



# Disinfection of dental unit water with ozone

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Figure 1. The author's prototype corona discharge ozone generator. The electrodes can be seen in the upper part of the unit covered by the glass chamber.

Ozone is a natural biocide that kills bacteria, viruses and fungi within seconds. It is also moderately soluble in water. At room temperature, its solubility in water by weight at 20°C is 3 grams/litre. An ozone level of 0.04 ppm for 4 minutes has been shown to kill any bacteria, virus, mold and fungus, as well as spores of molds and amoebae. However, in the dose required for disinfection of water, ozone does not produce noticeable or harmful fumes. In 1982, the United States Food and Drug Administration (FDA) affirmed the GRAS (Generally Recognized As Safe) status for ozone for water treatment.

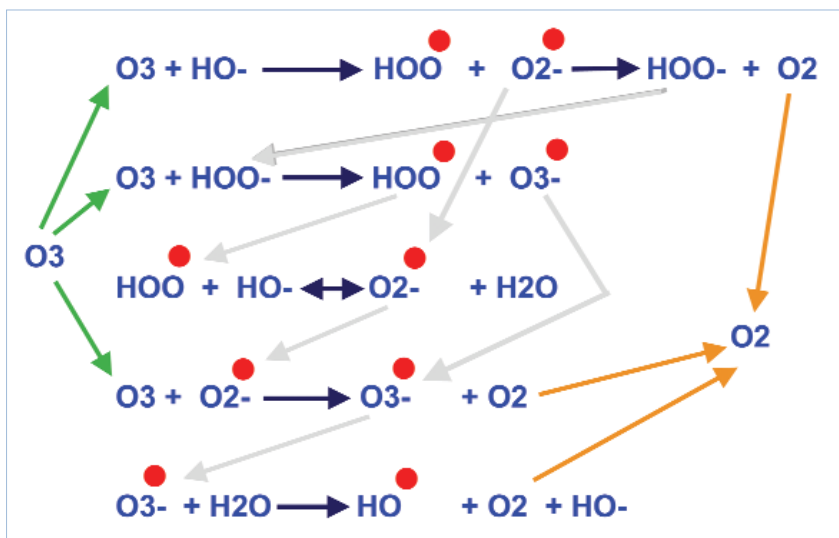


Figure 2. Reactions of ozone in water which give rise to radicals (marked with a red dot).

Ozone does not damage plumbing fittings or pipes, does not affect the pH of water, and helps reduce total dissolved solids in water. Moreover, it leaves no chemical by-products in water, as it breaks down to give di-atomic oxygen

For these reasons, ozone is now used widely for treatment of reticulated water and bottled water as an alternative to traditional biocides such as chlorine. The largest ozone water treatment plant in the world is in Los Angeles and the largest in Australia is in Sydney. As a comparison, based on 99.99% of bacterial concentration being killed and the time taken, ozone is 2,500 times more potent than hypochlorites. With ozone, bacterial killing occurs almost instantaneously through rupture of the cell wall. In contrast, hypochlorite requires diffusion into the cell where it then inactivates enzymes.

## Ozone production

In nature, ozone is created by the combination of oxygen in air under the influence of factors such as ultraviolet radiation or electrical discharges (lightning). Of interest, it is also created in areas where there is intense physical stress on water, such as waterfalls and ocean waves

breaking on rocks, where natural concentrations of ozone in the air can reach levels of up to 0.05 ppm, a point at which it is detectable by most individuals by its characteristic odour.

Because it has a short half-life, ozone will decay rather quickly once produced. It is therefore necessary to produce ozone just as it is required. At room temperature, the half life of ozone in dissolved water is about 30 minutes, whereas the half-life of ozone gas is 20 minutes.

Ozone can be produced in a controlled manner using several methods including electrical corona discharge, cold plasma units, ultraviolet radiation and by electrolytic and chemical reactions. In fact, one of the first patented designs for production of ozone by corona discharge was granted to the electrical genius Nikola Tesla in September 1896, some 110 years ago.

The author has successfully created ozone through a system of his own design which generates impulses of alternating current at voltages of up to 15,000 VAC, giving a dramatic discharge between two electrodes (Figure 1). Being heavier than air (density 1.6), the ozone sinks to the bottom of the glass chamber where it is then collected for use.



Commercial ozone systems for dental use typically employ the same corona discharge principle, but in order to address issues with heating of the electrodes, pass dried atmospheric air over metallic surfaces plated onto ceramic substrates, between which is established a high voltage alternating current electrical field.

## Ozone reactions

The driver of ozone oxidation reactions is the hydroxyl radical (OH), which forms when ozone comes into contact with water. This is the most potent of the various reactive oxygen species which exist. This radical is created by a cascade of electron transfer reactions, the first of which occurs between the ozone (O<sub>3</sub>) and hydroxyl ions (OH<sup>-</sup>) which are naturally present in water (Figure 2). As can be seen from these equations, in addition to the hydroxyl radical, other weaker radicals are also produced including the superoxide radical (O<sub>2</sub><sup>-</sup>), hydroperoxide radical (OOH) and ozone anion radical (O<sub>3</sub><sup>-</sup>).

## Dental unit water treatment

Using nuclear magnetic resonance spectroscopy, Professor Ed Lynch and his group in Belfast have obtained direct evidence for the effect of ozonation of water on biomolecules. Their studies of dental unit water lines (DUWL) water have shown that it contains a wide range of low-molecular-mass biomolecules which are linked to microbial activity of biofilm organisms. These molecules include organic acids such as acetate, formate, lactate and propionate. Other molecules detected included the amino acid glycine, a number of aromatic compounds and occasionally ethanol. Many of these components can be considered as chemotaxonomic 'markers' of the presence of microorganisms in DUWL biofilm.

Their work has shown convincingly that exposure of DUWL samples to ozone caused the oxidation of ethanol and an increase in the concentration of formate due to oxidation of carbohydrates. They also found evidence of oxidation of the aromatic compounds.<sup>1,2</sup> These types of changes were very similar to those seen when bacterially infected carious dentine was treated with ozone.<sup>3</sup>



Figure 3 (left). Ozident water treatment system (Protec) for dental units with removable bottles.  
Figure 4 (above). Operation of the Ozident water treatment system is a simple pushbutton procedure.

Several other studies from the same group have examined the potential for ozonated water to reduce the bacterial load in dental unit water lines.

A study of a newly installed dental unit examined the effect of ozone once this had become colonized with *Pseudomonas aeruginosa*, a gram negative bacterial species that can cause problematic wound and respiratory infections. A HealOzone unit (2100 ppm ozone, 615 mL/minute) was connected to the unit's water bottle and ozone bubbled through for 5 minutes, followed by flushing the high speed hand-piece waterline with ozonated water for another 10 minutes. This treatment was repeated after another week. This treatment reduced the total viable count and eliminated the pathogen for at least another 9 weeks.<sup>4</sup>

In another study, the water lines in a dental unit with existing biofilm was similarly treated with ozone and subjected to microbiological assessment. Ozone was applied for 3 minutes to the water bottle and the line was subsequently flushed for 2 minutes before water was immediately sampled into a sterile container. This was repeated daily each morning for 5 working days. After the weekend, on day 8, a final sample without ozone treatment was collected. There was a bacterial reduction from 5200 to 300 CFU/mL after the first ozone application and then to 0 CFU/ml after the second application onwards.<sup>4</sup>

In another study by the Belfast group, two dental units were treated for either 1 or 3 minutes each day. Samples of DUWL water showed a reduction of bacteria of 1000 fold on day 7 for the 1 minute treatment. Sterile water was found on day 2- for the 3-minute application, and up to 5 weeks thereafter.

A later study by the same group documented a 10,000 fold decrease in bacterial counts for treatment times of 2 minutes and above. The biofilm layer was reduced with a 15 minute application time followed by 10 minutes flushing, but was completely removed with a 15 minute application time and a 15 minute flushing time for 7 days.

Ozonation of dental unit water can be achieved by direct injection of ozone into water such that a controlled dose is delivered. This can be done using a modified apparatus fitted to the HealOzone unit.

An alternative approach that is convenient for dental units with self-contained water systems is the use of a purpose-built water ozonation device. This follows a well known "soda stream" design where the bottle is placed in the unit and the water ozonated immediately before attaching the bottle on to the dental unit. The dosing is regulated electronically to give a consistent ozone concentration. This provides a simple and rapid means to ozonate water in removable bottles.

## References

1. Al Shorman H et al. J Dent Res 82 (Spec Iss B): abstract number 2183. IADR Goteborg 2003.
2. Smith C et al. J Dent Res 81 (Spec Iss B): abstract number 0716. IADR San Diego 2002.
3. Silwood CJ et al. NMR Biomed 12; 345-356. 1999.
4. Al Shorman H et al. J Dent Res 81 (Spec Iss B): abstract number 0711. IADR San Diego, 2002.

## Useful web sites

- <http://www.ozoneapplications.com>
- <http://www.ozonetech.com>
- <http://www.lenntech.com/faqozone.htm>
- <http://wppinc.com/o3info.htm>

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