



American Water Works Association
Pacific Northwest Section

Jacobs

Challenging today.
Reinventing tomorrow.

Safe Operation with Ozone

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PNWS AWWA Conference 2025

Boise, ID

Roadmap

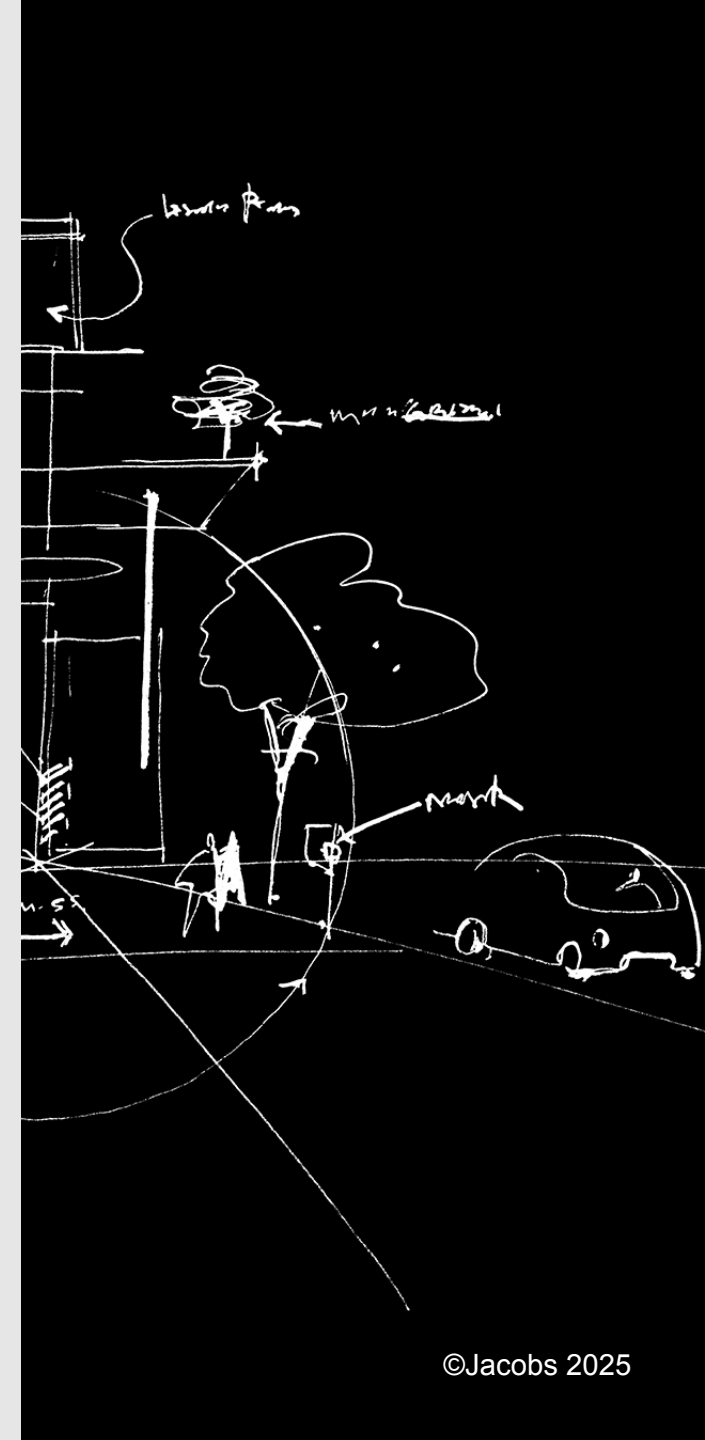
Background

- What is Ozone?
- Applications

Hazard and Risks

- Ozone Exposure Health Effects
- Hazards Related to Ozone Systems

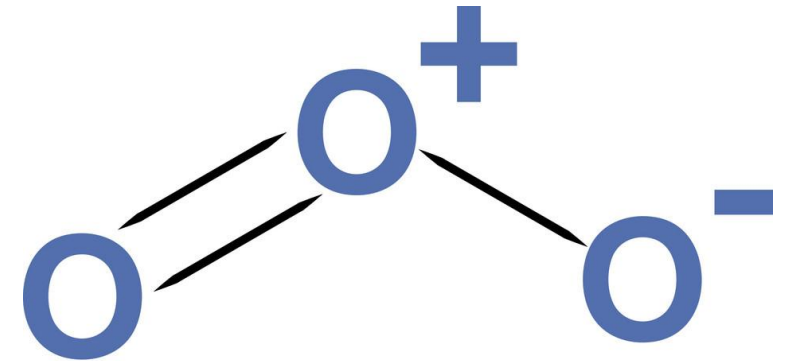
Case Studies



Background

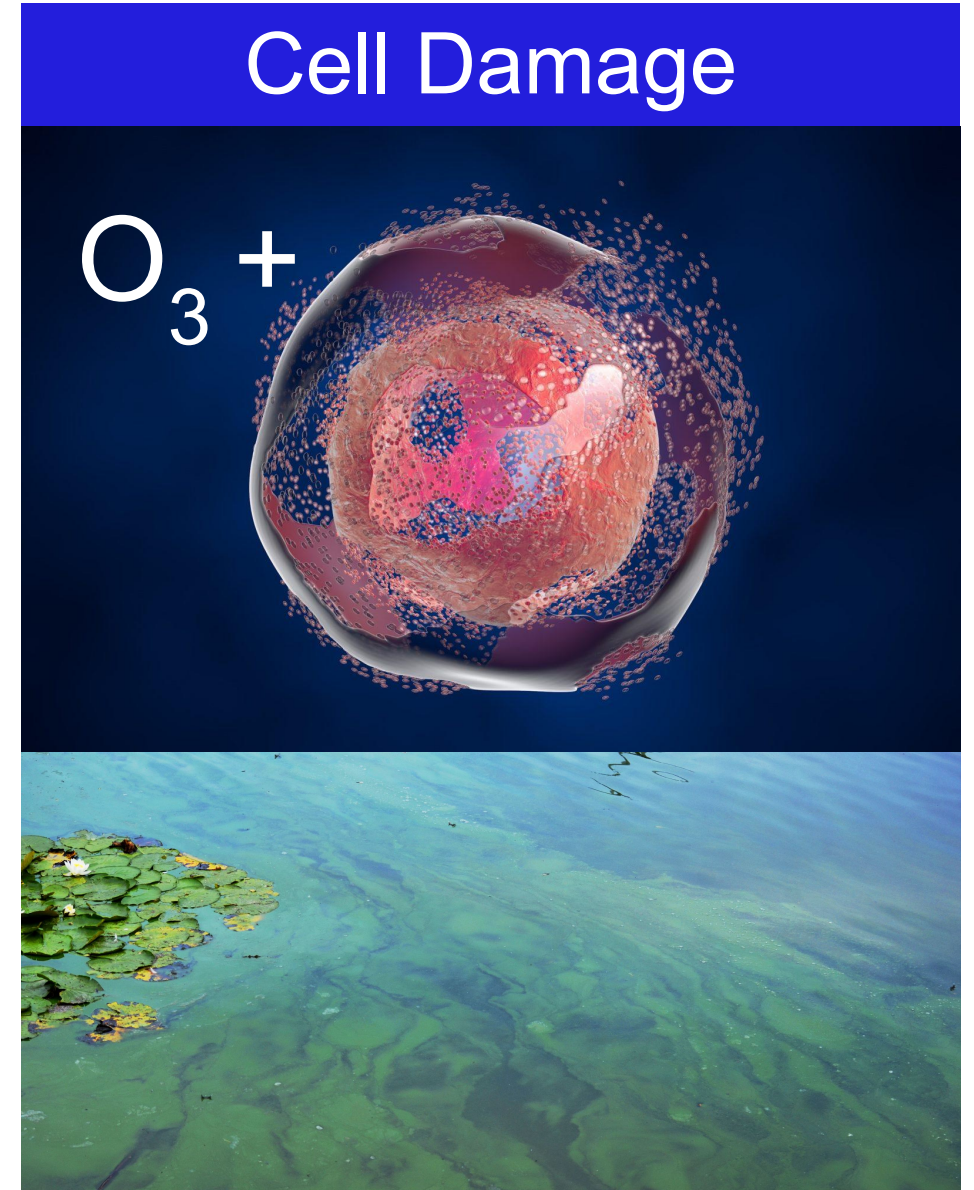
What is Ozone?

- Molecule with Three Oxygen Atoms
- Unstable Gas
- Naturally Occurring
- Smells Like Lightning or Commercial Printers
- Highly Reactive
- Poisonous
- Soluble in Water (Dependent on Temperature)



Applications

- Chemical Oxidation
- Biological Oxidation
 - Break cell walls
- Municipal Water and Wastewater Treatment
 - Direct oxidation of cell walls
 - Bacteria
 - Viruses
 - Parasites
 - Algae
- Taste, Odor, and Color
- Volatile Organic Compounds



Where do we use it in Drinking Water treatment?

Method	Treatment Stage
“Pre-Ozone”	Raw Water, Before Clarification or Sedimentation
“Intermediate-Ozone”	Settled Water, After Clarification or Sedimentation but Before Filtration
“Post-Ozone”	Treated Wastewater Effluent, After Clarification and Filtration

Hazards and Risks

Important Concepts Regarding Ozone Safety

- Inhalation is the most likely form of exposure to ozone.
- You can smell ozone before it will harm you.
- Leaks will occur and need to be fixed.
- Exposure limits exist
- Oxygen and/or ozone leaks will cause the system to shutdown.



Health Effects of Ozone Inhalation

Condition	Ozone Concentration
Detectable odor	0.01 – 0.04 ppm
OSHA 8 hour limit	0.1 ppm
Headache, shortness of breath	> 0.1 ppm
OSHA 15 minute limit	0.3 ppm
Chest pain, dry cough, lung irritation, severe fatigue	0.6 to 1.0 ppm (1 – 2 hours)
Immediately dangerous to life and health	5 ppm
Expected to be fatal	50 ppm (30 minutes)

Ozone Safety – Other Exposures

- **Eye Contact:** Ozone gas is an irritant to the eyes causing pain, and general inflammation.
- **Ingestion:** Not an expected route of exposure.
- **Skin:** Absorption through intact skin is not expected.

First Aid Measures

- **Inhalation:** Remove to fresh air; if breathing is impaired call 911
- **Ingestion:** Not an expected route of exposure.
- **Skin Contact:** Wash skin thoroughly with soap and water.
- **Eye Contact:** Immediately 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 medical attention.
- **Acute:** May cause irritation of skin, eyes, and mucous membranes of the respiratory tract.
- **Chronic:** Long term health effects are not expected from exposures to ozone. A partial tolerance appears to develop with repeated exposures

Types of Hazards Related to Ozone Systems

- LOX is cold, stored at -297F at 1 atm
- Ozone is a toxic gas and a fire hazard
- Can create oxygen enriched environments
- High voltage equipment (Power Supply Units)
- Confined spaces
- Chemical spills – bisulfite and peroxide
- Moving equipment (pumps, blowers)
- Hearing protection required



Oxygen System – Safety Considerations

- LOX is cold, stored at -297F at 1 atm. Liquid Oxygen systems include a low temperature shutdown.
- Liquid Oxygen (LOX) is inherently nonflammable, however, when combined with organic materials, energetic reactions can occur, e.g. combustion is accelerated. NO SMOKING.
- Oxygen rich environment (23%_{vol}) may result
 - Oxygen monitors are required in all indoor areas with oxygen (generally Ozone Generation Room and Destruct Room)
 - Clothing absorbs oxygen
 - Special lubricants are required
- Do not store LOX around asphalt or certain types of concrete joint filler.
- Provide pressure relief between all LOX isolation valves as it will expand and increase pressure significantly as it warms.

Oxygen Safety Equipment



Ambient Oxygen Monitor



Safety relief valve
between isolation
valves

Nitrogen Boost System – Safety Considerations

- Compressed air and electricity are dangerous.
- When performing maintenance or service work, make sure that the electrical supply has been disconnected and locked out, and the internal compressor system has been completely relieved of all pressure.



Ozone – Safety Considerations

- Ozone is a highly toxic gas.
- Ozone Generation Rooms should be well ventilated.
- Provide a light/horn at each entrance to an ozone area.
- Provide emergency shutdown buttons or pull stations inside and outside of the building.
- Some jurisdictions require sprinklers.
- Ozone generators must shut down on high ambient ozone levels. Fix leaks immediately. Leaks can be located with a bubble solution and generally occur around flanges and connections to instruments and equipment.
- Ozone is only 6 to 12% of the gas. The rest of the gas is oxygen, so the same oxygen considerations apply.

Ozone – Safety Procedures

- Employees are responsible for their own safety. *When in doubt, stay out.*
- Review MSDS and Safety Instructions.
- Watch for ozone alarm lights and listen for horns. High ambient ozone or oxygen level will trigger an alarm. This will initiate a system shutdown and illuminate the alarm light.
- If system does not shutdown automatically, system can be shutdown through SCADA or Emergency-stop button on front of PSU. Pull stations are also sometimes available on the outside of the building.
- Ventilate the room until the ozone or oxygen alarm clears before entering the room.

Fire Suppression

- Fire suppression systems may be required by local Fire Jurisdiction
 - Wet-pipe system is the least desirable because of the high voltage electrical equipment.
 - Dry chemical systems are recommended, but expensive. The gases released in this system are not harmful to the electrical components in the system or to personnel.
 - Dry-pipe sprinkler system is a common alternative. The sprinkler pipes are empty (dry) unless there is a fire in which case an activation valve opens to put water into the system. The ozone equipment should be turned off prior to the sprinklers turning on.



Dry Chemical Suppresion Systems | Fipro Fire

Signage

- Ozone is a highly toxic gas and appropriate signage is required on all entry doors into any rooms with ozone equipment, including ozone destruct rooms.
 - WARNING – Ozone/Irritant Gas Adequate Ventilation Required. Avoid Prolonged or Repeated Breathing of ozone.
- Ozone contactor hatches should also be labeled.
 - WARNING – Ozone Contactors are Confined Spaces. High Oxygen Atmosphere. Positively No Smoking.

Oxygen Gas

Odorless, colorless gas. Stored as a compressed gas in cylinders. Eye and skin contact may cause frostbite. Inhalation of pure oxygen can cause dizziness and cough above 1 atm. Strong oxidizer capable of igniting combustibles.



CAS No. 7782-44-7

Ozone

Unstable bluish gas; pungent odor. Severely irritating. Also causes: difficulty breathing, visual disturbances, decreased pulse rate/BP, incoordination, chest pain, fatigue, frostbite. Chronic: breathing disorders. Explosive. Oxidizer.



CAS No. 10028-15-6

Ozone Contactor and Destruct – Safety Considerations

- Systems operate under a vacuum. Include and maintain pressure-vacuum relief valves to protect people and structures.
- Ozone contactors are confined spaces. Especially important to use personal gas monitors to ensure that ozone is not present and air is not oxygen enriched.
- Ozone destruct equipment is moving ozone and pure oxygen. Ambient monitors are required.
- Ozone must be destroyed before vented to the atmosphere.
 - max allowable ozone = 0.1 ppm_v (8 hrs TWA)
 - compare with 500 ppm_v in contactor head space



Ozonated Water – Safety Considerations

- Water ozonated at levels common to water plants is not harmful to the skin.
- All ozone in the water should be consumed or destroyed within the ozone contactor. Do not allow ozone to carry over into downstream processes.
 - It will vent to the atmosphere.
 - Downstream materials may not be ozone resistant



Sodium Bisulfite – Safety Considerations

- Locate Sodium Bisulfite (SBS) tanks in containment area
- 38% solution is typically used.
- All tanks must be sealed. Vents must have water seal or trap.
- Overflows must have a dry or liquid scrubber to prevent free discharge of SBS to the containment area.
- SBS is not classified by IBC occupation classification.
- SBS is an irritant. Breathing the fumes will cause coughing and lung irritation.
- SBS is not a hazard per IBC, however it will release toxic sulfur dioxide gas at fire temperature

Case Studies

Case Study 1: Ozone Destruct Explosion

Incident Description

- Week before: Staff noted an odor in the Ozone Destruct Unit (ODU) area that would quickly dissipate.
- Day of: Odor returned stronger (acidic/vinegar) and was traced to ODU #2.
- Destruct units were swapped to determine if odor was from vent gas or ODU. Odor disappeared so ODU #2 was isolated for later troubleshooting.
- 2 hours after being removed from service ODU #2 exploded.

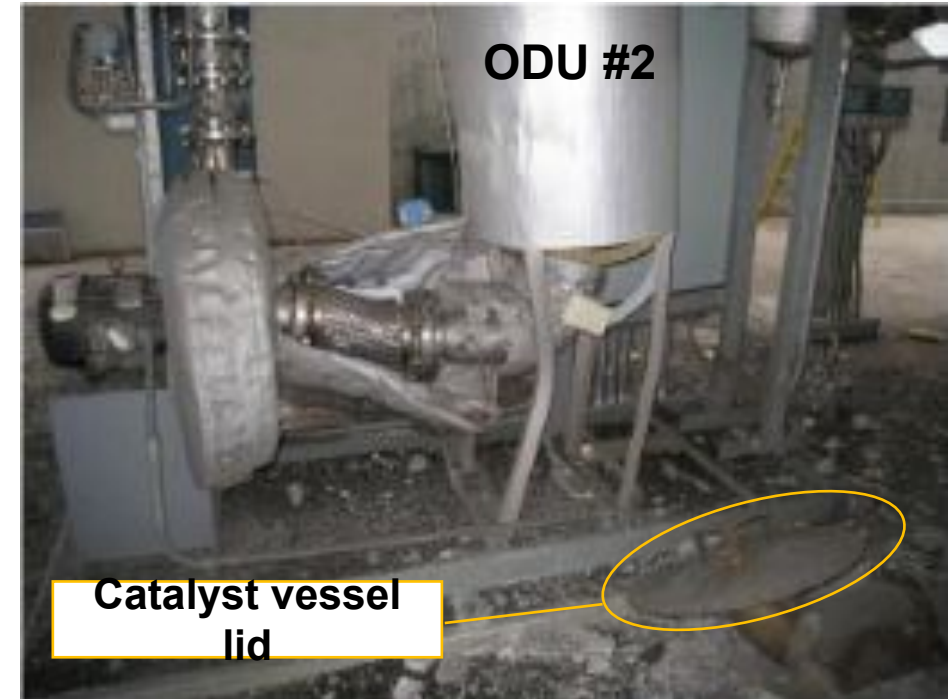
What Happened?????



Case Study 1: Ozone Destruct Explosion

Investigation

- ODU#2 Destruct Catalyst tested positive for organics (undecane and dodecane).
- Same Organics identified in headspace of emulsified anionic polymer.
- Poor water quality increased the pretreatment polymer dose.
- ODU#2 was in service for 91 continuous days.
- Cause: Oxygen reacted with VOCs from emulsified polymer on the catalyst surface and formed hot spots. This caused a runaway exothermic reaction that overpressurized the vessel.



Solution: Change polymer type to a dry type (no VOCs) and schedule regular rotation of ODUs.

Case Study 2: Ozone Contactor Pressure-Vacuum Relief Valve Failure

Incident Description

- Day of: Operators isolated and locked out Ozone Generator 2 to address a Power Supply Unit Alarm.
- Off-gas low pressure alarm for the operation was sounded.
- Generator 1 power supply alarm was sounded. The System was safely shutdown.
- After ozone production stopped, staff detected the smell of Ozone and vacated the area.
- Later, inspection of the contactor roof found a Pressure-Vacuum Relief valve had imploded.

What
Happened???

Case Study 2: Ozone Contactor Pressure-Vacuum Relief Valve Failure

Investigation

- While locking out Generator 2, one train was taken offline.
- The off-gas isolation valve was manually closed for the online Contact Basin, rather than the offline Contact Basin, in error.
- Vacuum built up in the off-line contactor.
- Cause: Due to the vibration during the event or an undiagnosed issue before the incident, the nut securing the pressure relief weight support plate came loose, restricting the valve opening and causing it to deform.
- Solution: add two locking nuts to secure the weight support plate. Add clear labels for manual valves to prevent future mistake. Add regular inspection of the Vacuum-Pressure Relief Valves to the maintenance plan.

Oxygen fires/explosions (OSHA Incident reports)

- Numerous reports of explosions and burns associated with oxygen systems.
- Common Ignition sources: Welding or cigarette
- 5 fatalities noted from uncontrollable fires in an oxygen enriched environment
- Heed all signage and avoid open flame near oxygen/ozone areas.



Accident Summary Number: 68157.015, 14509772, 14332993, 15185986
[Inspection Detail | Occupational Safety and Health Administration osha.gov](https://www.osha.gov)

Final Notes

- Ozone provides many benefits but is a process that should be respected.
- Maintain all life safety equipment and engineered control devices.
- If you see something unusual, trust your gut and stop operation to safely investigate.
- Operator safety is the HIGHEST PRIORITY!





Questions?

Thank you!

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