You are reading the first ever online ozone guide. We have created this guide to help you understand and appreciate ozone. This reading is meant to be fun and expand your mind with ozone possibilities. Enjoy!

**QUICK REFERENCE KEY**

- Indicates a unique question with answers that most people will find interesting
- Indicates information that ozone beginners and experts will find interesting
- Indicates information that challenges even those that consider themselves ozone experts, it will challenge your existing “ozone world view”
- Thumbs Up — Indicates tips for good Ozone System design

- Indicates an online learning opportunity. Click the button to learn more or visit the url shown.

If you find an incorrect fact in this guide, please email us at info@ozonesolutions.com

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### Properties of Ozone vs. Oxygen

<table>
<thead>
<tr>
<th>Property</th>
<th>Ozone</th>
<th>Oxygen</th>
</tr>
</thead>
<tbody>
<tr>
<td>Molecular Formula</td>
<td>$O_3$</td>
<td>$O_2$</td>
</tr>
<tr>
<td>Alternate Names</td>
<td>Triatomic Oxygen</td>
<td>--</td>
</tr>
<tr>
<td>Molecular Weight</td>
<td>48</td>
<td>32</td>
</tr>
<tr>
<td>Color</td>
<td>Light Blue</td>
<td>Colorless</td>
</tr>
<tr>
<td>Characteristic Smell</td>
<td>“Electrical” Odor</td>
<td>--</td>
</tr>
<tr>
<td>Solubility in Water ($0^\circ$ C)</td>
<td>0.64</td>
<td>0.049</td>
</tr>
<tr>
<td>Density (g/l)</td>
<td>2.144</td>
<td>1.429</td>
</tr>
<tr>
<td>Boiling Point</td>
<td>-111.9$^\circ$ C</td>
<td>-183$^\circ$ C</td>
</tr>
<tr>
<td>Flash Point</td>
<td>Not Applicable</td>
<td>Not Applicable</td>
</tr>
<tr>
<td>Auto-Ignition Temperature</td>
<td>Not Applicable</td>
<td>Not Applicable</td>
</tr>
<tr>
<td>Flammability</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>Electrochemical Potential (eV)</td>
<td>2.07</td>
<td>1.23</td>
</tr>
</tbody>
</table>

Did you know that the ozone layer is not really a layer but is a collection of ozone molecules in the lower portion of the stratosphere, 12-20 miles above the earth? If all these ozone molecules settled on the earth's surface, they would only be 1-inch thick!

All commercial planes and military jets have special filters to remove ozone from the air which permit passengers and pilots to breathe at these high altitudes. You didn't think that you kept breathing the same air over and over, did you?
HOW IS OZONE MADE? DID YOU KNOW THAT OZONE IS MADE IN NATURE? IT NATURALLY DOES IT IN TWO WAYS.

1. LIGHTNING (CORONA DISCHARGE)
   - Lightning passing through the air creates ozone from oxygen.

2. SUN (UV LIGHT)
   - Oxygen in the presence of 185 nm UV light creates ozone.

HOW DO WE MAKE OZONE? SAME METHODS AS ABOVE, BUT ON A MUCH SMALLER SCALE

1. CORONA DISCHARGE
   - Ozone, from the air, is forced between high voltage plates to simulate corona discharge. The oxygen is broken apart and recombines into ozone.
   - Advantages of corona discharge:
     - Generates high ozone concentrations
     - Best for water applications
     - Fast organic (odor) removal
     - Consistent ozone output

2. UV LIGHT
   - Oxygen turns into ozone after it is hit with 185 nm UV light from a UV bulb.
   - Advantages of UV light:
     - Simple construction
     - Lower cost than corona discharge
     - Output less affected by humidity

The first patent for an Ozone Generator was by Nikola Tesla in 1896.

Did you know that a single lightning strike can create over 300 pounds of ozone?
ADVANTAGES OF OZONE

- Ozone is the most powerful oxidant for disinfecting water or sanitizing surfaces
- Ozone can kill pathogens in seconds vs. several minutes for other oxidants
- Ozone is one of the strongest oxidants available for oxidizing organics
- Ozone decomposes into oxygen
- Ozone, by itself, does not affect pH
- Ozone cannot be stored, therefore, having a large volume of a dangerous oxidizer is not possible
- Ozone is excellent at oxidizing metals such as iron, manganese, and more
- Ozone enhances the flocculation and coagulation of organic material and consequently increases efficiency
- Ozone can be effective in partially oxidizing organics in the water to biodegradable compounds that can be removed by biological filtration

<table>
<thead>
<tr>
<th>OXIDIZING AGENT</th>
<th>OXIDIZING POTENTIAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>OZONE</td>
<td>2.07</td>
</tr>
<tr>
<td>HYDROGEN PEROXIDE</td>
<td>1.77</td>
</tr>
<tr>
<td>PERMANGANATE</td>
<td>1.67</td>
</tr>
<tr>
<td>HYPOCHLOROUS ACID</td>
<td>1.49</td>
</tr>
<tr>
<td>CHLORINE GAS</td>
<td>1.36</td>
</tr>
<tr>
<td>HYPOBROMOUS ACID</td>
<td>1.33</td>
</tr>
<tr>
<td>OXYGEN</td>
<td>1.23</td>
</tr>
<tr>
<td>BROMINE</td>
<td>1.09</td>
</tr>
<tr>
<td>HYPOIODOUS ACID</td>
<td>0.99</td>
</tr>
<tr>
<td>CHLORINE DIOXIDE</td>
<td>0.95</td>
</tr>
<tr>
<td>HYPOCHLORITE</td>
<td>0.94</td>
</tr>
<tr>
<td>CHLORITE</td>
<td>0.76</td>
</tr>
<tr>
<td>IODINE</td>
<td>0.54</td>
</tr>
</tbody>
</table>


In the summer of 1993 a cryptosporidium outbreak in Milwaukee, WI, resulted in the largest waterborne disease outbreak in documented United States history. An estimated 400,000+ were ill with over 100 deaths attributed to this outbreak. Chlorine, the primary disinfection technology, was useless against this cyst. A $5 million dollar ozone system was installed and effectively killed this organism. Milwaukee has not had an outbreak since!

NEGATIVES OF OZONE

Like every oxidant, ozone has its downsides. However, it is important we clarify the actual negatives vs. the perceived “negatives” that arise from misuse.

Commonly stated “negatives”:
• Oxidizes materials
• Material degradation
• Can harm people, pets, plants

In light of ozone’s effectiveness, are the three bulleted items really negatives, or do we just need to use it safely like electricity, or gasoline? All oxidizers will have a similar “negative” effect as ozone if used improperly. Proper implementation is key to achieving outstanding results in your process.

The real negatives are listed below:

Half Life
• Ozone is an unstable molecule which quickly changes back to oxygen. The half-life (time for half of the ozone in air to decompose) is 20-60 minutes depending on the temperature and humidity of the ambient air. The half-life in clean water is about the same. Note: the temperature, pH, and water quality will affect half-life.

Storage
• Ozone cannot be stored or transported, and must be made on site. This requires feedgas preparation and ozone generation equipment.
• When is a negative a positive? Since ozone cannot be stored, it is not possible to have a large, potentially dangerous volume of oxidizer such as you can have for chlorine or hypochlorite. Ozone equipment can neither be “punctured” with a fork lift nor “tipped over.”

HALF LIFE OF OZONE

Dissolved in Water (pH 7)

<table>
<thead>
<tr>
<th>Dissolved Ozone (mg/L)</th>
<th>Time (min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.0</td>
<td>30</td>
</tr>
<tr>
<td>2.0</td>
<td>20</td>
</tr>
<tr>
<td>3.0</td>
<td>15</td>
</tr>
<tr>
<td>4.0</td>
<td>12</td>
</tr>
<tr>
<td>5.0</td>
<td>8</td>
</tr>
</tbody>
</table>

Table: Ozone Dissolved in Water (pH 7)

Research References:
“Supplementary Swimming Pool Treatment" by PoolpakInternational.com – MK2_PTI_OZONE_Rev-20110527.pdf
OZONE SAFETY

Ozone is a strong oxidizer that is generally not harmful to mammals at low concentrations, but lethal to microorganisms such as bacteria. However, ozone, like any other strong oxidizing agent, can be harmful if not handled properly. Potential Health Effects as listed on the Ozone Material Safety Data Sheet (MSDS):

INHALATION: Ozone causes dryness of the mouth, coughing, and irritation of the nose, throat, and chest. It may cause labored breathing, headaches, and fatigue. However, the characteristic sharp, pungent odor is readily detectable at low concentrations (0.005 to 0.02 PPM).

CORRECTIVE MEASURE: Move to fresh air, loosen tight clothing around the torso; call medical attention if necessary; if breathing is difficult, a trained person/EMT should administer oxygen at 15 LPM via non-rebreather.

SKIN: Absorption through intact skin is not expected.

CORRECTIVE MEASURE: Wash skin thoroughly with soap and water.

EYE CONTACT: Ozone can be an irritant to the eyes causing minor inflammation.

CORRECTIVE MEASURE: Flush eyes with large amounts of water for at least 15 minutes while forcibly holding eyelids apart to ensure flushing of the entire eye surface. If irritation, pain, or other symptoms persist, seek professional medical attention.

INGESTION: It is not a route of exposure.

AGGRAVATION OF PREEXISTING CONDITIONS: Ozone may increase sensitivity to bronchi constrictors including allergens, especially individuals with asthma.

CHRONIC CONDITION: Long term health effects are not expected from exposure to ozone. A partial tolerance appears to develop with repeated exposures.

FOR SAFETY PROTECTION, personal awareness of an odor of ozone should not be relied upon. Instrumentation and equipment should be provided to measure ambient ozone levels and perform the following safety functions:

- Initiate an alarm signal at an ambient ozone level of 0.1 PPM. Equipment may stay operational, if desired.
- Initiate a second alarm signal at ambient ozone levels of 0.3 PPM. This signal would also immediately shut down the ozone generation equipment. The majority of humans can smell ozone long before it is dangerous. The odor detection threshold is 0.005-0.02 PPM.

<table>
<thead>
<tr>
<th>OBSERVED EFFECTS</th>
<th>CONCENTRATION (PPM)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Threshold of odor, normal person</td>
<td>0.005-0.02</td>
</tr>
<tr>
<td>Maximum 8 hour average exposure limit</td>
<td>0.1</td>
</tr>
<tr>
<td>Minor eye, nose and throat irritation, headache, shortness of breath</td>
<td>&gt;0.1</td>
</tr>
<tr>
<td>Breathing disorders, reduced oxygen consumption, lung irritation, severe fatigue, chest pain, dry cough</td>
<td>0.5-1.0</td>
</tr>
<tr>
<td>Headache, respiratory irritation, and possible coma. Possibility of severe pneumonia at higher levels of exposure</td>
<td>1-10</td>
</tr>
<tr>
<td>Immediately dangerous to life and health</td>
<td>10</td>
</tr>
<tr>
<td>Lethal to small animals within two hours</td>
<td>15-20</td>
</tr>
</tbody>
</table>
THE HISTORY OF OZONE

Ozone was first discovered in the late 1700s. It was scientifically identified as a compound in 1840. Ten years later, the first Ozone Generator was built and by the end of the nineteenth century, ozone was in use as a drinking water treatment in the Netherlands.

1785: The odor of ozone was first reported by Van Mauren in the vicinity of an electrical discharge.

1840: Christian Schönbein identifies ozone's characteristic odor, and names it after the Greek word “to smell.”

1857: First industrial Ozone Generator built by Werner Von Slemans.

1867: Ozone's structure identified as triatomic oxygen.

1893: Ozone first commercialized as full-scale drinking water treatment at Oudshroom, The Netherlands.

1903: First U.S. municipal water installation at Niagara Falls, NY.

1906: Bon Voyage water plant built in Nice, France. Considered “the birthplace of ozone” for drinking.

1909: Ozone first used as a preservative for cold storage of meat.

1914: German Army applies ozone to battlefield wounds and infections.

1915: German physician Albert Wolff uses ozone in the treatment of skin diseases.

1932: Dentist E.A. Fisch uses ozonated water as a disinfectant.

1939: Ozone found to prevent the growth of yeast and mold during storage of fruit.

1950's: Dr. W. Zable treats cancer using ozone.

1970's: Ozone first used in bottled water plants.

1992: First ozone delignification system starts up at Union Camp's Franklin, VA paper mill.

1996: USDA approves use of ozonated water for washing chicken carcasses.

2001: FDA approves ozone as an antimicrobial agent for direct contact with food.

2001: USDA approves ozone for contact with meat and poultry.

Nice, France is often credited with the first municipal ozone installation. This is not the case. The first municipal ozone installation was at Oudshroom, Netherlands. However, it is no longer in operation. Nice, France is considered the birthplace of ozone because it is the oldest, continuously operating, ozone installation.

Source: BCC Research
OZONE EFFECTS ON BACTERIA, VIRUSES, & MOLDS

HOW OZONE KILLS BACTERIA
1. A bacillus bacterial cell.
2. Ozone comes into contact with the cell wall. The cell wall is vital to the bacteria because it ensures the organism can maintain its shape.
3. As ozone molecules make contact with the cell wall, an oxidative burst occurs creating a tiny hole in the cell wall.
4. A newly created hole in the cell wall has injured the bacterium.
5. The bacterium begins to lose its shape while ozone molecules continue to create holes in the cell wall.
6. After thousands of ozone collisions over only a few seconds, the bacterial wall can no longer maintain its shape and the cell dies.
   - Bacteria cell oxidation via ozone contact typically occurs within 1-10 seconds!

The human body also protects itself via oxidative burst! White blood cells will seek out bacteria in the bloodstream. The bacteria will envelop the white cell. Once inside the cell wall, the white cell will metabolize water into oxidants such as hydroxyl (OH-) and hydrogen peroxide (H2O2). This action destroys the cell from the inside out. In 2002, the Scripps Research Institute Department of Chemistry in La Jolla, CA, discovered chemical signatures similar to ozone were present during oxidative burst.

Always have an ozone monitor present when generating ozone.

You don’t have to spend hundreds of dollars on an ozone monitor. Ozone badges exist for a great price!

Did you know that, to date, there has not been a single bacterium, virus or cyst discovered that can withstand ozone? Ozone kills them all!

- Ozone interferes with the metabolism of bacterium-cells, most likely through inhibiting and blocking the operation of the enzymatic control system. A sufficient amount of ozone breaks through the cell membrane, leading to the destruction of the bacteria.
- The effect of ozone below a certain concentration value is small or zero. Above this level all pathogens are eventually destroyed. This effect is called all-or-none response and the critical level the "threshold value."
<table>
<thead>
<tr>
<th>PATHOGEN</th>
<th>DOSAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aspergillus Niger (Black Mold)</td>
<td>Destroyed by 1.5 to 2 mg/l</td>
</tr>
<tr>
<td>Bacillus Bacteria</td>
<td>Destroyed by 0.2 mg/l within 30 seconds</td>
</tr>
<tr>
<td>Bacillus Anthracis</td>
<td>Ozone susceptible</td>
</tr>
<tr>
<td>Bacillus Cereus</td>
<td>99% destruction after 5 min at 0.12 mg/l in water</td>
</tr>
<tr>
<td>B. Cereus (Spores)</td>
<td>99% destruction after 5 min at 2.3 mg/l in water</td>
</tr>
<tr>
<td>Bacillus Subtilis</td>
<td>90% reduction at 0.10-PPM for 3.3 minutes</td>
</tr>
<tr>
<td>Bacteriophage F2</td>
<td>99.99% destruction at 0.41 mg/l for 10-seconds in water</td>
</tr>
<tr>
<td>Betaviridae Chimereae</td>
<td>3.8 mg/l for 2 minutes</td>
</tr>
<tr>
<td>Candida Bacteria</td>
<td>Ozone susceptible</td>
</tr>
<tr>
<td>Clavibacter Michiganense</td>
<td>99.99% destruction at 1.1 mg/l for 5 minutes</td>
</tr>
<tr>
<td>Cladosporium</td>
<td>90% reduction at 0.10-PPM for 12.1 minutes</td>
</tr>
<tr>
<td>Clostridium Bacterium</td>
<td>Ozone susceptible</td>
</tr>
<tr>
<td>Clostridium Botulinum (Spores)</td>
<td>0.4 to 0.5 mg/l threshold value</td>
</tr>
<tr>
<td>Coccidoides Virus A9</td>
<td>95% destruction at 0.035 mg/l for 10-seconds in water</td>
</tr>
<tr>
<td>Coccidoides Virus B5</td>
<td>99.99% destruction at 4.1 mg/l for 2.5-minutes in sludge effluent</td>
</tr>
<tr>
<td>Diptheria Pathogen</td>
<td>Destroyed by 1.5 to 2 mg/l</td>
</tr>
<tr>
<td>Eberth Bacillus Typhus Abdominalis</td>
<td>Destroyed by 1.5 to 2 mg/l</td>
</tr>
<tr>
<td>Echo Virus 29: The virus most sensitive to ozone</td>
<td>After a contact time of 1 minute at 1 mg/l of ozone, 99.999% killed</td>
</tr>
<tr>
<td>Enteric Virus</td>
<td>95% destruction at 4.1 mg/l for 29 minutes in raw wastewater</td>
</tr>
<tr>
<td>Escherichia Coli Bacteria (from feces)</td>
<td>Destroyed by 0.2 mg/l within 30 seconds in air</td>
</tr>
<tr>
<td>E-coli (clean water)</td>
<td>99.99% destruction at 0.25 mg/l for 1.6 minutes</td>
</tr>
<tr>
<td>Encephalomyocarditis Virus</td>
<td>Destroyed to zero level in less than 30 seconds with 0.1 to 0.8 mg/l</td>
</tr>
<tr>
<td>Endamebic Cysts Bacteria</td>
<td>Ozone susceptible</td>
</tr>
<tr>
<td>Enterovirus</td>
<td>Destroyed to zero level in less than 30 seconds with 0.1 to 0.8 mg/l</td>
</tr>
<tr>
<td>Fusarium Oxysporum S Sp. Lycopersici</td>
<td>1.1 mg/l for 10 minutes</td>
</tr>
<tr>
<td>Fusarium Oxysporum F Sp. Monogena</td>
<td>99.99% destruction at 1.1 mg/l for 20 minutes</td>
</tr>
<tr>
<td>GDVI Virus</td>
<td>Destroyed to zero level in less than 30 seconds with 0.1 to 0.8 mg/l</td>
</tr>
<tr>
<td>Hepatitis A Virus</td>
<td>95.5% reduction at 0.25 mg/l for 2-seconds in a phosphate buffer</td>
</tr>
<tr>
<td>Herpes Virus</td>
<td>Destroyed to zero level in less than 30 seconds with 0.1 to 0.8 mg/l</td>
</tr>
<tr>
<td>Influenza Virus</td>
<td>0.4 to 0.5 mg/l threshold value</td>
</tr>
<tr>
<td>Klebs-Leffler Bacillus</td>
<td>Destroyed by 1.5 to 2 mg/l</td>
</tr>
<tr>
<td>Legionella Pneumophila</td>
<td>99.99% destruction at 0.32 mg/l for 20 minutes in distilled water</td>
</tr>
<tr>
<td>Luminescent Basidiomycetes</td>
<td>Destroyed in 10 minutes at 100-PPM</td>
</tr>
<tr>
<td>Mucor Piriformis</td>
<td>3.8 mg/l for 2 minutes</td>
</tr>
<tr>
<td>Mycobacterium Avium</td>
<td>99.9 with a CT value of 0.17 in water</td>
</tr>
<tr>
<td>Mycobacterium Ferutum</td>
<td>90% destruction at 0.25 mg/l for 1.6 minutes in water</td>
</tr>
<tr>
<td>Penicillium Bacteria</td>
<td>Ozone susceptible</td>
</tr>
<tr>
<td>Phytophthora Parasitica</td>
<td>3.8 mg/l for 2 minutes</td>
</tr>
<tr>
<td>Polioomyelitis Virus</td>
<td>99.9% kill with 0.3 to 0.4 mg/l in 3-4 minutes</td>
</tr>
<tr>
<td>Poliovirus Type 1</td>
<td>95.5% destruction at 0.25 mg/l for 1.6 minutes in water</td>
</tr>
<tr>
<td>Proteus Bacteria</td>
<td>Very susceptible</td>
</tr>
<tr>
<td>Pseudomonas Bacteria</td>
<td>Very susceptible</td>
</tr>
<tr>
<td>Rhabdovirus Virus</td>
<td>Destroyed to zero level in less than 30 seconds with 0.1 to 0.8 mg/l</td>
</tr>
<tr>
<td>Salmonella Bacteria</td>
<td>Very susceptible</td>
</tr>
<tr>
<td>Salmonella Typhimurium</td>
<td>99.99% destruction at 0.25 mg/l for 1.67 minutes in water</td>
</tr>
<tr>
<td>Schistosoma Bacteria</td>
<td>Very susceptible</td>
</tr>
<tr>
<td>Staphylococcus</td>
<td>90% reduction at 0.1-PPM for 1.7 minutes</td>
</tr>
<tr>
<td>Staphylococcus</td>
<td>Destroyed by 1.5 to 2.0 mg/l</td>
</tr>
<tr>
<td>Stomatitis Virus</td>
<td>Destroyed to zero level in less than 30 seconds with 0.1 to 0.8 mg/l</td>
</tr>
<tr>
<td>Streptococcus Bacteria</td>
<td>Destroyed by 0.2 mg/l within 30 seconds</td>
</tr>
<tr>
<td>Verticillium Dahiae</td>
<td>99.99% destruction at 1.1 mg/l for 20 minutes</td>
</tr>
<tr>
<td>Vesicular Virus</td>
<td>Destroyed to zero level in less than 30 seconds with 0.1 to 0.8 mg/l</td>
</tr>
<tr>
<td>Vibrio Cholera Bacteria</td>
<td>Very susceptible</td>
</tr>
<tr>
<td>Vicia Faba Progeny</td>
<td>Ozone causes chromosome aberration and its effect is twice that observed by the action of X-rays</td>
</tr>
</tbody>
</table>

**KEY:**

- **Bacteria**
- **Virus**
- **Mold**
## OZONE COMPATIBLE MATERIALS

- Many of these materials were tested at the Ozone Solution’s lab. Some are commonly known and rated as shown by others. All tests were performed at high levels (>1000 PPM) of ozone concentration.
- For any materials not shown, please call. We may have data on file or we can use our labs to test the material for you!

<table>
<thead>
<tr>
<th>MATERIAL</th>
<th>RATING</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>ABS plastic</td>
<td>A</td>
<td>Excellent Ozone has no effect on these materials. They will last indefinitely.</td>
</tr>
<tr>
<td>Acetal (Delrin®)</td>
<td>B</td>
<td>Good Ozone has minor effect on these materials. Prolonged use with high concentrations of ozone will break down or corrode these materials beyond usefulness.</td>
</tr>
<tr>
<td>Acrylic (Perspex®)</td>
<td>C</td>
<td>Fair Ozone will break down these materials within weeks of use. Prolonged use with any ozone concentration will break down or corrode these materials beyond usefulness.</td>
</tr>
<tr>
<td>Aluminum</td>
<td>D</td>
<td>Peer Ozone will break down these materials within days or even hours of use. These materials are not recommended for use with ozone.</td>
</tr>
</tbody>
</table>

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</tr>
<tr>
<td>C</td>
<td>Fair Ozone will break down these materials within weeks of use. Prolonged use with any ozone concentration will break down or corrode these materials beyond usefulness.</td>
<td></td>
</tr>
<tr>
<td>D</td>
<td>Peer Ozone will break down these materials within days or even hours of use. These materials are not recommended for use with ozone.</td>
<td></td>
</tr>
</tbody>
</table>

**EPDM** is often listed as having an A rating or, no effect from ozone. This is not the case. Applying aqueous ozone to EPDM will result in small black streaks on your fingers when rubbed. This is a sign that ozone is breaking down the material. Do not use EPDM for water applications. Viton® is a superior alternative.
FEEDGAS GENERATION

There are three types of feed gases used for ozone generation. They are ambient air, dry air, and concentrated oxygen. Each of these are described below along with their advantages and disadvantages.

1. AMBIENT AIR — REFERS TO AIR FROM THE ENVIRONMENT, WHETHER IT IS LOCATED INDOORS OR OUTDOORS.

**ADVANTAGES**
- Free
- Readily available

**DISADVANTAGES**
- Results in corona cell maintenance every few days, weeks, or months.
- Can cause electrical component problems due to insects that can get lodged in the corona or corona plate.

**PROCESS:**

**OZONE GENERATOR**

Using oxygen as a feedgas typically provides 2-3x the output of dry air and 4-6x the output of ambient air.

2. DRY AIR — REFERS TO AIR WHICH HAS MOISTURE REMOVED SO THE DEW POINT IS -60°C OR LOWER

**ADVANTAGES**
- Allows a consistent ozone output over time
- Reduces corona cell maintenance (very important)
- All dust and insects are removed
- Associated equipment is less expensive than concentrated oxygen

**DISADVANTAGES**
- Low concentrations result in low solubility in water
- More expensive than ambient air since equipment is required to remove moisture
- Still result in some nitric acid production
- Systems are more complex than using ambient air (need vacuum driven or pressure swing absorption air dryer)

**PROCESS:**

**AIR DRYER**

**OZONE GENERATOR**

![Chart showing how ozone generator output decreases as dew point (moisture content) increases. Left axis shows the relative output of the ozone generator. E.g., at -10°C dew point, an ozone generator will be producing 60% of its maximum (rated) output.]

3. CONCENTRATED OXYGEN — REFERS TO OXYGEN WHICH IS OF MINIMUM 90% PURE WITH MOISTURE REMOVED -100°F DEW POINT. IT CAN BE PRODUCED FROM AN OXYGEN CONCENTRATOR OR DELIVERED FROM AN OXYGEN CYLINDER.

**ADVANTAGES**
- Allows a consistent ozone output over time
- Eliminates corona cell maintenance (very important)
- Virtually all moisture is removed
- Oxygen output is typically doubled (2x) vs. using dry air
- Higher concentrations mean very soluble in water

**DISADVANTAGES**
- More expensive than dry air systems since more equipment is required
- Systems are more complex than using dry air (need compressor and oxygen concentrator)

**PROCESS:**

**AIR COMPRESSOR**

**OXYGEN CONCENTRATOR**

**OZONE GENERATOR**
OZONE TRANSFER VIA BUBBLE DIFFUSION

Ozone is a gas, therefore proper gas/liquid contact mechanisms are critical to efficient system design. Bubble diffusers are a popular, inexpensive method to inject ozone into water. The ozone gas transfer area occurs immediately at the interface between the ozone bubble surface and the surrounding water.

**BUBBLE DIFFUSION:**

Diffusers permit ozone gas to pass through a porous membrane thus creating many small bubbles in the water, similar to a fish tank air stone. As the ozone bubble rises, the gas at the bubbles edge will transfer into the water. Using a diffuser requires enough pressure to overcome the height of the water and any restrictions in the diffuser due to hole size.

### ADVANTAGES
- Low cost
- Easy to set up
- Low energy – does not require a water pump

### DISADVANTAGES
- Low mass transfer
- High water columns/vessels are typically required
- Difficult to use in pressurized water flows
- Diffuser pores can become plugged

- The diameter of a gas bubble has a dramatic impact on surface area
- Be picky when it comes to selecting a bubble diffuser. It can mean the difference between success and failure.
- The transfer of ozone gas into water is directly related to its surface area (total bubble surface area)
- It is critical to prevent the water from back-flowing through the bubble diffuser and going into the Ozone Generator. The best method of prevention is to use multiple check values (for redundancy) and a water trap.

**BUBBLE(S) VOLUME = 1 CUBIC FOOT**

<table>
<thead>
<tr>
<th>Diameter (in)</th>
<th>Area (sq ft)</th>
<th>Bubbles</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.8</td>
<td>14.8</td>
<td>1</td>
</tr>
<tr>
<td>10</td>
<td>38.5</td>
<td>54,000</td>
</tr>
<tr>
<td>37</td>
<td>54,000,000</td>
<td></td>
</tr>
</tbody>
</table>

**CONCLUSION: SMALLER BUBBLES HAVE MUCH BETTER OZONE MASS TRANSFER!**


Want to know how many 0.5 mm bubbles it takes to contain 1 ft³ of ozone? Find out on our ozone diffuser page. It will blow your mind!
OZONE INJECTION VIA VENTURI

A more popular method for delivering ozone is through the use of Venturi Injectors. Venturi Injectors work by forcing water through a conical body. This action creates a pressure differential between the inlet and outlet ports, which results in a vacuum inside the injector body. This vacuum causes rapid ozone suction through the suction port.

ADVANTAGES
- Mass transfer efficiencies up to 98%*
- Works well in pressurized streams
- Minimal maintenance required
- More controlled and consistent over time

DISADVANTAGES
- Requires energy from a booster pump or pressurized water supply

Venturis require a constant pressure differential to initiate ozone injection. (15 PSI in this example).

Tiny air bubbles (white) can be seen mixed with the water.

Water, moving from left to right through a conical body creates suction which pulls air/ozone into the water stream.

A very high liquid to gas ratio is required to achieve 98% mass transfer efficiency. In fact, the ratio required would not be economical. Typical mass transfer efficiencies for Venturi range from 50-70% (without the use of pressure).
OZONE SOLUBILITY IN WATER

- Solubility is the property of a solid, liquid, or gaseous chemical substance called solute to dissolve in a solid, liquid, or gaseous solvent.
- One gas is oxygen or $O_2$. We breathe it every day, but so do fish who live under water. This means that $O_2$ is soluble with the water. Ozone gas ($O_3$) is 13 times more soluble in water than $O_2$ gas!

WATER TEMPERATURE AND SOLUBILITY

- Water at 86°F will have less ozone bubbles than water at 50°F.
- Water at 50°F will have more ozone bubbles than water at 86°F.

CONDITIONS WHICH EFFECT THE SOLUBILITY LEVEL OF A GAS INTO WATER

- One is the temperature of the water.
- Another factor is water pressure. At a higher pressure, more ozone will be dissolved into the water.
- Pressurized gas, meaning gas that is at an increased pressure, being applied into the water, which is also under an increased pressure, will increase the solubility.
- If the gas that you are placing into the water is at an increased pressure, this will allow additional solubility. This means a higher mass transfer of ozone into water.

CONCLUSION: HIGHER WATER PRESSURES RESULT IN HIGHER DISSOLVED OZONE LEVELS

Adding any one of the above list to your process will improve the solubility. Incorporating more than one will be even better.
OZONE FORMULAS
Here is the formula for determining the actual flow rate of a gas under pressure inside a flowmeter.

ADJUST FLOW RATE CONVERSION

\[
(\text{ADJUSTED FLOW}) = (\text{MEASURED FLOW}) \cdot \frac{\text{(OXYGEN PRESSURE)} + 14.7}{14.7}
\]

CALCULATE OZONE DOSAGE IN WATER

- The formula is actually very simple.
- It is water flowrate x ozone dosage = required ozone production.

**UNITS CONSISTENCY IS VERY IMPORTANT.**

- Blow is the formula for determining ozone generation requirements if you know common water and ozone parameters (flowrate in GPM and ozone dosage in mg/l).

**FLOWRATE (GPM x 3.75 l/gal x 60 min/hr x ozone dosage (mg/l)) = ozone production (mg/hr).**

- Let’s work through an example. How much ozone production is needed to dose 2 PPM into 20 GPM of water? (We will be using PPM throughout the rest of this example knowing that 1 mg/l = 1 PPM).

\[
20 \text{ GPM} \times 3.75 \text{ l/gal} \times 60 \text{ min/hr} \times 2 \text{ PPM} = 9084 \text{ mg/hr (9 g/hr)}. 
\]

- Remember that 9 g/hr will permit one to dose the water with 2 PPM of ozone. This does not mean that 2 PPM will be the final dissolved ozone concentration. Due to efficiency losses with injecting ozone and ozone demand of the water, the dissolved ozone concentration will be less.

CALCULATE THE OUTPUT OF AN OZONE GENERATOR

- The formula is flowrate (lpm) x ozone concentration (g/m³) = ozone production (mg/hr).
- Let’s work through another example: The ozone concentration exiting an Ozone Generator is 120 g/m³ at 5 lpm of oxygen flow. What is the output?

\[
5 \text{ l/min} \times 120 \text{ g/m³} \times (1 \text{ m³/1,000 l}) = 0.60 \text{ g/min}. 
\]

- g/min are not common units so we simply convert minutes to hours to get g/hr: 0.60 g/min x 60 min/hr = 36 g/hr.

SAMPLE CONVERSIONS

- Convert 140 g/m³ to wt% (oxygen feedgas)
- 100 g/m³ is equivalent to 6.99 wt%
- Therefore 140 g/m³ / 100 g/m³ x 6.99 wt% = 9.8 wt%

Did you know that managers of hog confinements have reported reductions in fly populations when ozone is used in the gaseous form?
CT VALUE - WHAT IS IT?

CT VALUE DEFINED

- “CT” is the product of “residual disinfectant concentration” (C) in mg/l, and the corresponding “disinfectant contact time” (T) in minutes. In other words, for ozone CT, it is the dissolved ozone concentration multiplied by the contact time. (remember that 1 mg/l = 1 PPM)
- Some sanitizing treatments with ozone can be accomplished very quickly, but some treatments will require sufficient ozone in the water along with an adequate contact time. This contact time is required for the dissolved ozone to oxidize organic contaminants and to disinfect the water.
- This CT value is assumed to be unit-less. Either the Concentration can be held constant while the Time is varied, or visa-versa, to assure a given level of disinfection is obtained.
- For example, a CT value the bottled water industry uses is 1.6. This means the dosage rate is 1.6 mg/l minutes. The operator has a choice of ozonating at 0.2 PPM for 8 minutes or 0.4 PPM for 6 minutes. It is up to them as long as the final CT is 1.6.

HERE’S HOW IT WORKS OUT:

Both charts present a CT value of 1.0, Concentration (PPM) x Time (Minutes).

You may have heard the claim, “ozone is 3,000x more germicidal than Chlorine.” What does this mean? This statement hinges on the fact that for some organisms, you need a CT value 3,000x higher when using chlorine vs. ozone. Put another way, if a dissolved ozone level of 0.2 PPM for 1 minute (CT is 0.2) is needed to inactivate a specific microorganism, you will need 200 PPM of chlorine for 3 minutes (CT = 600) to achieve the same kill effect.
OZONE CONVERSIONS

PHYSICAL PROPERTIES, STANDARD CONDITIONS; P=1013.25 MB, T=273.3 K

• Density of ozone: 2.14 kg/m³
• Molecular weight of ozone: 48
• Density of oxygen: 1.43 kg/m³
• Molecular weight of oxygen: 32
• Density of air: 1.29 kg/m³
• Density of water: 1,000 kg/m³

USEFUL CONVERSION FACTORS: (FOR WATER)

• 1,000 liters = 1 m³ = 264 US gallons = 35.3 ft³
• 1 gal = 3.785 liters = 3.785 ml

OZONE CONCENTRATION IN WATER

• 1 mg/l = 1 PPM = 1 g/m³ water (By weight)

OZONE CONCENTRATION IN AIR BY VOLUME

• 1 g/m³ = 467 PPM
• 1 PPM = 2.14 mg/m³

OZONE CONCENTRATION IN AIR BY WEIGHT

• 100 g/m³ = 6.99% (Approximate)
• 1% = 14.3 g/m³ (Approximate)
• 1% = 6,520 PPM

OZONE CONCENTRATION IN OXYGEN BY WEIGHT

• 100 g/m³ = 6.99% (Approximate)
• 1% = 14.3 g/m³ (Approximate)
• 1% = 6,520 PPM

Did you know that in semiconductor applications it takes an estimated 1,500-3,000 gallons of water to make a single 12-in wafer? (3,000 gallons is the approximate volume inside a 15-passenger van).

One part per million is equivalent to one blue golf ball in a room 18-ft x 18-ft x 8-ft high filled with white golf balls!
OZONE DOSAGE VS. DISSOLVED OZONE

- The quantity of ozone applied to the water will always exceed the amount of ozone actually absorbed into solution.
- Often times, due to system inefficiencies, a portion of the ozone off-gases without being absorbed into the water. This wasted ozone must then be vented outside or destroyed with an ozone destruct unit.

WHAT ARE THE UNITS OF DISSOLVED OZONE?
The units are PPM or mg/l. They are equivalent with a 1:1 ratio.

WHAT ARE THE UNITS OF OZONE DOSAGE?
The units are also PPM or mg/l. But how can this be, if ozone has not actually been dissolved into solution?

Remember that PPM is a ratio. 1 PPM is one part ozone for every 1,000,000 parts (molecules) of water. An operator will know the quantity of ozone being produced. They will also know the quantity of water passing through a Venturi (the typical method of injecting ozone). The ratio of generated gas to moving liquid will give us a value which can be expressed in PPM (or mg/l).

You might see an Ozone System parameter which states 2.0 PPM ozone dosage. Do not confuse this with dissolved ozone. 2 PPM ozone dosage will often times translate into 1 PPM, or less, dissolved ozone due to losses.

The amount of ozone that you place into the water will not remain that same value. The dissolved ozone will be reduced by the water conditions, such as the temperature, organic pathogens, etc. To obtain the desired dissolved ozone level, you must add ozone until you overcome the contaminants and the other ozone diminishing conditions.

Did you know that there are a few Ozone Injection Systems that can exceed 90% mass transfer efficiency in clean water? They utilize pressure and high ozone concentrations.
OZONE FALLACIES

We have heard them all. Now it is time we set the record straight. Below is a list of a few ozone fallacies we have heard over the years.

"OZONE WILL OXIDIZE MY METAL PIPES."

This claim conjures an image of ozonated water running through pipes and when you come in the next morning, they are rusted through. This is not the case. The pH level has more effect on corrosion rates of metals than most industry accepted dissolved ozone levels. While a powerful oxidizer, ozone has minimal effect on corrosion rates. Iron pipes that carry ozone gas, while not recommended, will last for months, or years, before any noticeable corrosion is present. For ozonated water, iron pipes will oxidize faster than water with just oxygen, but the pipes can last for years before needing replacement.

Ozone Solutions recommends the use of ozone approved materials. Iron pipes are not ideal but they will not degrade within a few days or even weeks as most people would have you believe. The same is true for most rubber seals.

"THE SKY IS BLUE BECAUSE OF OZONE."

Okay, this one is not related to our business, but we have heard it mentioned before so we will address it. While ozone is a blue gas, the sky is blue for a very different reason.

The blue color of the sky is due to Rayleigh scattering. Blue light has a shorter wavelength than the other "rainbow colors." This blue light is absorbed by the gas molecules. The absorbed blue light is then radiated in different directions. It gets scattered all around the sky. Whichever direction you look, some of this scattered blue light reaches you. Since you see the blue light from everywhere overhead, the sky looks blue.

So the next time your kid asks "Why is the sky blue?" you will have the answer!

"OZONE DOES NOT HAVE ANY RESIDUAL."

This one is also false, but clarification is needed. Ozone has an extremely short half-life. This short half-life makes it very reactive and excellent at killing pathogens. In very clean water, ozone can last for several hours*. In most food processing applications, ozone half-life is anywhere from 10-20 minutes. For wastewater applications, the ozone residual is dependent on the organic loading with high organic loading resulting in short ozone half-life.

In 2003, Manassis Mitrakas reported that ozone can remain in a bottle up to 6 hours with an ozone dose of 0.10 PPM*.  


The Definitive Guide to Understanding Ozone - www.ozonesolutions.com
FDA & USDA PERMIT OZONE USE ON FOOD

CAN OZONE BE USED ON FOOD?

YES IT CAN!

See official directives below.

Ozone has been given GRAS approval by the USDA and the FDA for direct contact with food products, including all meat and poultry products. While good manufacturing procedures must be in place, no regulations exist on levels of ozone in food processing applications. The final rule from the FDA providing GRAS approval was given in 2001. The USDA followed with the final rule granting GRAS approval for ozone in 2002. References for all these actions, along with the specific rules, are provided below.

REGULATIONS

USDA final rule on ozone dated 12/17/2002, FSIS Directive 7120.1
States: Ozone can be used on all meat and poultry products. Ozone can be used in accordance with current industry standards of good manufacturing practice. No other guidelines are given on levels or dosages of ozone.

USDA Guidance on Ingredients and sources of radiation used to reduce microorganisms on carcasses, ground beef, and beef trimmings: Ozone is classified as a Secondary direct food additive/processing aid allowable for all meat and poultry products.

FDA Federal Register Vol. 66 No. 123
The Food and Drug Administration (FDA) is amending the food additive regulations to provide for the safe use of ozone in gaseous and aqueous phases as an antimicrobial agent on food, including meat and poultry. This action is in response to a petition filed for the Electric Power Research Institute, Agriculture and Food Technology Alliance.

This rule is effective June 26, 2001.

USDA Reference 21 CFR 173.368
Ozone (CAS Reg. No. 10028—15—6) may be safely used in the treatment, storage, and processing of foods, including meat and poultry (unless such use is precluded by standards of identity in 9 CFR part 319). In accordance with the following prescribed conditions: (a) The additive is an ionic, colorless gas with a pungent, characteristic odor, which occurs freely in nature. It is produced commercially by passing electrical discharges or ionizing radiation through air or oxygen. (b) The additive is used as an antimicrobial agent as defined in §170.3 (a) (2) of this chapter. (c) The additive meets the specifications for ozone in the Food Chemicals Codex, 4th ed. (1994), p. 227, which is incorporated by reference. The Director of the Office of the Federal Register approves this incorporation by reference in accordance with 5 U.S.C. 552(a) and 1 CFR part 51. Copies are available from the National Academy Press, 2101 Constitution Ave. NW, Washington, DC 20055, or may be examined at the Office of Premarket Approval (HFS—200), Center for Food Safety and Applied Nutrition, Food and Drug Administration, 200 C St. SW, Washington, DC, and the Office of the Federal Register, 800 North Capitol St. NW, suite 700, Washington, DC. (d) The additive is used in contact with food, including meat and poultry (unless such use is precluded by standards of identity in 9 CFR part 319 or 9 CFR part 181, subpart P), in the gaseous or aqueous phase in accordance with current industry standards of good manufacturing practice. (e) When used on raw agricultural commodities, the use is consistent with section 201(q)(1)(B)(i) of the Federal Food, Drug, and Cosmetic Act (the act) and not applied for use under section 201(p)(1)(B)(i), (q)(1)(B)(i)(I), or (q)(1)(B)(i)(II) of the act.
# SAFETY DATA SHEET (FORMERLY MSDS)

## 1. PRODUCT IDENTIFICATION

**Product Name:** OZONE

**Common Names/Synonyms:** Triatomic Oxygen, Trioxgen

**Ozone Generator Manufacturer/Supplier**

Ozone Solutions, Inc.  
www.ozonesolutions.com  
451 Black Forest Rd.  
Hull, IA 51239  
712-439-6880

**Product Use:** This SDS is limited to ozone produced in gaseous form on site by an ozone generator, in varying concentrations, in either air or aqueous solution, for the purposes of odor abatement, oxidation of organic compounds, or antimicrobial intervention, in a variety of applications.

## 2. HAZARD IDENTIFICATION

**GHS Classifications:**

<table>
<thead>
<tr>
<th>Physical</th>
<th>Health</th>
<th>Environmental</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oxidizing Gas</td>
<td>Skin Irritation – Category 3</td>
<td>Acute Aquatic Toxicity – Category 1</td>
</tr>
<tr>
<td>Eye Irritation – Category 2B</td>
<td>Respiratory System Toxicity – Category 1</td>
<td>(Single &amp; Repeated)</td>
</tr>
</tbody>
</table>

**NOTE:** Severe respiratory toxicity will develop before skin or eye irritation goes beyond listed categories. *Anyone with chronic pulmonary problems, especially asthma, should avoid exposure to ozone.*

**WSMIS Classifications (Workplace Hazardous Materials Information System, Canada):** C, D1A, D2A, D2B, F

Source: CCROM CHEMINFO Record Number 774

## 3. COMPOSITION

**Chemical Name:** Ozone  
**Common names:** Triatomic oxygen, trioxgen  
**Chemical Formula:** O3  
**CAS Registry Number:** 10028-15-6

## 4. FIRST AID MEASURES

**Route of Entry**  
**Symptoms**  
**First Aid**

- **Skin Contact:** YES  
  **Irritation:** Rinse with water  

- **Eye Contact:** YES  
  **Irritation:** Rinse with water, remove contacts  

- **Ingestion:** NO  
  **MAK:** NA  

- **Inhalation:** YES  
  **Irritation:** Headache, cough, heavy chest, shortened breath  
  **Remove to fresh air; provide oxygen if necessary**

**For severe cases, or if symptoms don’t improve, seek medical help.**

## 5. FIRE FIGHTING MEASURES

**Ozone itself is not flammable.** As a strong oxidant it may accelerate, even initiate, combustion, or cause explosions. Use whatever extinguishing agents are indicated for the burning materials.

## 6. ACCIDENTAL RELEASE MEASURES

**Turn off the ozone generator, and ventilate the area. Evacuate until ozone levels subside to a safe level (>0.1 ppm).**

## 7. HANDLING AND STORAGE

**Ozone must be contained within ozone-resistant tubing and pipes from the generation point to the application point.**

## 8. EXPOSURE CONTROLS/PERSONAL PROTECTION

**OSHA Permissible Exposure Limit:** 8 hour TWA 0.1 ppm  
**ANSI/ASTM:** 8 hour TWA 0.1 ppm, STEL 0.3 ppm  
**ACGIH:** 8 hour TWA 0.1 ppm, STEL 0.3 ppm  
**NIOSH:** ELVC 0.1 ppm; light: 0.08 ppm moderate: 0.05 ppm; heavy: moderate, heavy work TWA = 2 hours: 0.6 ppm; immediately Dangerous to Life or Health (IDLH): 5 ppm  
**Respiratory Protection:** Use face self-contained breathing apparatus for entering areas with a high concentration of ozone.

**Engineering Control:** Use ozone destruct unit for off gassing of ozone.

## 9. PHYSICAL AND CHEMICAL PROPERTIES

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Physical state</td>
<td>Gas</td>
</tr>
<tr>
<td>pH</td>
<td>NA</td>
</tr>
<tr>
<td>Molecular Weight</td>
<td>48.0</td>
</tr>
<tr>
<td>Decomposition temperature</td>
<td>NA</td>
</tr>
<tr>
<td>Appearance</td>
<td>Clear at low concentration, blue at high concentration</td>
</tr>
<tr>
<td>Evaporation rate</td>
<td>NA</td>
</tr>
<tr>
<td>Odor</td>
<td>Distinct pungent odor</td>
</tr>
<tr>
<td>Flash point</td>
<td>NA</td>
</tr>
<tr>
<td>Odor threshold</td>
<td>0.02 to 0.05 ppm; exposure desensitizes</td>
</tr>
<tr>
<td>Auto-ignition temperature</td>
<td>NA</td>
</tr>
<tr>
<td>Melting point</td>
<td>-193°C / -315°F</td>
</tr>
<tr>
<td>Relative density</td>
<td>NA</td>
</tr>
<tr>
<td>Boiling point</td>
<td>-193°C / -315°F</td>
</tr>
<tr>
<td>Partition coefficient</td>
<td>NA</td>
</tr>
<tr>
<td>Vapor pressure</td>
<td>&gt; 1 atm</td>
</tr>
<tr>
<td>Flammability</td>
<td>NA</td>
</tr>
<tr>
<td>Vapor density</td>
<td>1.6 (air = 1)</td>
</tr>
<tr>
<td>Explosive limits</td>
<td>NA</td>
</tr>
<tr>
<td>Solubility in water</td>
<td>570 mg/L at 20°C &amp; 100% O3; 0.64 @0°C</td>
</tr>
<tr>
<td>Viscosity</td>
<td>NA</td>
</tr>
</tbody>
</table>

## 10. STABILITY AND REACTIVITY

Ozone is highly unstable and highly reactive. Avoid contact with oxidizable substances. Ozone will readily react and spontaneously decompose under normal ambient temperatures.

## 11. TOXICOLOGICAL INFORMATION

**Likely routes of exposure:** inhalation, eyes, skin exposure.  
**Effects of Acute Exposure:** Discomfort, including headache, coughing, dry throat, shortness of breath, pulmonary edema; higher levels of exposure intensify symptoms. Possible irritation of skin and/or eyes.  
**Effects of Chronic Exposure:** Similar to acute exposure effects, with possible development of chronic breathing disorders, including asthma.

**LC50:** mice, 12.6 ppm for 3 hours; hamsters, 35.5 ppm for 3 hours

**Irritancy of Ozone:** YES

**Sensitization to Ozone:** NO

**Carcinogenicity (NTP, IARC, OSHA):** NO

**Reproductive Toxicity, Teratogenicity, Mutagenicity:** Not Proven

**Toxicologically Synergistic Products:** Increased susceptibility to allergens, pathogens, irritants

## 12. ECOLOGICAL INFORMATION

The immediate surrounding area may be adversely affected by an ozone release, particularly plant life. Discharge of ozone in water solution may be harmful to aquatic life. Due to natural decomposition, bioaccumulation will not occur, and the area affected will be limited.

## 13. DISPOSAL CONSIDERATIONS

**Off gassing of ozone should be through an ozone destruct unit which breaks ozone down to oxygen before release into the atmosphere.**

## 14. TRANSPORT INFORMATION

**NOT APPLICABLE,** as ozone is unstable and either reacts or decomposes, and must be generated at the location and time of use.

## 15. REGULATORY INFORMATION

**SARA Title III Section 302 EHS TPQ: ** 100 lbs.  
**SARA Title III Section 304, EHS RQ: ** 100 lbs.  
**SARA Title III Section 313: ** > 10,000 lbs. used/year.  
Source: EPA List of Lists

## 16. OTHER INFORMATION

**Half-life of ozone in water at 20°C = 20 min. In dry still air at 24°C = 25 hr.** decreases significantly with increase in humidity, presence of contaminants, air movement, and/or increase in temperature.

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Disclaimer: Ozone Solutions provides this information in good faith, but makes no claims as to its completeness or accuracy. It is intended solely as a guide for the safe handling of the product by properly trained personnel, and makes no representations or warranties, express or implied, of the merchantability or fitness of this product for any purpose, and Ozone Solutions will not be responsible for any damages resulting from the use of, or reliance upon, this information.
APPLICATIONS & INDUSTRIES

- Air Treatment & Odor Control
- Aquaculture & Zoos
- Biofuel
- Bottled Water
- CIP (Clean in Place)
- Cooling Tower
- Dairy
- Drinking Water Treatment
- Food Processing & Storage
- Grain & Feed Remediation
- Groundwater & Soil Remediation
- HVAC
- Laundry
- Livestock
- Medical
- Pharmaceutical
- Pools, Waterparks, & Spas
- Pulp & Paper
- Semiconductor Production
- Wastewater Treatment
- Wine & Beer

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