The Science Of Ozone

The chemistry behind *cleaner water*.

A closer look at how ozone is made, what it does when it meets water, and why it leaves nothing behind. Written for homeowners, pool owners, property managers and growers who want the mechanism, not just the promise.

$2\ O_3 \rightarrow 3\ O_2$ // every molecule of ozone ends as ordinary oxygen

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Three oxygen atoms, and one of them *wants to leave*.

The oxygen we breathe is O_2: two atoms held by a stable double bond. Ozone, O_3, adds a third atom. That arrangement is strained and energetically uphill, so the molecule is always looking to shed its extra atom and return to O_2.

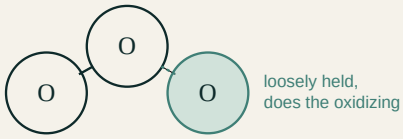
That instability is the whole point. When ozone meets something it can oxidize, the extra oxygen atom goes to work pulling electrons away from it. Bacterial cell walls, dissolved iron, sulfur compounds and odor-causing organics all break down this way. When there is nothing left to react with, the leftover ozone simply decays back to oxygen.

Because it breaks down so quickly, ozone can't be bottled or shipped. It has to be generated at the point of use, seconds before it touches the water.

OXYGEN · O_2 · stable



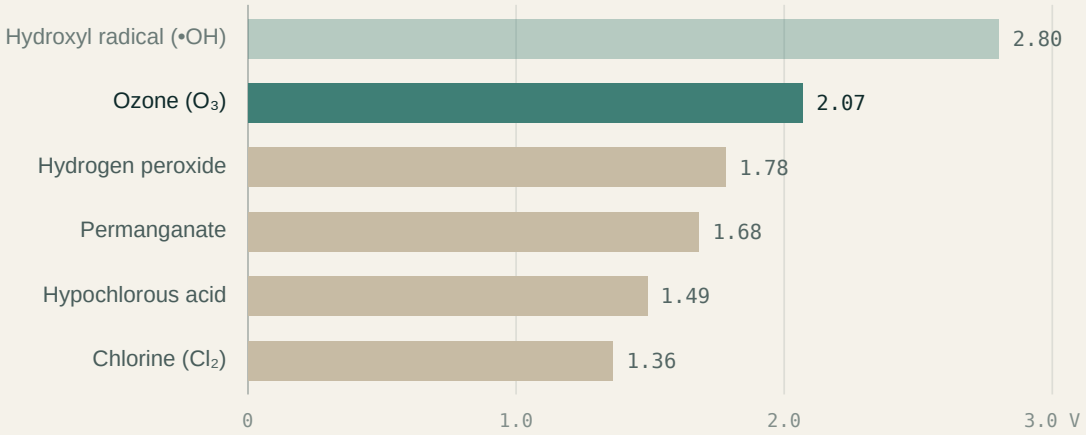
OZONE · O_3 · reactive



The O–O bonds in ozone sit at roughly 117°, with electrons shared across the three atoms. The weakly held third atom is what makes it such a strong oxidizer.

Oxidation potential, in volts

Higher means a stronger pull on electrons. Standard reduction potentials, commonly cited values.



Ozone is the strongest oxidizer used in routine water treatment. The hydroxyl radical, stronger still, is something ozone produces itself as it decomposes (see section 04).

Lightning in a tube, *made from the air*.

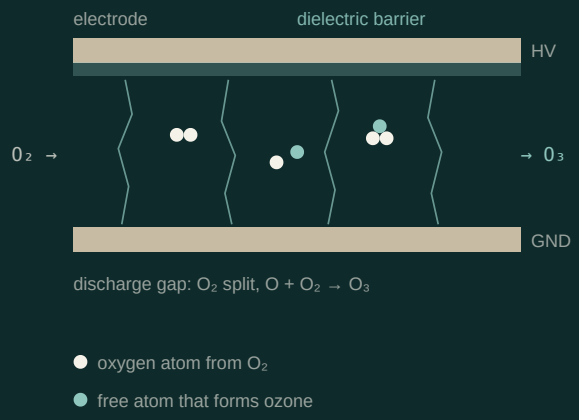
Nature makes ozone two ways: ultraviolet light in the upper atmosphere, and electrical discharge during thunderstorms. That clean smell after a storm is a trace of it. Water-treatment generators copy the second method, called corona discharge.

Dried air or concentrated oxygen flows through a narrow gap between two electrodes separated by a dielectric barrier. A high-voltage field across that gap splits some O_2 molecules into single oxygen atoms. Each free atom quickly bonds to an intact O_2 molecule, and the result is O_3.

$$O_2 + \text{energy} \rightarrow O + O$$
$$O + O_2 \rightarrow O_3$$

The only input is oxygen from the surrounding air and electricity. There is no chemical tank to refill and nothing stored on site. When the system isn't producing, there is no ozone in it.

CORONA DISCHARGE CELL · CROSS-SECTION



discharge gap: O_2 split, $O + O_2 \rightarrow O_3$

Why the feed gas is dried first: moisture in the discharge gap cuts ozone output and can form nitric acid inside the cell.

Ozone only works once it's *dissolved*.

Ozone gas sitting on top of water does nothing. It has to cross from gas bubble to liquid before it can react, and engineers call this step mass transfer. Ozone is far more soluble in water than oxygen is, but getting it dissolved efficiently still takes design.

The usual tool is a venturi injector. Water is forced through a narrowing throat, which speeds it up and drops its pressure. That low pressure pulls ozone gas into the stream as a cloud of very fine bubbles. Small bubbles mean more surface area per unit of gas, and more surface area means faster dissolving.

Once dissolved, ozone needs time in contact with the water to finish its work. Treatment engineers measure disinfection with a single number called CT: dissolved concentration multiplied by contact time.

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CT = C (mg/L) × T (minutes)
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The U.S. EPA publishes the CT each disinfectant needs to reach a given kill rate. The comparison below is why municipal plants around the world use ozone for the organisms that are hardest to kill.

Target, at 10 °C	Ozone CT	Free chlorine CT	Difference
99.9% of *Giardia* cysts (3-log)	1.43	104*	About 70× less
99.9% of viruses (3-log)	0.8	4*	About 5× less
Cryptosporidium	Inactivated at practical doses	Highly resistant at practical doses	Chlorine is largely ineffective

CT in mg·min/L, from U.S. EPA Surface Water Treatment Rule guidance tables. *Free chlorine at pH 7. Lower CT means less disinfectant, or less time, for the same result.

01

Supply line

Water is intercepted at the main, before any fixture draws from it.

02

Generation

Dried air passes through the corona cell. Ozone is made only while it's needed.

03

Injection

A venturi draws ozone into the flow as fine bubbles for fast dissolving.

04

Contact

Dissolved ozone oxidizes contaminants in the stream. Minerals pass through.

05

Carbon polish

Catches oxidized particles and turns any remaining ozone back into oxygen.

04 Two Ways It Reacts

A precise tool and a *blunt one*, from the same molecule.

Once dissolved, ozone attacks contaminants by two separate routes at once. Water chemistry, mainly pH, decides the balance between them.

DIRECT · O_3

Molecular ozone

Intact ozone molecules react selectively. They go after electron-rich targets: carbon–carbon double bonds, dissolved metals, sulfur compounds, and the unsaturated structures that give water color, taste and odor.

This is the route that handles iron, manganese and hydrogen sulfide.

Selectivity	High
Favored by	Lower pH
Speed	Varies widely by compound

INDIRECT · •OH

Hydroxyl radicals

As ozone decomposes in water, part of it forms hydroxyl radicals. At 2.80 V these are stronger than ozone itself and almost completely unselective. They react with nearly any organic molecule they touch, within microseconds.

This route reaches compounds that resist molecular ozone.

Selectivity	Very low
Favored by	Higher pH
Speed	Near diffusion-limited

> Both routes end the same way. The oxidant is used up, and what remains of the ozone decays to O_2. In water, dissolved ozone typically lasts minutes, not hours, which is why it adds nothing to what comes out of the tap.

What goes in, what happens, *where it ends up*.

"Removes contaminants" is vague. Here is what ozone actually does to the common problems in well and municipal water.

Contaminant	Reaction	What happens	Where it goes
Bacteria	cell-wall oxidation	Ozone oxidizes the cell membrane directly and ruptures it (lysis). Chlorine, by contrast, has to diffuse into the cell to disable enzymes.	Inactivated
Viruses & cysts	capsid & wall oxidation	Damages the protein coat and genetic material. Effective against chlorine-resistant cysts like *Cryptosporidium*.	Inactivated
Iron	$Fe^{2+} \rightarrow Fe^{3+}$	Dissolved "clear-water" iron is oxidized to insoluble ferric iron, which forms particles instead of staining fixtures.	Filtered out
Manganese	$Mn^{2+} \rightarrow MnO_2$	Oxidized to insoluble manganese dioxide, the source of black staining when left untreated.	Filtered out
Hydrogen sulfide	$H_2S \rightarrow S$ / SO_4^{2-}	The rotten-egg smell is oxidized to elemental sulfur or odorless sulfate.	Filtered or dissolved, odorless
Taste, odor & color	bond cleavage	Breaks apart the organic molecules behind earthy, musty tastes and the tea color from tannins.	Smaller fragments, taken up by carbon
Chlorine & chloramine	carbon stage	Municipal disinfectant is removed as water passes through the activated carbon polish (section 06).	Removed
Calcium & magnesium	none	Hardness minerals are already fully oxidized, so ozone passes them by. Nothing is exchanged for sodium.	Retained in the water

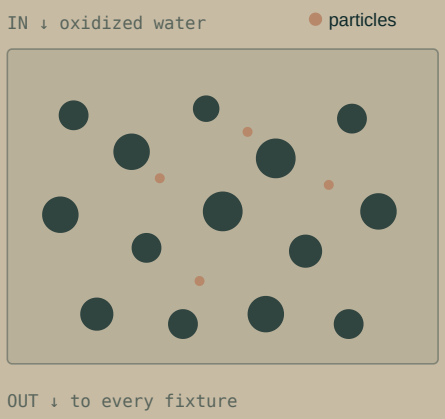
Results depend on source water. A water test at consultation tells us which of these apply to your supply and at what levels.

The last stage does *three jobs*.

Activated carbon is carbon that has been processed to riddle it with microscopic pores. A single gram can hold several hundred to over a thousand square meters of internal surface. Molecules that brush against that surface stick to it, a process called adsorption.

Paired with ozone, the carbon stage finishes the work in three ways. It captures the particles and fragments that oxidation created. It adsorbs remaining organics and removes municipal chlorine. And its surface catalytically breaks down any ozone still dissolved in the water, converting it to oxygen before the water reaches a tap.

Because ozone has already done the heavy lifting upstream, the carbon has less to capture than it would in a stand-alone carbon filter.



Capture, adsorption and ozone destruction all happen in the same bed.

Each technology does one thing well. *Here's the full picture.*

Homeowners are usually choosing between four or five approaches. They work on different principles, so they solve different problems.

	Ozone + carbon	Chlorination	UV lamp	Reverse osmosis	Salt softener
Mechanism	Oxidation, then adsorption	Oxidation	DNA damage by light	Membrane separation	Ion exchange
Microbes	Inactivated, including cysts	Inactivated; cysts resist	Inactivated if water is clear	Physically blocked	No effect
Iron, manganese, H_2S	Oxidized and filtered	Partial	No effect	Point-of-use only	Some iron, fouls resin
Adds to water	Nothing; reverts to O_2	Chlorine residual, byproducts	Nothing	Nothing	Sodium
Minerals	Retained	Retained	Retained	Stripped	Exchanged for sodium
Water waste	None	None	None	2–5 gal per gal made	Brine to drain each cycle
Lasting residual	No	Yes	No	No	No
Consumables	Annual check	Chemical refills	Lamp yearly	Filters, membrane	Salt monthly

> A note on residual. Because ozone reverts to oxygen, it doesn't leave a disinfectant in the water after treatment. For a home, that's the goal. For public pools, health codes require a measurable chlorine residual, so commercial pools pair ozone with a reduced chlorine dose (section 08).

The "pool smell" is a *chemistry problem*, not a cleanliness one.

In a chlorinated pool, chlorine forms hypochlorous acid, the actual sanitizer. Swimmers bring in nitrogen compounds: sweat, urea, body oils. Hypochlorous acid reacts with that nitrogen in steps, forming chloramines.

$$HOCl + NH_3 \rightarrow NH_2Cl \text{ monochloramine}$$
$$HOCl + NH_2Cl \rightarrow NHCl_2 \text{ dichloramine}$$
$$HOCl + NHCl_2 \rightarrow NCl_3 \text{ trichloramine}$$

Trichloramine is volatile. It escapes into the air above the water, and it's the sharp smell and the red, stinging eyes people blame on "too much chlorine." Usually the real problem is too much nitrogen load for the chlorine to handle.

Ozone intervenes earlier in the chain. It oxidizes the organic and nitrogen load directly, so there is far less for chlorine to react with and far fewer chloramines form.

Residential pools and spas

With an O3 Water Pros system, residential pools run with zero added chemicals. Ozone handles the organic load day to day, with no chlorine dosing and no test-strip routine.

Commercial pools

Hotels, HOAs and other public pools are required by health code to hold a chlorine residual. Ozone doesn't replace that residual, but it reduces how much chlorine the pool consumes and cuts chloramine formation, so guests get better air and water.

Tested on a working Utah farm, *side by side*.

A season-long comparison: one field irrigated with ozone-treated water, one untreated control. Same crop, same conditions, same growing window.

+44.6 t

More hay harvested from the treated field this season, 54 more bales than the control.

22% less

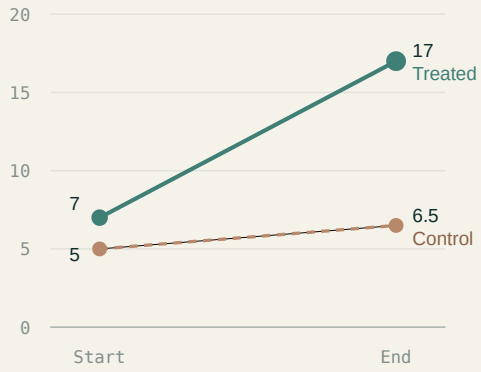
Water used on the treated field to reach that harvest.

RFV 198

Lab-graded Supreme, the top quality tier, by SDK Laboratories (NFTA-certified). RFQ 217.

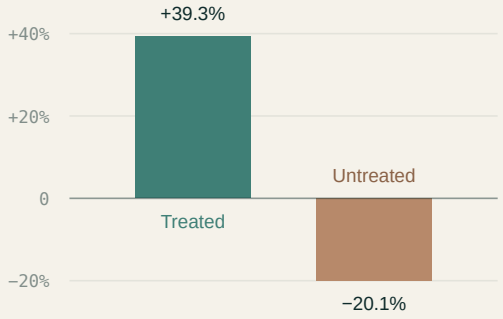
Brix, start to end of season

Percent dissolved solids in plant sap



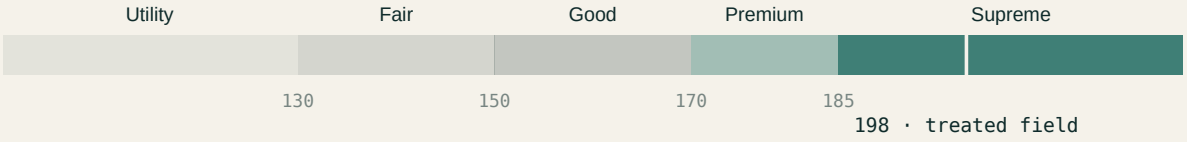
Four-year change in growth

Treated field vs. untreated field over the same period



Where RFV 198 sits on the USDA hay quality scale

Relative Feed Value, USDA market-news quality designations



BRIX

Percent dissolved solids, mostly sugars, in plant sap, read with a refractometer. Higher Brix generally tracks with healthier, more nutrient-dense plants.

RFV

Relative Feed Value. Combines how much of a forage an animal will eat with how digestible it is. Full-bloom alfalfa sets the baseline at 100.

RFQ

Relative Forage Quality. A newer index that factors in fiber digestibility, so it better predicts how animals actually perform on the hay.

> One farm and one season is a strong signal, not a controlled study. We're collecting results as this season progresses. Ask us for the latest numbers and for data closer to your operation.

Good results come from *matching the system to the water*.

Ozone is only as effective as its dose, contact time and flow allow. These are the questions we work through at every consultation, and the ones worth asking any installer.

What's in the water now?	A water test sets the baseline: iron, manganese, sulfur, hardness, pH and, for municipal supplies, chlorine or chloramine. Oxidant demand drives the ozone output needed.
How much water moves, and how fast?	Peak flow in gallons per minute determines injector sizing and contact time. A home with five bathrooms needs different numbers than a two-bath condo.
Where does it enter the property?	Installing at the main line treats every fixture. For farms, treating at the well or source covers irrigation, troughs and spigots from one system.
How is the ozone generated and fed?	Feed-gas drying and generator output determine how much ozone actually reaches the water, not just what's printed on the box.
What finishes the job?	A post-treatment stage should capture oxidized particles and eliminate leftover dissolved ozone before water reaches a tap.
Who installs it, and what backs it?	Licensed, insured installation, a warranty that covers the system for the long term, and a maintenance plan that fits your schedule.

Next Step

Let's test your water and *run the numbers*.

A free, 15-minute consultation covers your water source, what's in it, and the system size that fits. No obligation.

Lifetime warranty Licensed & insured Financing available

Phone

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Service area

Southern California, Utah & Nevada

Systems

Whole-home · Pool & spa · Agricultural · Commercial

References. CT values: U.S. EPA, Guidance Manual for Compliance with the Filtration and Disinfection Requirements (Surface Water Treatment Rule), CT tables. Oxidation potentials: standard reduction potentials as commonly reported in water-treatment literature. Hay grades: USDA Agricultural Marketing Service, hay quality designation guidelines. Field data: O3 Water Pros side-by-side trial, Utah; forage analysis by SDK Laboratories.

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