviolet (UV) light or electrical discharge break the O_2 bonds, forming single oxygen atoms which recombine with O_2 molecules to form ozone. Ozone is produced naturally during lightning storms and in the formation of the ozone layer in earth's upper atmosphere. Ozone is generated commercially by electrical (corona) discharge or UV ozone generators.

Ozone is an unstable molecule owing to the weak bonds holding the third oxygen atom. This instability makes ozone a naturally powerful oxidizing and disinfecting agent, with twice the oxidative potential of chlorine.[1] Oxidation occurs when ozone molecules come in contact with oxidizable substances, including microorganisms (viruses, molds, and bacteria), as well as organic and inorganic (metal ions, plastics and rubbers) compounds. In these reactions, the unstable third oxygen atom is transferred, with a release of energy, from ozone to the molecule being oxidized.

Why ozone?

Ozone is an ideal component in a comprehensive water purification strategy. The low activation energy of ozone causes it to be very reactive with a broad range of compounds and organisms. Ozone treatment results in little or no residual compounds and eliminates adverse taste and odor. Further, ozone is a proven technology and the application of ozone to water treatment is well understood and documented.

Disinfection: The transfer of energy in oxidation causes the outer membranes of microorganisms to rupture. As ozone molecules enter lysed microorganisms, genetic material (DNA and RNA) is oxidized and destroyed. As a result, a broad range of source water can be easily disinfected with ozone to meet local health code standards.

Oxidation of metals: As shown in the chemical formulae below, ozone-mediated oxidation hydrolyzes inorganic molecules, causing them to become insoluble. This precipitation of inorganic molecules facilitates removal by filtration.

$Fe^{+2} + O_3 \rightarrow Fe(OH)_3$

$H_2S + O_3 \rightarrow H_2O + S$ (s)

$MnO_2 + O_3 \rightarrow MnO_4^{+2} \rightarrow MnO_4 + K \rightarrow K_2MnO_4$ (s)

Elimination of organics: Organic molecules vary in their reactions with ozone. Most organic molecules partially or completely disintegrate as a result of oxidation, destroying their biological activity. Partial oxidation of organic molecules also promotes aggregation and precipitation (microflocculation) as well biodegradability.[1]

Improved aesthetics

The precipitation of unwanted metals, salts and organics by ozone oxidation eliminates unwanted tastes and odors.

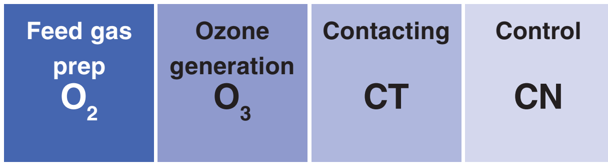
Enhanced filtration

Treatment of water and waste water with ozone aggregates inorganic and organic compounds through a process called microflocculation.[1] The net result is increased clarity and filtration effectiveness.

Interaction with bromide

Care must be exercised when the source water contains bromide ion. Bromide can be oxidized by chlorine-based oxidants as well as ozone to yield bromate ion (BrO_3^-). Studies in mice and rats conclude that bromate can cause thyroid and kidney cancers at very low levels.[1] The oxidation of bromide to bromate with ozone is accelerated by increased concentration of ozone and length of contacting time.

Figure 1. The four components of integrated ozone contacting systems



Ozone water treatment methods

A typical ozone-based water treatment scheme for small mutual water systems includes the following steps:

Pre-treatment and coarse filtration: depending of the characteristics of the input water, a variety of methods are used to remove large particles and materials, such as mechanical separation and mixed-bed sand filtration.

Pre-ozonation and flocculation: brief exposure to ozone promotes aggregation, precipitation and microflocculation of metals and organic compounds. Pre-ozonation increases water clarity and the effectiveness of subsequent filtration.

Filtration: removes aggregated/flocculated materials.

Oxidation and disinfection: a second exposure to ozone ensures complete disinfection of the treated water.

Residual disinfection/protection: chlorine-based or similar water treatment compounds must be added at the end of the process to provide residual protection of the output water from the treatment station through the distribution system to the tap.

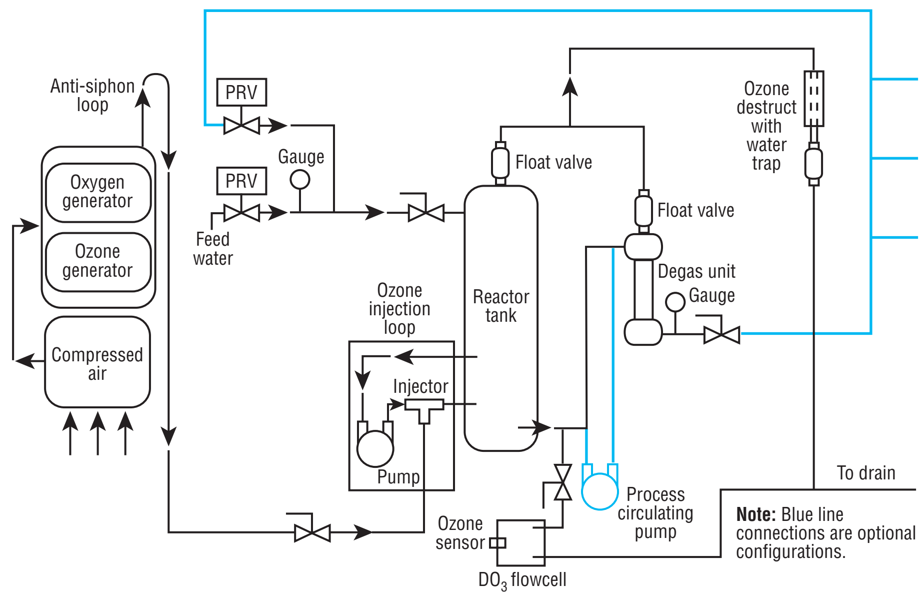
Integrated ozone contacting systems: all integrated ozone contacting systems include four components: feed gas preparation, ozone generation, ozone contacting and control—as shown in block diagram form in Figure 1.

Feed gas preparation: for demanding applications, such as water treatment, ozone is generated from concentrated oxygen (>90 percent O_2) to yield higher concentrations of ozone. Clean dry air is supplied from an air compressor to an oxygen concentrator which strips the nitrogen from the air and channels the concentrated oxygen to the ozone reaction cells. Note: Processes requiring low concentrations of ozone may be serviced with clean, dry input air (21 percent O_2).

Ozone generation: the ozone reaction cell produces ozone via corona discharge. Concentrated oxygen gas flowing through the electrical corona in the reaction cell is converted to ozone. Conversion of four to eight percent of O_2 to O_3 is typical, depending on reaction conditions.

Contacting: in the contacting step, ozone gas is injected into a stream of water via a Venturi injector and transferred to a contacting or reactor tank. Excess ozone gas that does not integrate into the water is vented from the top of the tank through a destruct device that converts the excess ozone back to el-

Figure 2. Schematic diagram of the ozone contacting system for the small mutual water application



emental oxygen.

Control: controls are typically designed into ozone systems to monitor and optimize ozone production and demand. Systems can be designed to automatically compensate for changes in demand and maintain a preset level of residual ozone.

Case study

The development of a small group of luxury homes in a semi-rural setting in central California required the formation of a small mutual water company to treat and distribute ground water from a central well. Chemical analysis of the water from the well yielded the following results:

Iron concentration: 400 ug/L =
Ozone demand of 0.172 mg/L

Manganese concentration: 60ug/L =
Ozone demand of 0.0522 mg/L

Sum of inorganic ozone demand =
0.2242 mg/L

Another one mg/L of ozone demand was added for disinfection potential. The total ozone generator output requirement was 1.98 mg/L. The ozone contacting system developed for this case is shown in the schematic in Figure 2. The system is shown in Figure 3.

Scalability

The benefits of ozone can be easily expanded to meet the needs of larger MWCs. For example, a conceptually similar system was designed and installed to serve a 720-home resort community at Clear Lake, Calif. Shown in Figure 4, the twin banks of these ozone generators can produce up to 400 grams of ozone per hour and are capable of servicing up to 1,600 homes. Only one bank is required to meet the current needs. The second bank provides additional capacity for expansion and system backup.

Adapting ozone to single-home POE

Ozone-based water purification and disinfection presents an attractive opportunity for addressing the limitations of alternative water sources in single-family dwellings. Adapting ozone-based water systems to single home point-of-entry (POE) presents unique challenges. The technical challenges include appropriate configuration of the contacting system to meet the overall ozone demand of the source water and controlling ozone production to compensate for variation in ozone demand. Other challenges include appropriate downsizing and packaging of the components to the scale of the home environment, simplification of operation and maintenance and cost reduction to meet consumer price points.

In order to properly configure ozone contacting systems, one must have good knowledge of the ozone demand requirements of the source water. For well water, the simplest and most stable example, the ozone demand requirements can be determined from a comprehensive chemical analysis of the source water. Once the levels of soluble metals, minerals and organic materials are quantified, additional ozone demand is added to provide adequate disinfection. These calculations yield clear specifications for ozone production and contacting. The relative stability of ozone demand in well water allows a single ozone production level to be set for long-term operation.

The variability of ozone demand in other water sources complicates the specification of ozone requirements. For example, the ozone demand for surface water may vary greatly due to seasonal dilution or concentration of contaminants. This variability can be overcome by adding dissolved ozone sensors and control systems to monitor residual dissolved ozone in the contacting tank and adjust ozone output to compensate for variations in ozone demand. The control system maintains the residual ozone at a set concentration. Unfortunately, sophisticated monitoring and control systems negatively impact the total costs of the system.

One of the benefits of mutual water systems is that the costs of acquisition, installation and maintenance of the water purification and disinfection system are spread over several homes and over many years of operation. In the single-family dwelling scenario, these costs must be borne entirely by the individual homeowner. Consumer price sensitivities suggest that significant cost reduction will be required to create commercially viable home POE ozone contacting systems.

Conclusions

Ozone is a very useful tool for safe and effective water treatment in small mutual water systems. The strong oxidation potential of ozone can easily overcome the challenges of lower-quality sources by disinfecting the source water, aggregating metals and organic molecules and improving the taste and smell of the output water. Medium-sized ozone contacting systems are recommended for small-city and community water systems. Such systems are practical and compact. What's more, they are economically viable for even the smallest communities. Ozone disinfection is very scalable and can effectively and economically serve MWCs, from a handful of homes to hundreds of dwellings. Adaptation to single home POE requirements is feasible but will require additional technical development and cost reduction.

Reference

1. *Ozone for Point-of-use, Point-of-entry, and Small Water Treatment Application*; Joseph F. Harrison, P.E.; Editor; Water Quality Association; 2004.

About the systems

♦ *Figure 3 shows Pacific Ozone Technology's IOCS 05 A24 integrated ozone contacting system and Figure 4 shows two 9M24 ozone generation systems.*

About the author

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