Sanzonate Global Ozone Fact Sheet

This fact sheet provides information about ozone, including its production, properties, benefits, and safe use. Ozone is a molecule made up of three oxygen atoms, and it is naturally formed by reactions involving ultraviolet rays or by the electrical discharge of lightning. The fact sheet includes a chart comparing the oxidation potential of ozone to other oxidizers, explaining that ozone has no toxic byproducts or potential health hazards when used properly as a microbicide. The fact sheet also provides information on the half-life of ozone in water and the methods for producing ozone, such as corona discharge and plasma block. Additionally, it discusses the factors affecting mass transfer in ozone-contacting systems. This fact sheet is informative and useful for anyone interested in understanding ozone and its properties.

- Ozone O3, is the tri-atomic form of oxygen. In simple it is a molecule composed of three oxygen atoms.
- In nature, ozone is formed by reactions involving ultraviolet rays or by the electrical discharge of lighting.
- Behind fluorine and hydroxyl radicals, ozone has the third-highest oxidation potential at 2.07 (see chart below).
- Ozone O3 is 50 times more powerful and over 3000 times faster, acting than chlorine bleach. During its short "lifespan," ozone is highly reactive.
- The third molecule in O3 is bonded loosely; it will break away, leaving pure oxygen, O2, and a single atom, O.
- Ozone is a high-energy molecule. Its half-life in water at room temperature is only 20 minutes, and it decomposes into simple oxygen.
- Because ozone can be produced on-site and on-demand, the effect is reduced chemical cost, storage, handling, and added plant safety.
- There are no toxic byproducts or potential health hazards when properly used as a microbicide," said Myron Jones, EPRI Food Technology Center Manager. (Microbial contaminants include salmonella and giardia.)

Oxidation Potential of Ozone Compared to Other Oxidizers

Ozone, or O3, is a powerful oxidizer widely used in various applications such as water treatment, food processing, and air purification. One of the key advantages of ozone is its high oxidation potential, which measures its ability to remove electrons from other substances and cause oxidation. Ozone has a relatively high oxidation potential compared to other common oxidizers, making it an effective and efficient option for many applications.

Fluorine	3.06	2.25
Hydroxyl Radicals	2.80	2.05
Ozone	**2.70**	**1.52**
Hydrogen Peroxide	1.77	1.30
Permanganate	1.67	1.23
Hypochlorous Acid	1.49	1.10
Chlorine	1.36	1.00

This high oxidation potential of ozone means it can oxidize a wide range of contaminants, including bacteria, viruses, and organic compounds. It is also effective at removing odors and improving the overall quality of air and water. In water treatment applications, ozone is often used to oxidize organic compounds and other contaminants, helping to improve water quality and reduce the risk of waterborne illnesses.

OZONE HALF-LIFE

The half-life of ozone refers to the amount of time required for half of a given quantity of ozone to decay into oxygen. Ozone is an unstable gas and readily decomposes into oxygen. Therefore, the half-life of ozone is an important factor to consider when determining its effectiveness in various applications.

Typical Gaseous Ozone Half-life time as a Function of Temperature

~ 3 months	-50 °C
~ 18 days	-35 °C
~ 8 days	-25 °C
~ 3 days	20 °C
~ 1.5 hours days	120 °C
~ 1.5 seconds	250 °C

Typical Dissolved in Water Ozone Half-life (PH=7) time as a Function of Temperature

~ 30 minutes	15 °C
~ 20 minutes	20 °C
~ 15 minutes	25 °C
~ 12 minutes	30 °C
~ 8 minutes	35 °

*pH 6.0 ~ 20 minutes, at pH 7.0 ~ 15 minutes, at pH 8.0 ~ 5 minutes

OZONE O3

Ozone (O3) is a molecule consisting of three oxygen atoms with a molecular weight of 48.00 g/mol. It is a pale blue gas with a distinct pungent odor and is heavier than air, with a vapor density of 1.65 compared to air's 1.0. Ozone is an unstable molecule that readily decomposes to form oxygen molecules (O2).

Ozone can also form hydroxyl radicals (HO) when it reacts with water, which are powerful oxidizing agents that can further degrade organic pollutants. This process is known as the advanced oxidation process (AOP). Ozone is a versatile and powerful oxidizing agent with many applications in water and wastewater treatment, air purification, and industrial processes.

- **Molecule**
  - 1840: C. F. Schönbein
  - Three oxygen atoms
- **Properties**
  - Molecular weight: **48,00 g/mol**
  - Boiling point: **-111,9°C (1 atm)**
  - Gas density: **2,144 g/l (0°C, 1 atm)**
  - Enthalpy of formation: **142,12 kJ/mol**
  - Solubility in water: **1370 mg/l (1 atm)**

OZONE GAS CHARACTERISTICS

- Invisible at normal concentrations
- It has a distinct pungent odor
- Heavier than air (vapor density =1.65; air =1.0)
- Decomposes to oxygen molecules
- Is the strongest commercial oxidant
- Is a strong disinfectant
- Can form HO radicals for AOP
- It has a residual short-lived; it converts to O2
- Is Generated On-site

CHEMISTRIES OF OZONE IN WATER

When ozone is dissolved in water, it can undergo various chemical reactions. These reactions depend on pH, temperature, dissolved organic and inorganic substances, and ozone concentration. The most common chemistries of ozone in water are:

DIRECT REACTION

Ozone reacts directly with organic and inorganic compounds in water to form aldehydes, ketones, carboxylic acids, and peroxides. This reaction is rapid and typically occurs within a few seconds.

- Cycloaddition, electrophilic reaction, electron transfer, oxygen atom transfer
- Highly selective reactions with a wide range of organics and inorganics

INDIRECT REACTION

In this reaction, ozone reacts with water to form hydroxyl radicals (OH•). These radicals are highly reactive and can oxidize organic and inorganic substances in water. The reaction rate is slower than direct oxidation, and it requires the presence of dissolved organic and inorganic substances.

- Decomposition into HO° (E° = 2.80 V) on initiation
- Fast and unselective reactions
- Scavenging effect

OZONE FEED GAS

Ozone is generated using pure oxygen as a feed gas. This method is called "oxygen-fed" ozone generation, resulting in higher ozone concentrations than dry air as feed gas. Using oxygen-feed gas is more efficient and cost-effective in applications where high ozone concentrations are required, such as in water treatment and industrial processes.

- The first step in generating ozone is creating concentrated oxygen to feed the ozone generator.
- On average, over 90% of all ozone equipment problems are due to poor-quality air or oxygen.

OXYGEN INFO

- makes up 20.94% (by volume) of the air we breathe
- Is colorless, odorless, & tasteless
- The most widely occurring element on earth
- The second-largest volume of industrial gas produced

- Forms compounds with all chemical elements except the nine noble gases
- Highly valued for its reactivity by itself & in its more reactive form, Ozone

HOW TO PRODUCE OXYGEN

- All systems utilize molecular sieves to perform the separation process
- The size of the sieve varies depending on the volume & pressure of air being separated
- The formula of the sieve varies depending on the function of the sieve
- The maximum purity that can be achieved with PSA & VPSA is 95.6%

METHODS OF OZONE GENERATION

- Ultraviolet (UV): Ultraviolet light at 185 nm generates a low concentration of O3.
- Corona Discharge: The most popular method for large and small applications. Used extensively for municipal water treatment
- Electrolysis: In-situ generation of ozone in water. Frequently used in high-purity water applications, cleanliness, and low dissolved oxygen is important.
- Plasma Block: The most effective, reliable, and economical method. Used in wastewater, bottled water plants, and others.

OZONE CONTACTING SYSTEM

Factors Affecting Mass Transfer

- Gas-Phase Concentration
- Gas to Liquid Ratio (Vg/Vl)
- Pressure within the Contacting System
- Water Temperature
- Mixing (Gas/Liquid Interface Renewal)
- Contact Time
- Instantaneous O3 Demand

OZONE OFF-GAS DESTRUCTION

- Thermal
- Catalyst

- Thermal/Catalytic
- Chemical
- Deliver Off-Gas to other use locations

OZONE SAFETY

- Materials of Construction
- Ventilation
- Safety Monitoring
- Exposure Limits
- Ozone Destructs

SAFETY OZONE ADVANTAGES

- Ozone is not stored in bulk on-site
- The catastrophic large-scale release is not likely because generator shutdown stops the ozone supply
- Ozone is not explosive or flammable
- leaks are identifiable – repair when they occur
- No reported fatalities from ozone exposure

IMPORTANT OZONE SAFETY CONCEPTS

- Automatic warning – You can smell ozone before it harms you
- Effects of ozone exposure are a function of time and concentration
- First aid
- Low-level exposure – get fresh air
- High-level exposure – seek medical attention
- Fix leaks when they occur

RESIDUAL DISSOLVED OZONE DESTRUCTION

- UV at 254 nm wavelength.
- 90mJ/cm2 UV fluence is effective for 1 mg/l O3 destruction to below detectable limits in high purity water.
- Confirm UV sizing for the actual application
- Produces OH· radicals (short-lived) & O2
- Germicidal or TOC UV lamps both works
- Protects downstream process from undesirable O3 oxidation

WHY USE OZONE?

- Oxidation of organic color and odor compounds
- Micro flocculation improves water clarity
- Reduced Chemical Consumption(residual sanitizer & pH)
- Improved Aesthetics
- Bather comfort (skin, eyes, hair)
- Reduced odors
- Superior disinfection protection
- Visibility

EPA QUOTES ABOUT OZONE:

- *Ozone is more effective than chlorine in destroying viruses and bacteria.*
- *The ozonation process utilizes a short contact time.*
- *No harmful residuals need to be removed after ozone because ozone decomposes rapidly.*
- *After ozonation, microorganisms are not re-growth except those protected by the particulates in the wastewater stream.*
- *Ozone is generated on-site, and thus, there are fewer safety problems associated with shipping and handling.*
- *Ozonation elevates the dissolved oxygen (DO) concentration of the effluent. The increase in DO can eliminate the need for re-aeration and raise the DO level in the receiving stream.*