Ozone Fact Sheet

- **Evolution of Ozone**
  - Ozone first discovered by Dr. Shoenbein, Basil, Switzerland, born August 1799.
  - First commercially used for disinfection in a municipality in France in 1899.
  - Oldest operating municipal plant using ozone is in Poland (commissioned in 1901) & Nice, France since 1906
  - Oldest US plant in Whiting, Indiana 1940
  - 3,000 municipal plant Worldwide (400+ in USA)
  - 1,000's Commercial and Industrial Installations

- Ozone, or O_3, is the tri-atomic form of oxygen.
- Stated simply, 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.
- Mountain High uses plasma block technology to produce ozone and Seair's Diffusion System to inject the ozone.
- Behind fluorine and hydroxyl radicals, ozone has the third highest oxidation potential at 2.07 (see chart below).
- Ozone 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 O_3 is bonded very loosely; it will break away, leaving pure oxygen, O_2, and the single atom, O.
- The separated O_2 stays in water tripling its dissolved oxygen. It turns water from an anaerobic environment to an aerobic environment.
- 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 onsite 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 microbiocide," said Myron Jones, EPRI Food Technology Center Manager. (Microbial contaminants include salmonella and giardia.)

Oxidation Potential of Ozone Compared to Other Oxidizers

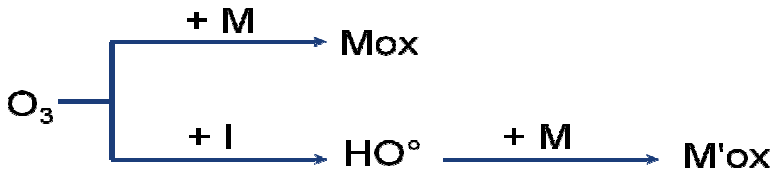
Compound	Oxidation Potential	Relative Power Of Chlorine
Fluorine	3.06	2.25
Hydroxyl Radicals*	2.80	2.05
Ozone	**2.07**	**1.52**
Hydrogen Peroxide	1.77	1.30
Permanganate	1.67	1.23
Hypochlorous Acid	1.49	1.10
Chlorine	1.36	1.00

***This ion is formed when ozone decomposes**

- **EPA Quotes about Ozone:**
  - Ozone is more effective than chlorine in destroying viruses and bacteria.
  - The ozonation process utilizes a short contact time (Approximately 10 to 30 minutes).
  - There are no harmful residuals that need to be removed after ozonation because ozone decomposes rapidly.
  - After ozonation, there is no re-growth of microorganisms, except for those protected by the particulates in the wastewater stream.
  - Ozone is generated onsite, 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 also raise the level of DO in the receiving stream.

- **Ozone O3**
  - Molecule
    - 1840: C. F. Schönbein
    - 3 oxygen atoms
  - Properties

Molecular weight	48,00 g/mol
Boiling temperature	-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)

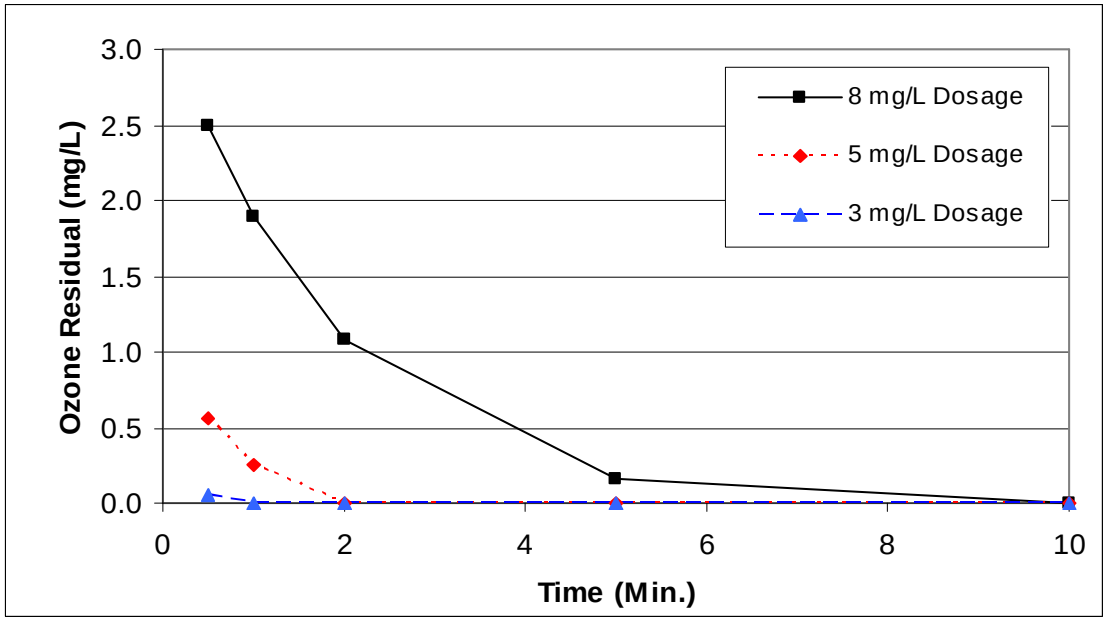
- **Ozone Gas Characteristics**
  - Invisible at normal concentrations
  - Has distinct pungent odor
  - Heavier than air
    (vapor density =1.65; air =1.0)
  - Decomposes to oxygen molecules
- **Ozone**
  - Strongest Commercial Oxidant
  - Strongest Disinfectant
  - Can form HO• radicals for AOP
  - Adds no Chemicals
  - Residual short lived, converts to O2
  - Can create DBP (Bromate)
  - Generated On-site
- **Chemistries of ozone in water**
  - 

- **Direct Reaction**
  - Cycloaddition, electrophilic reaction, electron transfer, oxygen atom transfer

- Highly selective reactions with a wide range of organics and inorganics

- **Indirect Reaction**
  - Decomposition into HO° (E° = 2.80 V) on initiation
  - Fast and unselective reactions
  - Scavenging effect
- **Ozone feed gas**
  - The first step in generationg ozone is creating concentraded oxygen to feed the ozone generator with.
  - On average over 90% of all ozone equipment problems are due to poor quality air or oxygen.
- **Oxygen Info**
  - It makes up 20.94% by volume of the air we breathe
  - It is colorless, odorless, & tasteless
  - It is the most widely occurring element on earth
  - It is the second largest volume industrial gas produced
  - It forms compounds with all chemical elements except the 9 noble gases
  - It is highly valued for its reactivity by itself & in its more reactive form, Ozone
- **How to produce oxygen**
  - All systems utilize molecular sieve 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 low concentration O_3.
  - 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 efficta, reliable, and economic method. Used is wastewater, bottled water plants, and golf.
- **Ozone Contacting System**
  - "Putting Ozone to Work by Dissolving it in Water"
  - *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 location
- **Ozone Destruction Technologies**
    - Thermal Destruction
    - Chemical/GAC Destruction
    - Catalytic Destruction
    - Ultraviolet
- **Ozone Safety**
    - Materials of Construction
    - Ventilation
    - Safety Monitoring
    - Exposure Limits
    - Ozone Destructs
- **Ozone Safety Advantages**
    - Ozone is not stored in bulk on-site
    - Catastrophic large-scale release is not likely because generator shutdown stops ozone supply
    - Ozone is not explosive or flammable
    - leaks are identifiable - repair when they occur
    - No reported fatalities from ozone exposure
      Please. Think safety.
- **Important ozone Safety Concepts**
    - Automatic warning - You can smell ozone before it will harm 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
- **Ozone Demand-Decay Curve**



- **Ozone Half Life**
    - Gas Phase ~ 20 minutes (20° C)

    - Residual (Dissolved Ozone) - Decay
    - at pH 6.0 ~ 20 minutes
    - at pH 7.0 ~ 15 minutes
    - at pH 8.0 ~ 5 minutes
    - Will vary with reaction rate
- Residual Dissolved ozone Destruction
    - UV at 254 nm wavelength.
    - 90mJ/cm^2 UV fluence effective for 1 mg/l O_3 destruction to below detectable limits in high purity water.
    - Confirm UV sizing for actual application
    - Produces OH• radicals (short lived) & O_2
    - Germicidal or TOC UV lamps both work
    - Protects downstream process from undesirable O_3 oxidation
- Why Use Ozone?
    - Oxidation of organic color and odor compounds
    - Microflocculation improves water clarity
    - Reduced Chemical Consumption(residual sanitizer & pH)
    - Improved Aesthetics
    - Bather comfort (skin, eyes, hair)
    - Reduced odors
    - Superior disinfection protection
    - Visibility