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Electrolytic ozonation of water: a new solution to the problem of dental unit waterline biofilms

By Professor Laurence J. Walsh

"Ozone requires only a short contact time to kill and inactivate bacteria, parasites, viruses and fungi and its antimicrobial action is relatively unaffected by pH..."

Biofilms form in wet environments and are ubiquitous in dental unit water lines (DUWL). Biofilms begin to form in waterlines once the equipment is connected to a water supply which is not sterile, hence the emphasis on strategies such as ozonation which can render water sterile and thus eliminate the problem at its source.

The problem of waterline biofilm

If bacteria are present in the water entering the dental unit, its waterlines provide the ideal environment for microbial colonization and proliferation because the high surface area to fluid volume ratio results in stagnation and low flow. Because of the laminar flow characteristics of narrow bore tubing (a central high flow rate, but a low flow rate on the periphery), water-borne organisms are dispersed onto the surfaces of the tubing, where they can then attach. Bacterial fouling of dental water systems has been recognized as a problem for almost 60 years[1] and there are a number of documented cases of infection of both dental staff and dental patients, including serious infections such as Legionnaire's disease.[2]

Water exiting DUWL and entering triplex syringes, handpieces or ultrasonic scalers and the water used for filling rinsing cups must be potable (contain less than 500 microorganisms per mL), with recommended levels of less than 200 microorganisms per mL for any patient who is a smoker, immune suppressed or elderly. While reticulated tap water typically contains only 20-50 microorganisms per mL, water exiting DUWL may contain as many as 100,000 microorganisms per mL in newly installed dental waterlines lines after only five days operation and in excess of one million microorganisms per mL in older dental units.[3,4] Out of 55 English dental practices, 95% had DUWL contamination which failed the standard for potable water and typical levels recorded across the UK and Ireland show average levels of 2500 microorganisms per mL.[5,6] A study conducted by the author in 1999 involving 60 dental units in 40 Australian dental practices showed that over 86% of dental unit water samples were not potable and only 12% of water samples were under the target level of 200 microorganisms per mL.[7] By comparison, 93% of the tap water samples from the same 40 locations were potable. The 7 dental units in the study with baseline levels of less than 200 CFU/mL either used self-contained water supplies which were filled only with sterile water or the units were fed with reticulated water that was continuously injected with peroxide.

Water from DUWL is not only delivered into the patient's mouth (where it can come in contact with wounds, or be swallowed), but it is also aerosolized by handpieces, air-water syringes and ultrasonic scalers. This gives respiratory exposure to DUWL bacteria. Major organisms of concern which can be found in DUWL biofilms and in exit water from waterlines are summarized in Table 1.

Table 1. Dental unit waterline pathogens

Microorganism	**Diseases**
Parasites	
Cryptosporidium muris, Cryptosporidium parvum	Cryptosporidiosis (diarrhoea, vomiting and fever)
Giardia lamblia	Giardiasis (diarrhoea)
Bacteria	
Escherichia coli	Gastroenteritis
Legionella pneumophila, Legionella micdadei	Legionnaire's disease, Pontiac fever, wound infections
Pseudomonas aeruginosa	Wound infections, pneumonia
Non-tuberculous mycobacteria	Wound infections, pneumonia

Water ozonation

In the challenge of providing water of high microbial quality to supply dental units, ozone has attracted attention because it possesses several of the properties of an ideal disinfectant: it effectively removes pathogens over a range of physical and chemical conditions; it produces no residues and no unacceptable by-products (only oxygen); it is easy to generate, safe to handle, suitable for widespread use and cost-effective. Ozone requires only a short contact time to kill and inactivate bacteria, parasites, viruses and fungi and its antimicrobial action is relatively unaffected by pH. Unlike chlorination, it is able to give greater than 99% reductions in the levels of parasites such as *Giardia lamblia* and *Cryptosoridium spp.*

Water ozonation is used widely at an industrial scale for water treatment - for example, the domestic water supply for Sydney is ozonated by Sydney Water and the water treatment plant for the Grampians ozonates water to overcome problems caused by algal contamination of the local water source. The latter relies on the ability of ozone to oxidize organic compounds and thus reduce the amount of coagulant required and increase their removal by granular activated carbon. Ozone was approved by NHMRC in 2005 for drinking water treatment and is used routinely to treat bottled water as well as reticulated water. Ozone treatment of reticulated water was introduced in 1893 in Europe and internationally there are over 300 large volume water treatment plants which use this technology. Today water ozonation is used in food processing, restaurants and swimming pools to provide water of high microbial technology.

Ozone versus Legionella

Point-of-use ozonation provides a useful strategy for a dental practice to obtain sterile water with which to supply dental units through a bottled system. The work of Al Shorman[8] has shown that dental unit water ozonation can decontaminate dental units which contain high levels of biofilm, with repeated flushing of freshly ozonated water causing physical removal of biofilm from DUWL tubing (as shown by scanning electron microscopy) and leading to sterility of the exit water. This strategy was used in a recent Australian case of Legionella infection arising from a dental unit, in which water ozonation was used to both treat the supply water and to flush through the contaminated dental unit. This combination of measures successfully sanitized the affected unit and eliminated pathogenic Legionella species, as determined by bacterial culture of sequential water samples.

Pathogenic species of Legionella are found commonly in dental units, with reported frequency rates in the literature of 1-8% across the UK, Europe and North America using culture based tests,[9-11] but over 60% using molecular methods,[12] which makes it surprising that the number of known infections in dental staff and dental patients is low.

Exposure to Legionella bacteria seems to be an inevitable consequence of involvement in dentistry, as shown by studies of DUWL in large dental teaching facilities and of the development of serum antibodies to Legionella in dental students during their dental education and subsequent clinical practice after graduation.[13,14] The development of Pontiac fever in both dental staff members and patients would normally go undetected because this mimics acute influenza, with symptoms such as fever, headache and muscle aches, of short duration with an uneventful convalescence. Staff or patients would not normally attribute such symptoms to an exposure in the dental workplace or indeed report for care to their medical practitioner (although they would still probably have the day off work because of the "flu"). As a result, the epidemiology of transmission of Legionella in the dental workplace has not yet been studied in exquisite detail. There is, however, one well documented case of death of a dentist caused by Legionella organisms.[9] In this 1995 case in northern California, examination of formalin-preserved lung tissue collected at autopsy revealed the presence of Legionella, which was attributed to his exposure to the high levels of Legionella spp. found in his dental operatory, through contaminated aerosols from his dental units, which were identified as the source of his fatal infection.

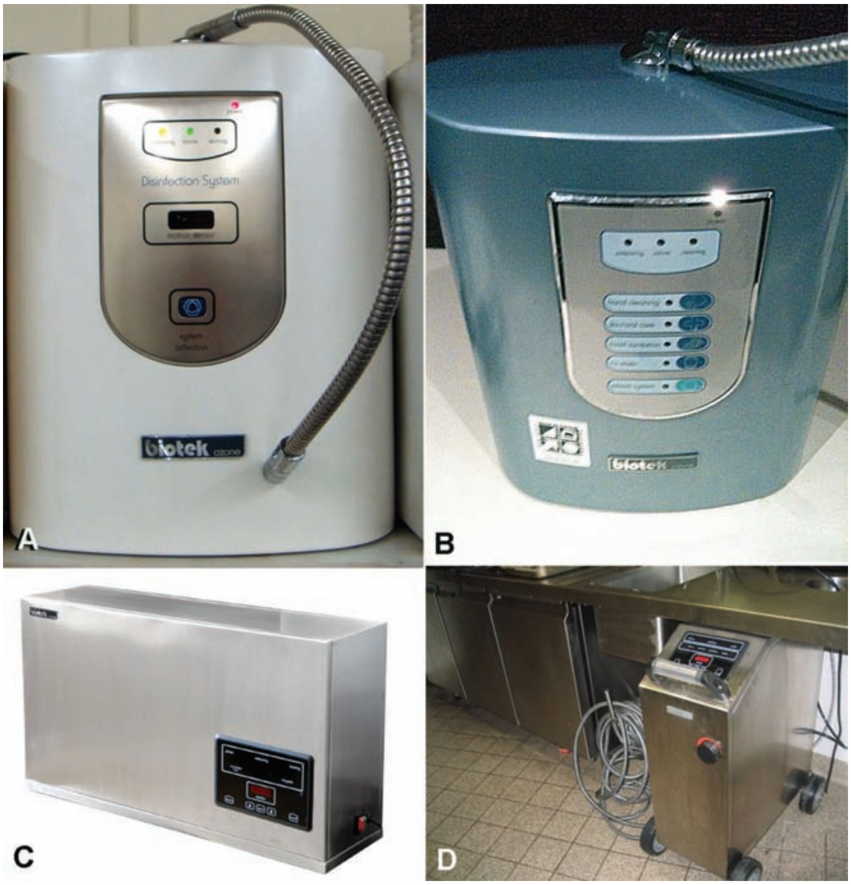

Figure 1. Electrolytic generators for ozonated water from Biotek. A, Unit used by the author for water disinfection; B, unit with additional capabilities for supplying oxygenated water (20 ppm) as well as ozonated water; C, high volume water ozonating unit suited for larger facilities; D, industrial water ozonator used in a large restaurant (Rockpool, Sydney).

Current technology

Point-of-use ozone systems from industry are now available for use in dentistry, at both the small office practice level as well as at the enterprise level.[15] These are suitable for inactivating the range of pathogens which may be found in reticulated water. Dissolved ozone at 0.2 ppm inactivates *Legionella pneumophila, Pseudomonas spp.* and *E. coli* and levels of several ppm can be achieved by current systems (Figure 1). The system used by the author generates some 3.66 ppm under continuous flow conditions (mains pressure water flow).

The most recent technology optimizes the transfer efficiency so that as much ozone is dissolved as possible (generating the ozone anion and other reactive oxygen species) rather than being produced as out-gassed vapour. Older ozone generation technology, such as corona discharge, requires dry air and high voltage and generates considerable heat as a side effect. Using electrolytic generation methods, a high transfer efficiency is achieved, only low voltage direct current is required and no special preparation of feeder gases is required. The systems connect directly to mains pressure water and produce ozonated water at modest pressure with capacities of up to 120-150 litres per hour.

These systems generate ozone at high concentrations in water (1-4 ppm) which is ideal for then filling the water bottles of dental units. The systems have very low energy consumption (typically 80-140 watts) and thus low running costs, as well as low maintenance requirements, with the main issue being periodic replacement of electrodes because of the effects of corrosion and erosion.

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About the author

Professor Laurence J. Walsh is the technology editor of Australasian Dental Practice magazine. He is also a noted commentator on and user of new technologies and is the Head of The University of Queensland School of Dentistry.