

THE DEFINITIVE GUIDE  
TO UNDERSTANDING



# OZONE ELEMENT

[ozonesolutions.com](http://ozonesolutions.com)

## READING THE OZONE GUIDE

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.

[LEARN MORE](#)

If you find an incorrect fact in this guide, please email us at [info@ozonesolutions.com](mailto:info@ozonesolutions.com)

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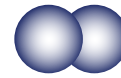
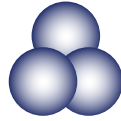
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## PROPERTIES OF OZONE VS. OXYGEN



PROPERTY	OZONE	OXYGEN
Molecular Formula	O <sub>3</sub>	O <sub>2</sub>
Alternate Names	Triatomic Oxygen	--
Molecular Weight	48	32
Color	Light Blue	Colorless
Characteristic Smell	"Electrical" Odor	--
Solubility in Water (0° C)	0.64	0.049
Density (g/l)	2.144	1.429
Boiling Point	-111.9° C	-183° C
Flash Point	Not Applicable	Not Applicable
Auto-Ignition Temperature	Not Applicable	Not Applicable
Flammability	None	None
Electrochemical Potential (eV)	2.07	1.23



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!

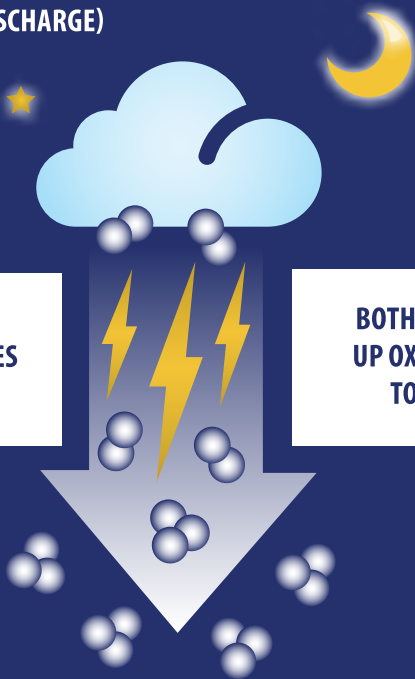


All commercial planes and military jets have special filters to remove ozone from the air which permit passengers and pilots to breathe at these high altitudes. You didn't think that you kept breathing the same air over and over, did you?

**HOW IS OZONE MADE? DID YOU KNOW THAT OZONE IS MADE IN NATURE? IT NATURALLY DOES IT IN TWO WAYS.**

**1 LIGHTNING  
(CORONA DISCHARGE)**

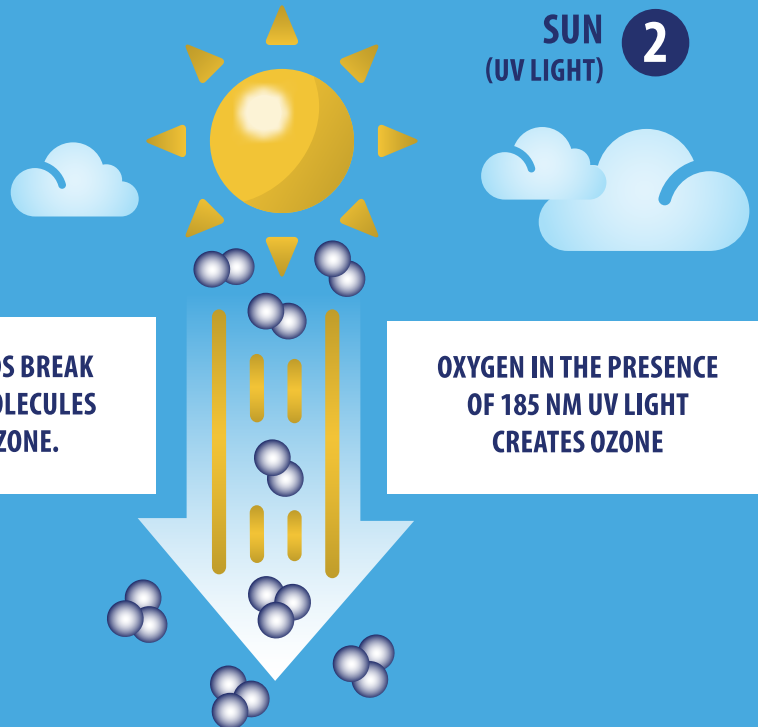
LIGHTNING PASSING THROUGH THE AIR CREATES OZONE FROM OXYGEN



BOTH METHODS BREAK UP OXYGEN MOLECULES TO FORM OZONE.

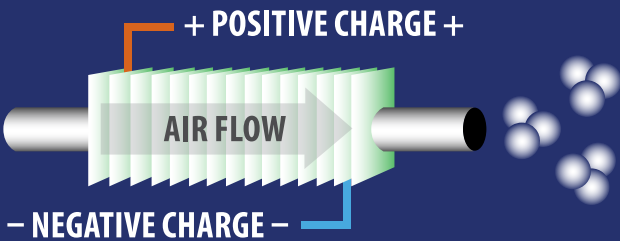
**SUN  
(UV LIGHT) 2**

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**



OXYGEN, 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

**UV LIGHT 2**



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

OXIDIZING AGENT	OXIDIZING POTENTIAL
OZONE	2.07
HYDROGEN PEROXIDE	1.77
PERMANGANATE	1.67
HYPOCHLOROUS ACID	1.49
CHLORINE GAS	1.36
HYPOBROMOUS ACID	1.33
OXYGEN	1.23
BROMINE	1.09
HYOIODOUS ACID	0.99
CHLORINE DIOXIDE	0.95
HYPOCHLORITE	0.94
CHLORITE	0.76
IODINE	0.54

Source: [water.epa.gov/lawsregs/rulesregs/swda.mdbp/upload/2001\\_01\\_12\\_mdbp\\_alter\\_chapt\\_3.pdf](http://water.epa.gov/lawsregs/rulesregs/swda.mdbp/upload/2001_01_12_mdbp_alter_chapt_3.pdf)



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 55 million dollar ozone system was installed and effectively killed this organism. Milwaukee has not had an outbreak since!



Want to know the estimated financial cost of this outbreak? Click to learn about Milwaukee's financial cost of not using ozone: [http://wwwnc.cdc.gov/eid/article/9/4/02-0417\\_article?utm\\_source=Ozone+Book&utm\\_medium=qr&utm\\_campaign=Ozone%20Book](http://wwwnc.cdc.gov/eid/article/9/4/02-0417_article?utm_source=Ozone+Book&utm_medium=qr&utm_campaign=Ozone%20Book)

**LEARN MORE**



# 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.

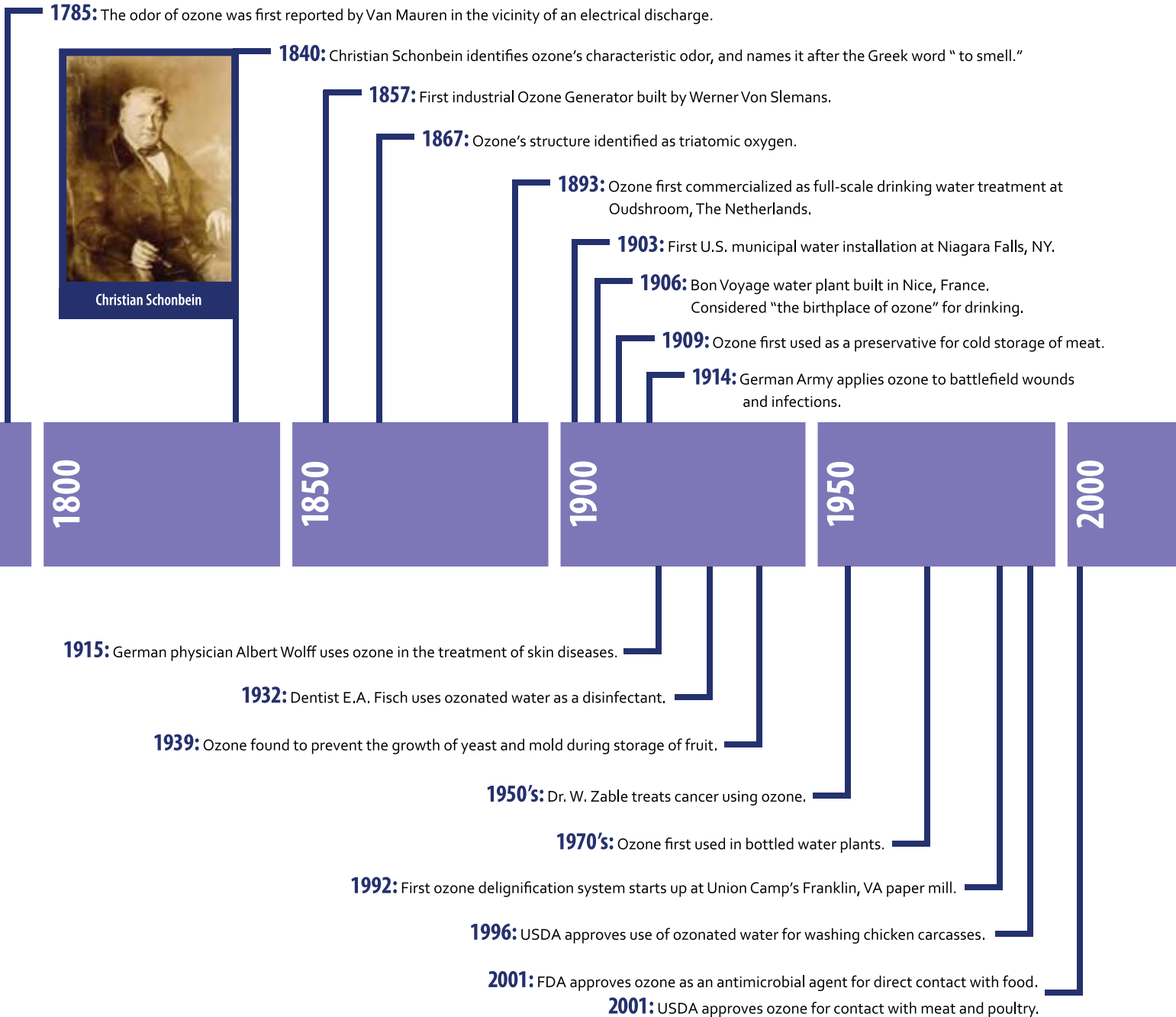
OBSERVED EFFECTS	CONCENTRATION (PPM)
Threshold of odor, normal person	0.005-0.02
Maximum 8 hour average exposure limit	0.1
Minor eye, nose and throat irritation, headache, shortness of breath	>0.1
Breathing disorders, reduced oxygen consumption, lung irritation, severe fatigue, chest pain, dry cough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





# 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.

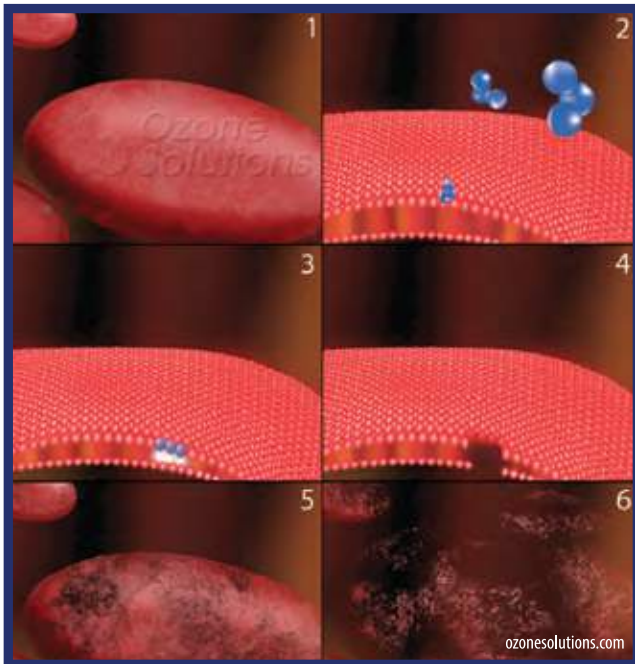


Nice, France is often credited with the first municipal ozone installation. This is not the case. The first municipal ozone installation was at Oudshroom, Netherlands. However, it is no longer in operation. Nice, France is considered the birthplace of ozone because it is the oldest, continuously operating,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



Source: BCC Research

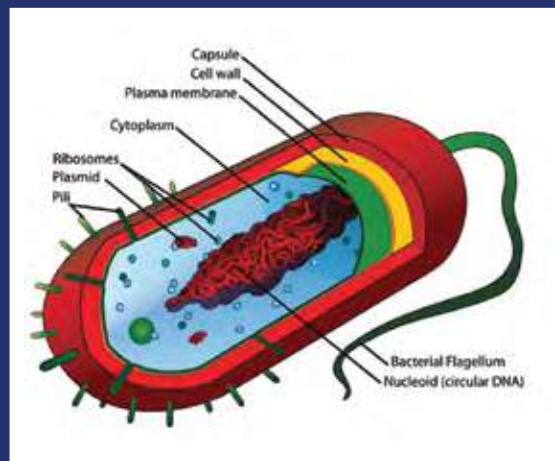
# OZONE EFFECTS ON BACTERIA, VIRUSES, & MOLDS



## 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!

**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 envelope the white cell. Once inside the cell wall, the white cell will metabolize water into oxidants such as hydroxyl (OH<sup>-</sup>) and hydrogen peroxide (H<sub>2</sub>O<sub>2</sub>). 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."



PATHOGEN	DOSAGE
Aspergillus Niger (Black Mount)	Destroyed by 1.5 to 2 mg/l
Bacillus Bacteria	Destroyed by 0.2 m/l within 30 seconds
Bacillus Anthracis	Ozone susceptible
Bacillus Cereus	99% destruction after 5-min at 0.12 mg/l in water
B. Cereus (Spores)	99% destruction after 5-min at 2.3 mg/l in water
Bacillus Subtilis	90% reduction at 0.10-PPM for 33 minutes
Bacteriophage F2	99.99% destruction at 0.41 mg/l for 10-seconds in water
Botrytis Cinerea	3.8 mg/l for 2 minutes
Candida Bacteria	Ozone susceptible
Clavibacter Michiganense	99.99% destruction at 1.1 mg/l for 5 minutes
Cladosporium	90% reduction at 0.10-PPM for 12.1 minutes
Clostridium Bacteria	Ozone susceptible
Clostridium Botulinum (Spores)	0.4 to 0.5 mg/l threshold value
Coxsackie Virus A9	95% destruction at 0.035 mg/l for 10-seconds in water
Coxsackie Virus B5	99.99% destruction at 4.1 mg/l for 2.5-minutes in sludge effluent
Diphtheria Pathogen	Destroyed by 1.5 to 2 mg/l
Eberth Bacillus Typhus Abdomanalis)	Destroyed by 1.5 to 2 mg/l
Echo Virus 29: The virus most sensitive to ozone	After a contact time of 1 minute at 1 mg/l of ozone, 99.999% killed
Enteric Virus	95% destruction at 4.1 mg/l for 29 minutes in raw wastewater
Escherichia Coli Bacteria (from feces)	Destroyed by 0.2 mg/l within 30 seconds in air
E-coli (in dean water)	99.99% destruction at 0.25 mg/l for 1.6 minutes
Encephalomyocarditis Virus	Destroyed to zero level in less than 30 seconds with 0.1 to 0.8 mg/l
Endamoebic Cysts Bacteria	Ozone susceptible
Enterovirus	Destroyed to zero level in less than 30 seconds with 0.1 to 0.8 mg/l
Fusarium Oxysporium S Sp. Lycopersici	1.1 mg/l for 10 minutes
Fusarium Oxysporium F Sp. Melonogea	99.99% destruction at 1.1 mg/l for 20 minutes
GDVII Virus	Destroyed to zero level in less than 30 seconds with 0.1 to 0.8 mg/l
Hepatitis A Virus	99.5% reduction at 0.25 mg/l for 2-seconds in a phosphate buffer
Herpes Virus	Destroyed to zero level in less than 30 seconds with 0.1 to 0.8 mg/l
Influenza Virus	0.4 to 0.5 mg/l threshold value
Klebs-Loffler Bacillus	Destroyed by 1.5 to 2 mg/l
Legionella Pneumophila	99.99% destruction at 0.32 mg/l for 20 minutes in distilled water
Luminescent Basidiomycetes	Destroyed in 10 minutes at 100-PPM
Mucor Piriformis	3.8 mg/l for 2 minutes
Mycobacterium Avium	99.9 with a CT value of 0.17 in water
Mycobacterium Foruitum	90% destruction at 0.25 mg/l for 1.6 minutes in water
Penicillium Bacteria	Ozone susceptible
Phytophthora Parasitica	3.8 mg/l for 2 minutes
Poliomyelitis Virus	99.99% kill with 0.3 to 0.4 mg/l in 3-4 minutes
Poliovirus Type 1	99.5% destruction at 0.25 mg/l for 1.6 minutes in water
Proteus Bacteria	Very susceptible
Pseudomonas Bacteria	Very susceptible
Rhabdovirus Virus	Destroyed to zero level in less than 30 seconds with 0.1 to 0.8 mg/l
Salmonella Bacteria	Very susceptible
Salmonella Typhimurium	99.99% destruction at 0.25 mg/l for 1.67 minutes in water
Schistosoma Bacteria	Very susceptible
Staph Epidermidis	90% reduction at 0.1-PPM for 1.7 minutes
Staphylococci	Destroyed by 1.5 to 2.0 mg/l
Stomatitis Virus	Destroyed to zero level in less than 30 seconds with 0.1 to 0.8 mg/l
Streptococcus Bacteria	Destroyed by 0.2 mg/l within 30 seconds
Verticillium Dahliae	99.99% destruction at 1.1 mg/l for 20 minutes
Vesicular Virus	Destroyed to zero level in less than 30 seconds with 0.1 to 0.8 mg/l
Virbrio Cholera Bacteria	Very susceptible
Vicia Faba Progeny	Ozone causes chromosome aberration and its effect is twice that observed by the action of X-rays

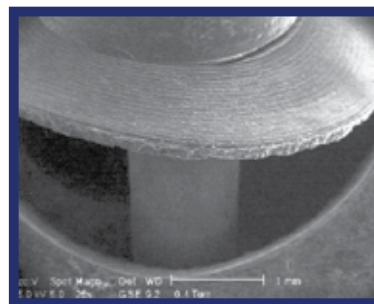
<b>KEY:</b>	Bacteria	Virus	Mold
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# OZONE COMPATIBLE MATERIALS

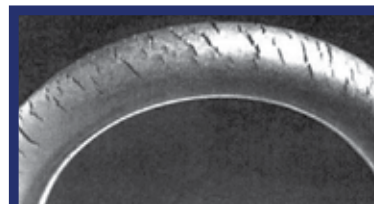
- Many of these materials were tested at the Ozone Solution's lab. Some are commonly known and rated as shown by others. All tests were performed at high levels (>1000 PPM) of ozone concentration.
- For any materials not shown, please call. We may have data on file or we can use our labs to test the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

MATERIAL	RATING
ABS plastic	B
Acetal (Delrin®)	C
Acrylic (Perspex®)	B
Aluminum	C (Wet Ozone) B (Dry Ozone)
Brass	B
Bronze	B
Buna-N (Nitrate)	D
Butyl	A
Cast Iron	C
Chemraz	A
Copper	B
CPVC	A – Does get brittle
Cross-Linked Polyethylene (PEX)	A
Durachlor – 51	A
EPDM	B (Dry Ozone) C (Wet Ozone)
EPR	A
Ethylene-Propylene	A
Fiber Reinforced Plastics (FRD)	D
Flexelene	B
Fluorosilicone	A
Galvanized Steel	C
Glass	A
Hastelloy-®	A
HDPE	A
Hypalon®	C
Hytrel	C
Inconel	A
Kalrez	A
Kel-F® (PCTFE)	A
LDPE	B
Magnesium	D
Monel	C
Natural Rubber	D
Neoprene	C
Nylon	D
PEEK	A
Polyacrylate	B
Polyamide (PA)	C
Polycarbonate	A
Polyethylene	B
Polypropylene	C
Polysulfide	B
Polyurethane, Millable	A
PVC	A (Ozone in water) Does get brittle B (Ozone in air) Does get brittle
PVDF (Kynar®)	A
Santoprene	A
Silicone	A
Stainless Steel – 304/316	A
Stainless Steel – other grades	B
Steel (Mild)	D
PTFE	A
Titanium	A
Tygon	B
Vamac	A
Viton	A
Zinc	D

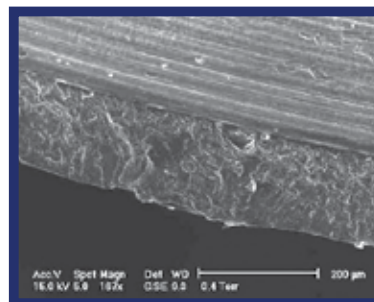
RATING	DESCRIPTION
A Excellent	Ozone has no effect on these materials. They will last indefinitely.
B Good	Ozone has minor effect on these materials. Prolonged use with high concentrations of ozone will break down or corrode these materials beyond usefulness.
C Fair	Ozone will break down these materials within weeks of use. Prolonged use with any ozone concentration will break down or corrode these materials beyond usefulness.
D Poor	Ozone will break down these materials within days or even hours of use. These materials are not recommended for any use with ozone.



Electron microscope image of a nitrile butadiene rubber diaphragm seal after exposure to ozone. Note the cracks are formed at sharp corners in the seal.



Ozone cracking in natural rubber tubing.



Close-up of ozone cracking on nitrile butadiene rubber, taken with an electron microscope.

**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.**





# 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

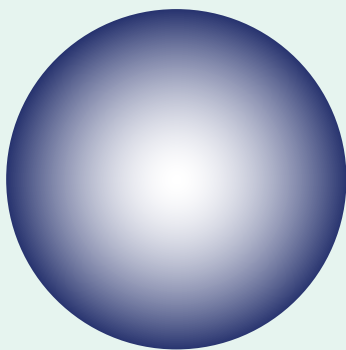
- Low cost
- Easy to set up
- Low energy – does not require a water pump

### DISADVANTAGES

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

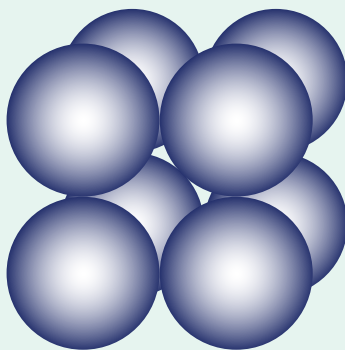
- The diameter of a gas bubble has a dramatic impact on surface area
- Be picky when it comes to selecting a bubble diffuser. It can mean the difference between success and failure.
- The transfer of ozone gas into water is directly related to its surface area (total bubble surface area)
- It is critical 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 valves (for redundancy) and a water trap.

## BUBBLE(S) VOLUME = 1 CUBIC FOOT



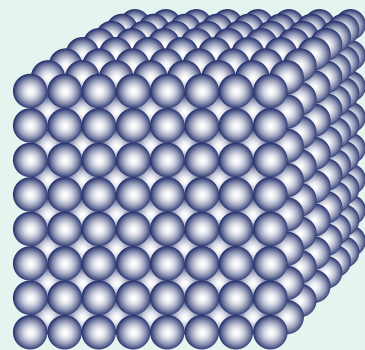
4.8 SQUARE FEET

14.8 IN. DIAMETER  
AREA = 1  
1 BUBBLE



185 SQUARE FEET

10 MM DIAMETER  
38.5X AREA  
54,000 BUBBLES



1,800 SQUARE FEET

1 MM DIAMETER  
375X AREA  
54,000,000 BUBBLES

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

Sources: ("Supplementary Swimming Pool Treatment" by Poolpakinternational.com – MK2\_PTL\_OZONE\_Rev-20110527.pdf.)  
www.wastewater.com/techbulletins/117%20What%20is%20a%20Fine%20Fine%20Bubble.pdf

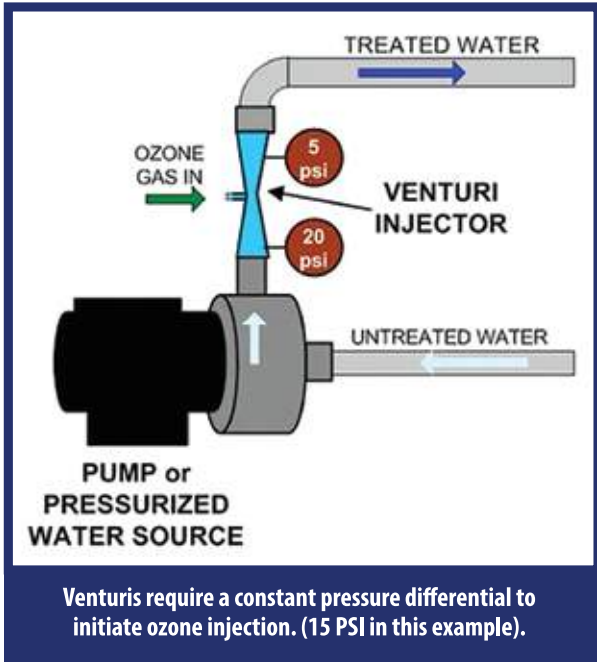


Want to know how many 0.5 mm bubbles it takes to contain 1 ft<sup>3</sup> of ozone? Find out on our ozone diffuser page. It will blow your mind!



# 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.

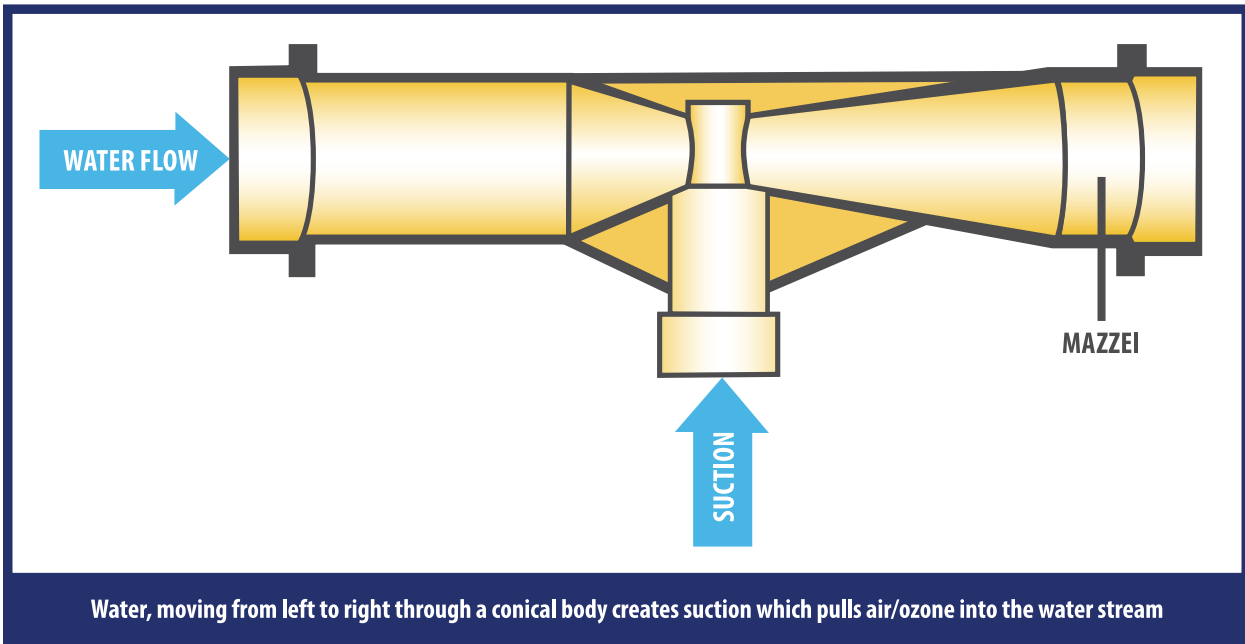


### ADVANTAGES

- 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



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).









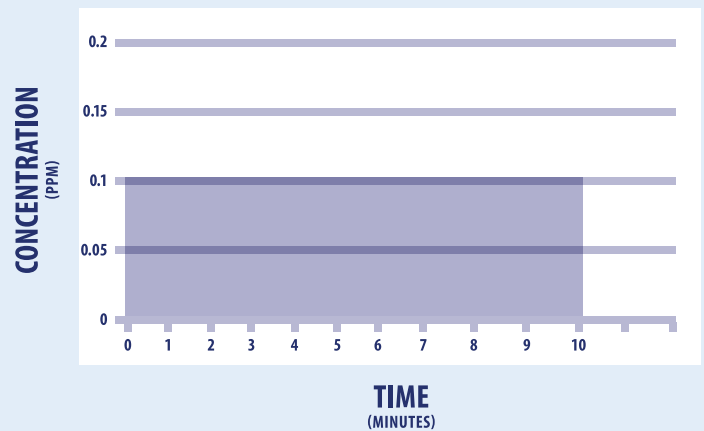
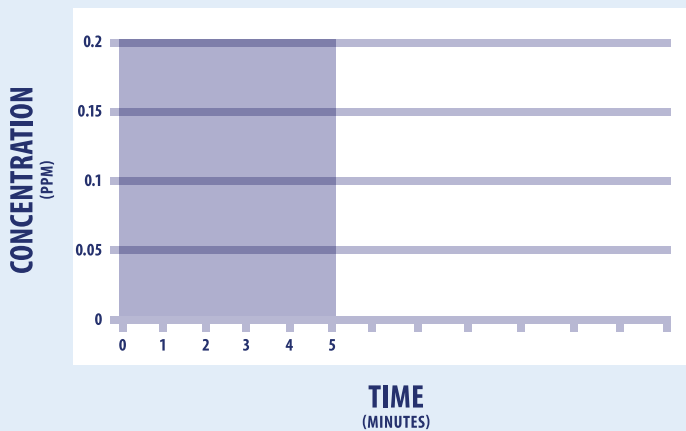
# CT VALUE - WHAT IS IT?

## 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/m<sup>3</sup>
- Molecular weight of ozone: 48
- Density of oxygen: 1.43 kg/m<sup>3</sup>
- Molecular weight of oxygen: 32
- Density of air: 1.29 kg/m<sup>3</sup>
- Density of water: 1,000 kg/m<sup>3</sup>

## **USEFUL CONVERSION FACTORS: (FOR WATER)**

- 1,000 liters = 1 m<sup>3</sup> = 264 US gallons = 35.5 ft<sup>3</sup>
- 1 gal = 3.785 liters = 3,785 ml

## **OZONE CONCENTRATION IN WATER**

- 1 mg/l = 1 PPM = 1 g/m<sup>3</sup> water (By weight)

## **OZONE CONCENTRATION IN AIR BY VOLUME**

- 1 g/m<sup>3</sup> = 467 PPM
- 1 PPM = 2.14 mg/m<sup>3</sup>

## **OZONE CONCENTRATION IN AIR BY WEIGHT**

- 100 g/m<sup>3</sup> = 6.99% (Approximate)
- 1% = 14.3 g/m<sup>3</sup> (Approximate)
- 1% = 6,520 PPM

## **OZONE CONCENTRATION IN OXYGEN BY WEIGHT**

- 100 g/m<sup>3</sup> = 6.99% (Approximate)
- 1% = 14.3 g/m<sup>3</sup> (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).

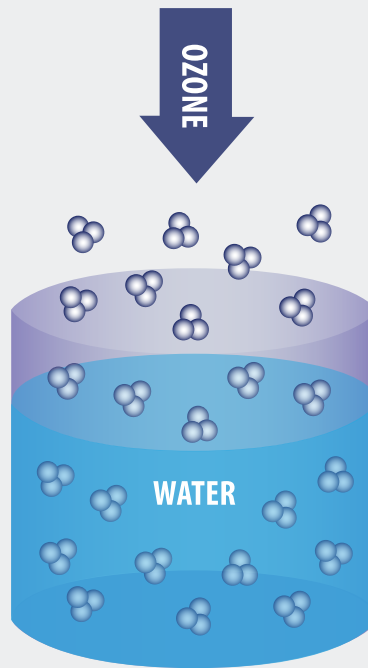


One part per million is equivalent to one blue golf ball in a room 18-ft x 18-ft x 8-ft high filled with white golf balls!

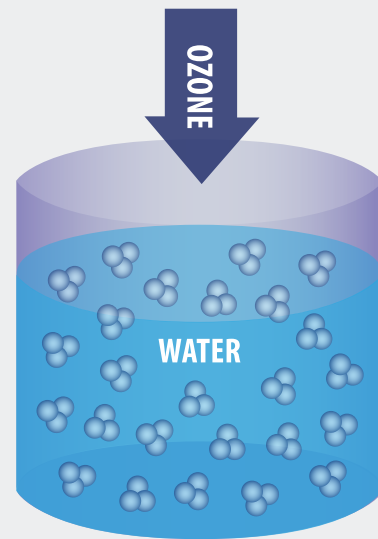


# OZONE DOSAGE VS. DISSOLVED OZONE

- 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.



OZONE DOSAGE: THE AMOUNT OF OZONE APPLIED TO THE WATER



DISSOLVED DOSAGE: THE AMOUNT OF OZONE MEASURED IN THE WATER

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**WHAT ARE THE UNITS OF DISSOLVED OZONE?**

The units are PPM or mg/l. They are equivalent with a 1:1 ratio.

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**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).



Dissolved Ozone Monitor

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.

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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.

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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.



# 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 unstable, 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 (o) (2) of this chapter. (c) The additive meets the specifications for ozone in the Food Chemicals Codex, 4th ed. (1996), 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 381, 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(q)(1)(B)(i)(I), (q)(1)(B)(i)(II), or (q)(1)(B)(i)(III) of the act.



Ozone has been given GRAS approval by the USDA and the FDA for direct contact with food products, including all meat and poultry products.



# SAFETY DATA SHEET (FORMERLY MSDS)

1. PRODUCT IDENTIFICATION			
<b>Product Name: OZONE</b>			
<b>Common Names/Synonyms:</b> Triatomic Oxygen, Trioxygen			
<b>Ozone Generator Manufacturer/Supplier</b> Ozone Solutions, Inc. <a href="http://www.ozonesolutions.com">www.ozonesolutions.com</a> 451 Black Forest Rd. <a href="mailto:info@ozonesolutions.com">info@ozonesolutions.com</a> Hull, IA 51239 712-439-6880			
<b>Product Use:</b> 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:			
Physical:	Health:	Environmental:	
Oxidizing Gas	Skin Irritation – Category 3 Eye Irritation – Category 2B Respiratory System Toxicity – Category 1 (Single & Repeated)	Acute Aquatic Toxicity – Category I	
NOTE: Severe respiratory toxicity will develop before skin or eye irritation go beyond listed categories. <i>Anyone with chronic pulmonary problems, especially asthma, should avoid exposure to ozone.</i>			
WHMIS Classifications (Workplace Hazardous Materials Information System, Canada): <b>C, D1A, D2A, D2B, F</b> Source: CCOHS CHEMINFO Record Number 774			
3. COMPOSITION			
Chemical name:	Ozone		
Common names:	Triatomic oxygen, trioxygen		
Chemical Formula:	O <sub>3</sub>		
CAS Registry Number:	10028-15-6		
4. FIRST AID MEASURES			
Route of Entry	Symptoms	First Aid	
Skin Contact	YES Irritation	Rinse with water	
Skin Absorption	NO NA	NA	
Eye Contact	YES Irritation	Rinse with water, remove contacts	
Ingestion	NO NA	NA	
Inhalation	YES Headache, cough, heavy chest, shortness of breath	Remove to fresh air, provide oxygen therapy as needed	
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 <b>0.1 ppm</b>			
ANSI/ASTM: 8 hour TWA <b>0.1 ppm</b> , STEL <b>0.3 ppm</b>			
ACGIH: 8 hour TWA <b>0.1 ppm</b> ; STEL <b>0.3 ppm</b>			
NIOSH: ELCV <b>0.1 ppm</b> light; <b>0.08 ppm</b> moderate; <b>0.05 ppm</b> , heavy Light, moderate, heavy work TWA <= 2 hours: <b>0.2 ppm</b> Immediately Dangerous to Life or Health (IDLH) <b>5 ppm</b>			
<b>Respiratory Protection:</b> Use full face self-contained breathing apparatus for entering areas with a high concentration of ozone.			
<b>Engineering control:</b> Use ozone destruct unit for off gassing of ozone.			

9. PHYSICAL AND CHEMICAL PROPERTIES			
Physical state	Gas	pH	NA
Molecular Weight	48.0	Decomposition temperature	NA
Appearance	Clear at low concentration, blue at higher concentration	Evaporation rate	NA
Odor	Distinct pungent odor	Flash point	NA
Odor threshold	0.02 to 0.05 ppm; exposure desensitizes	Auto-ignition temperature	NA
Melting point	-193°C/-315°F	Relative density	NA
Boiling point	-193°C/-315°F	Partition coefficient	NA
Vapor pressure	> 1 atm	Flammability	NA
Vapor density	1.6 (air = 1)	Explosive limits	NA
Solubility in water	570 mg/L @20°C & 100% O <sub>3</sub> ; 0.64 @0°C	Viscosity	NA
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.			



Disclaimer: Ozone Solutions provides this information in good faith, but makes no claim as to its comprehensiveness 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 the 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

## 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

## CONTACT US FOR MORE INFORMATION

# CONTACT



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