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GDC 'Highly Recommended' CPD topic  
*Disinfection and Decontamination*

# Dental Unit Water Lines and their Disinfection and Management: A Review

**Abstract:** The perceived threat to public health from dental unit water line (DUWL) contamination comes from opportunistic and respiratory pathogens such as *Legionella* spp, Nontuberculous Mycobacteria (NTM) and pseudomonads. These organisms can grow and multiply in the DUWL biofilm to reach infective concentrations, with the potential for inhalation leading to respiratory infections or direct contamination of surgical wounds. In this paper we discuss current legislation and practical methods for delivering water within the DUWL that meets the standards for safety.

**CPD/Clinical Relevance:** Understanding the clinical relevance and methods for decontaminating DUWL is essential to create a safe working environment in dentistry.

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It was first recognized in the 1960s that water sampled from the DUWL contained large numbers of organisms in the range  $10^4$ – $10^6$  colony forming units (cfu)/mL.<sup>1</sup>

Two decades later the American Dental Association (ADA) set the goal of <200 cfu/mL of aerobic heterotrophs as the standard for dental unit water lines.<sup>2</sup> This figure is reflected in the current recommendation for England, Wales and

Northern Ireland for dental unit water quality of 100–200 cfu/mL of aerobic heterotrophs at 22°C.<sup>3</sup> Since then, our understanding of the physiology of the biofilm,<sup>4</sup> incidence data on legionellae in dental practice<sup>5,6</sup> and the first proven case of *Legionella* transmission and death of a patient associated with contaminated DUWLs have transformed the management of DUWLs.<sup>7</sup> Challenges caused by *Legionella* contamination have not just affected dentistry but, around the world, there have been major outbreaks of Legionnaires' disease with resultant deaths of many of those infected.<sup>8</sup> Indeed, dentistry is specifically included in the Approved Code of Practice for Legionnaires' disease control in water systems, which states that DUWL management is viewed in the context of the dental practice's overall hot and cold water supply systems.<sup>9</sup>

## Biofilm formation in DUWLs

The effluent organisms from DUWLs essentially originate from the biofilms on the luminal surface of the water

line. Biofilms are defined as an organized community of microbes attached to a biotic or an abiotic surface, and encased in an extracellular polymeric substance.

The usual source of feed water to the dental unit which nourishes the luminal biofilm on DUWL is from the potable municipal supply or, preferably, from an independent bottled water supply.<sup>3</sup> After entering the unit proper, the water passes through a multichannel control box which distributes the water to dental unit water lines (hoses) feeding the high-speed handpiece, the air/water syringe and the ultrasonic scaler. DUWLs have a number of characteristics that promote biofilm growth unless they are regularly cleaned and disinfected. For instance, they have a very small bore but a high surface area, slow flow rate and the whole column of water in the DUWL can be stagnant for long periods of time. Biofilms develop rapidly in such systems within about 8 hours,<sup>6</sup> forming a mature bacterial community enveloped in a protective matrix within 6 days that is capable of shedding  $10^4$ – $10^6$  cfu/ml if left untreated.<sup>4</sup>

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## Biofilms and risk to health

Biofilms on the lumen walls of DUWLs act as a reservoir of micro-organisms. A wide range of species of environmental and oral bacteria, fungi, amoebae and protozoa have been isolated from DUWLs. The majority are harmless, so called saprophytic, Gram negative environmental bacterial species. However, the lipopolysaccharide (LPS) cell wall of all Gram-negative bacteria, a potent source of non-infectious endotoxins, can evoke mild or severe inflammatory responses leading to diseases such as periodontitis and systemic, septic shock.

A high bacterial load in the DUWL equates with a high endotoxin concentration. Endotoxin has been detected in dental unit water up to 500<sup>10</sup>–2,560<sup>11</sup> Endotoxin Units/mL compared to a mean level of 66 EU/mL found in water samples collected from adjacent sinks. Putnins *et al*<sup>11</sup> have suggested that the endotoxin in DUWLs might stimulate proinflammatory cytokines in gingival tissue during surgery and adversely affect healing. Endotoxins are known to trigger occupational asthma in susceptible people. An association between the onset of occupational asthma in dentists and the concentration of bacteria in their DUWLs has been demonstrated in a cross-sectional multicentre DUWL survey of 265 dentists in general dental practice. Fourteen

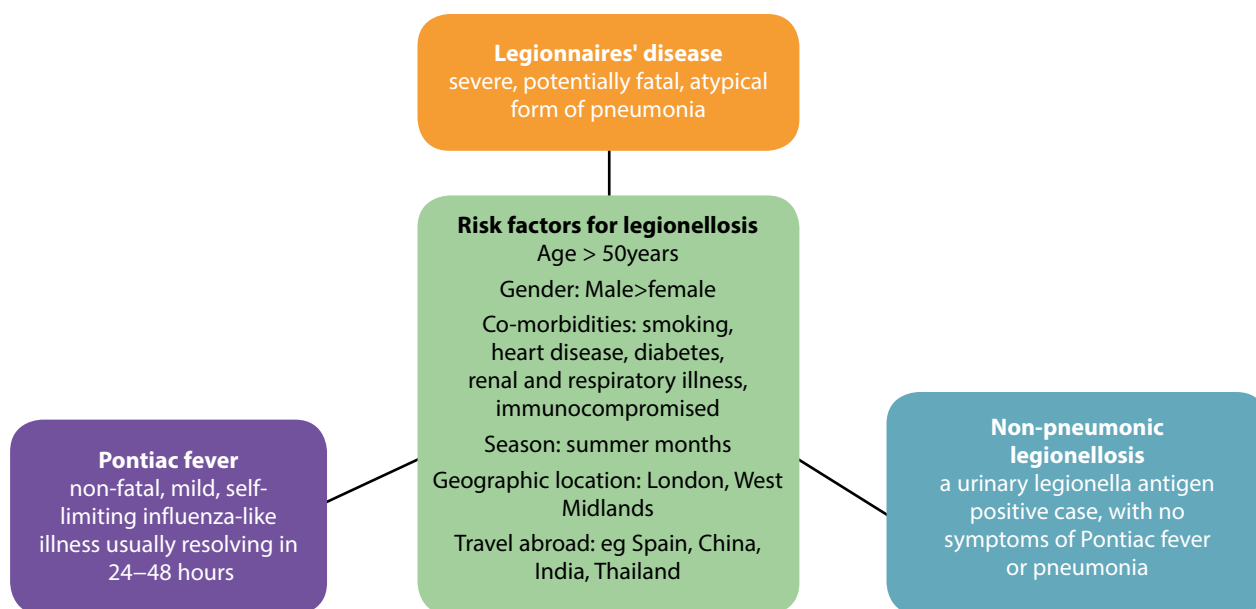
percent of the dentists enrolled in the study reported 'ever having suffered' from asthma either in childhood or as an adult.<sup>12</sup> Endotoxin derived from DUWL bacteria may account for this increase in occupational asthma, as dentists who were exposed in their dental surgery to total aerobic counts at 37°C at a concentration of 200 cfu/mL were more likely to report symptoms of asthma 'since starting dentistry'.<sup>12</sup>

## Legionella and respiratory pathogens

Legionellae can cause a variety of respiratory infections (Figure 1). Legionnaires' disease, or Legionellosis, is a severe infection which typically presents as pneumonia and symptoms may include a high fever, chills, cough, muscle aches, headaches, and diarrhoea.<sup>13</sup> Although healthy young adults can develop Legionnaires' disease in two thirds of patients, there are other co-morbidities and risk factors.<sup>13</sup> Legionnaires' disease is a notifiable disease in England and Wales and is a relatively uncommon cause of pneumonia, with approximately 350–500 cases per annum in the UK, the majority of which are due to *Legionella pneumophila* serogroup 1.<sup>13</sup> European Legionnaires' Disease Surveillance Network in 2016 reported the notification rate of Legionnaires' disease in the EU/EEA in 2014 was 13.5 cases per million/

population, the highest ever observed, and suggested that this may be due to favourable meteorological conditions that supported the growth of legionellae.<sup>14</sup> Although, when viewed from a global burden of disease perspective, the incidence of Legionellosis is very low, compared to other major respiratory infectious diseases such as tuberculosis, which has an estimated incidence of 10.5 per 100,000 of the population (5,758 cases) in 2015 in the UK,<sup>15</sup> and an estimated 10.4 million TB cases worldwide.<sup>16</sup> However, regardless of the relatively small number of cases of Legionellosis, registered providers of dental services have a duty of care to prevent and control the risks from contamination of practices' water supplies with legionellae. The registered provider of dental services is legally obliged to take account and comply with the standards as specified within ACOPL8<sup>9</sup> for water quality standards in healthcare premises.

There is no reported person to person transmission of legionellae, and infection is essentially associated with exposure to a contaminated water source. Legionellae are ubiquitous in warm, stagnant natural waters either free living or growing within amoebae.<sup>17</sup> They proliferate in man-made water supplies with similar properties, eg water cooling towers, humidifiers, hot tubs, birthing



**Figure 1.** The risk factors and three different clinical presentations of Legionellosis.

pools, hot and cold plumbing systems and shower heads, etc.<sup>9</sup> Legionellae favour growth temperatures in the range 20–45°C. Though clinical cases can occur in outbreaks associated with travel and as hospital acquired infection, most cases are sporadic and community acquired. Cases arise from exposure of the person to inadequately managed water supplies, including in the dental surgery. When investigating epidemiological risk factors associated with notified cases and outbreaks of Legionnaires' disease, Health Protection England include exposure to 'dental treatment' during the incubation period (2–14 days) as a pertinent risk factor on their case assessment protocols.<sup>13</sup> Two large studies conducted before the current regulations were introduced showed the incidence of legionellae in DUWLs to be low (0.37% in London and Northern Ireland<sup>18</sup> and 1.9% in the South-west of England<sup>19</sup>), but legionellae was also recovered from the cold water supply of three dental practices.<sup>18</sup> Where legionellae are present in the water supply, raised legionella antibody titres can be found in the dental team, indicating occupational exposure.<sup>20,21</sup> There is insufficient data to determine whether such exposures lead to infection such as Pontiac fever; but a death of a dentist was recorded in the USA following exposure to an unusual strain of legionella in his DUWL.<sup>22</sup>

Nontuberculous Mycobacteria (NTM) and pseudomonads are other pathogens that pose a transmission risk via DUWLs. NTM found naturally in potable waters are amplified 400-fold in DUWL and have been linked to two published cases of serious infection.<sup>23</sup> Pseudomonas in dental primary care water lines in the UK can often be at high levels in untreated water lines.<sup>5</sup> In the UK, Walker *et al* found that the most common species detected in their study was *Pseudomonas* species, isolated from 16% of untreated water lines.<sup>19</sup>

Martin<sup>24</sup> demonstrated that *Pseudomonas aeruginosa* recovered from the dental abscesses in two immunocompromised patients treated in a dental school were identical to those found in the DUWL of the dental units where they were treated. In a follow-on prospective study, 78 non-compromised patients treated in one of six *P. aeruginosa* contaminated dental units were transiently colonized for 3–5 weeks with *P. aeruginosa*, but no

infection ensued.<sup>24</sup> But it is the death of an elderly lady in Italy following two visits to her dentist where she was exposed to legionellae in the DUWL that subsequently caused her pneumonia, the first proven case of dental-associated Legionnaires' disease, that is the most significant.<sup>7</sup> The DUWLs were allegedly managed with a standard biocide (a hydrogen peroxide product), which has previously been shown to be effective. In summary, although the number of proven published cases of infection resulting from exposure to water from DUWLs is limited, these incidences are noteworthy cautionary tales that need attention to prevent further cases and improve our management of dental water supplies.

## Legislation and regulations

Criterion 2 of *The Health and Social Care Act 2008: code of practice on the prevention and control of infections and related guidance* (2015)<sup>25</sup> sets out the criteria against which a registered provider's compliance with the management of DUWLs and water supplies will be assessed by the Care Quality Commission (England and Wales) for compliance with the law. Taking account published national guidance outlined in Approved Code of Practice. *Legionnaires' Disease: The Control of Legionella Bacteria in Water Systems*, usually referred to as L8,<sup>9</sup> HSG274<sup>26</sup> and HTM 01-05,<sup>3</sup> the practice should have a policy for preventing contamination of dental unit water lines, including an appropriate water supply and maintenance schedules. Dental practices must, with the help of a Competent Person (Water Engineer<sup>3</sup>), prepare a legionella risk assessment and written control scheme (water plan) for *Legionella* prevention and control for their

hot and cold water systems.<sup>9,25-27</sup>

## Risk factors for legionella contamination of dental water systems

Practitioners should be aware of the main risk factors for legionella contamination as control of these hazards determines the management of the water supply. The type of questions to consider when formulating a water plan are listed in Table 1.

If the answer to any of these questions in Table 1 is 'yes' for either the practice's plumbing or DUWL, as is the case in most dental practices, then these risks must be managed according to the regulations.<sup>9,3,27</sup> Practices are under the regulations specified in the ACOP-L8 and are required to employ the services of a suitably qualified water engineer (Competent Person) such as a member of the Legionella Control Association or similar.<sup>9,27</sup> The Competent Person's role is to provide professional specialized advice on preparing the risk assessment, writing the water management plan to control the risk, maintaining the cleanliness of the plumbing system and boiler and training the staff on taking sentinel water temperatures. An annual inspection by the engineer is recommended. The dental practice staff have the duty of recording and monitoring the water temperatures in the hot and cold water systems on a monthly, 6-monthly and annual basis, as set out in the water plan. Records must be kept for 5 years.<sup>3,9</sup> A brief résumé of the basic principles on managing the risk from legionella in the practice's hot and cold plumbing are outlined in Tables 2 and 3. Readers are referred to HSG274<sup>26</sup> and HTM 01-05<sup>3</sup> for a full description of the guidance and regulations. For readers in Scotland further information is also available

- Is the water temperature in all or some parts of the system between 20–45°C?
- Is water stored or re-circulated as part of your system?
- Are there sources of nutrients such as rust, sludge, scale, organic matter and biofilms?
- Are the conditions likely to encourage bacteria to multiply?
- Is it possible for water droplets to be produced and, if so, can they be dispersed over a wide area, eg aerosols from handpieces?
- Is it likely that any of your employees, patients, visitors, etc are more susceptible to infection due to age, illness and a weakened immune system?
- Could they be exposed to any contaminated water droplets?

**Table 1.** Risk assessment questions for practice plumbing and DUWLs.

from *Scottish Health Technical Memorandum 04-01*<sup>28</sup> and the websites for Health Protection Scotland and Scottish Water. A discussion of the methods used to manage the DUWL is outlined in the next section.

## Managing risk factors for legionellae in DUWLs

Dental unit water is both swallowed and inhaled by the patient. Therefore, the microbial quality of the water must take these factors into account. Health Technical Memorandum (HTM) 01-05<sup>3</sup> recommends that the bacterial count in water sampled from the DUWLs should have a bacterial total viable count (TVC) of  $\leq 100$ – $200$  cfu/mL, which is comparable with drinking water standards in the European Union ( $\leq 100$  cfu/mL) and USA ( $\leq 500$  cfu/mL). Generally, the water entering the DUWL contains very few organisms: 0–100 colony-forming units (CFU)/ml. However, water exiting the handpieces may contain up to 10 000–1,000,000 cfu/mL. This is mainly as a result of the organisms that are shed from the bacterial biofilms growing within untreated lines; from the independent bottled water supply and from suck-back from the mouth due to negative pressure in the handpieces when drilling is stopped.

Although water can be taken from the mains supply (potable water), to achieve the specified water quality, dental units are usually fitted with a separate water reservoir that is independent of the public water supply. This allows dentists to have

better control over the microbial quality of the water used in patient care by the addition of biocides and other methods to control contamination. In addition, they act as a type A air-gap, a physical gap that prevents back siphonage of contaminated water into the mains supply. Reservoir water bottles are recommended to be filled with freshly produced (less than 12 hours old<sup>9</sup>) reverse osmosis or distilled water. These purified waters are not sterile but are unlikely to contain legionella, NTMs and pseudomonads found in potable tap water.

## Recommendations on care of water lines

The dental unit is classified as a medical device under the Medical Devices Directive 2002 and equipment used in practices must carry the European CE mark. It is well recognized that a combination of methods are required to prevent contamination and maintain water quality in the DUWL.<sup>3</sup> This goal can currently be achieved using antiretraction and check valves, flushing, biocides and purified water in the reservoir bottle. Other methods are also commercially available.

### The technical guidance HSG274 (part 3)<sup>26</sup> of the L8 ACOP<sup>9</sup>

This recommends dental practices to '*Drain down, clean, flush and disinfect all system components, pipework and bottles TWICE daily, eg at the start and finish of each day*'. Disinfection contact time is as

recommended by the biocide (disinfectant) manufacturer. Biocides employed to prevent the growth of legionellae in DUWLs must comply with bacteriocidal activity specified in the standard BS EN 13623:2010 and before purchasing a DUWL biocide check in which the manufacturer states compliance with the standard on the accompanying data sheet.

Furthermore, HSG274 (part 3)<sup>26</sup> recommends that '*independent water storage bottles should be cleaned, rinsed with reverse osmosis or distilled water, dried and stored dry and inverted overnight*'.

### Microbiological measurements

These are not mandatory under the L8 ACOP<sup>9</sup> or HTM 01-05<sup>3</sup> but are dictated by the individual dental practice's risk assessment, highlighting a possible hazard. Examples of possible hazards that would trigger microbiological measurements include, amongst others for example, technical factors causing an inability to comply with the regulations; after disruption in the service or physical changes noticed in the DUWL quality, such as foul taste or odour and cloudiness of the water.<sup>3</sup> Dip-stick methods are not suitable for estimating legionella and water samples should be processed by a UKAS accredited water and environmental testing laboratory.<sup>3,18</sup> The Laboratory will advise on sample collection methods but typically 1L of water is collected in a thiosulphate-coated bottle and transported directly to the laboratory for legionella testing, and enumeration of water-borne indicator organisms and aerobic colony counts obtained as specified in national standard operating procedures. Usually, the Laboratory will provide result interpretation guidance.

### Daily flushing to reduce stagnation

According to HTM 01-05, all DUWLs should be flushed for two minutes at the beginning of each day, prior to commencing treatment, and at the end of the day.<sup>3</sup> Staff should be alert to malodour, cloudiness and bad taste imparted to the water by microbial contamination, which are particularly noticeable after periods of stagnation.<sup>3</sup> They signal that conditions are appropriate to support the growth of legionella. The practice should seek advice on microbial sampling for legionella

<b>Regulations under ACOP – L8</b>	<b>Identify and assess sources of risk</b> (risk assessment)
	<b>Prepare a written scheme for preventing or controlling the risk</b> (water plan)
	<b>Implement, manage and monitor precautions</b>
	<b>Keep records of the precautions</b> (retain records for 5 years)
	<b>Appoint a competent person with sufficient authority and knowledge of the installation to help take the measures needed to comply with the law</b> (water engineer to help in applying health and safety law, eg HSG274; COSHH; provide staff training)

**Table 2.** Legionella control in the dental practice – requirements that have legal status under the Approved Code of Practice L8.



detection.<sup>3</sup> Care should be taken by the operator to avoid splatter and aerosol exposure during DUWL flushing and masks and eyewear should be donned. Irregularly used dental units should be flushed on a routine basis (at least weekly) to prevent stagnation.<sup>3</sup>

#### Flushing to reduce the risk of cross contamination

This is a simple and efficient means of reducing the planktonic (suspended) bacterial load in the water line due to oral suck-back. Thereby helping to prevent cross contamination from a previous patient. DUWLs supplying handpieces, ultrasonic scalers and air/water syringes should all be flushed. Although flushing can reduce the numbers of bacteria in expelled water, the effect is transient and has no impact on the water line biofilm and may even increase the bacterial shedding momentarily as it disturbs the biofilm.<sup>29</sup> Flushing also has the advantage of drawing up fresh biocide into the DUWL and thereby facilitating disinfection of the line.

#### Antiretraction valves (check valves)

All DUWLs should be fitted with check valves (non-retractable devices), to prevent suck-back (backflow/back-siphonage) of contaminants. If the dental unit takes water directly from the mains supply, then the unit should be fitted with a type A air gap. However, it is now known that the antiretraction valves can become

a scaffold for biofilm formation and are very inefficient unless they are regularly maintained and replaced periodically.<sup>30</sup> Antiretraction valves are also located in the dental handpieces. They prevent the re-aspiration of fluid contaminated with oral flora of the patient into the water line. Routine decontamination and periodic handpiece maintenance helps in maintaining the integrity of the handpiece anti-retraction valves.

#### Biocides and disinfectant systems

Thermal disinfection and avoidance of temperature between 20–45°C, though highly effective as a control measure against legionella in the water distribution system, is not applicable to DUWLs. The ambient temperature in the DUWL is approximately 18–23°C.<sup>5</sup>

Therefore, in DUWLs, we are reliant on biocides and disinfectants to remove, inactivate and prevent formation of biofilm. The disinfectant must be active against the range of micro-organisms found in the DUWL, including legionella spp. Biocides can either be continuously infused into, or intermittently added to, the dental unit water by varying technologies. A huge variety of products are available for use as intermittent purges and continuous disinfection. A range of different disinfectants are deployed by manufacturers, eg alkaline or hydrogen peroxide, hydrogen peroxide/silver ions,

peracetic acid formulations, Tetrasodium EDTA, chlorhexidine formulations, iodine, quarternary ammoniums and chlorine dioxide.<sup>31,32,33,34</sup> Hypochlorite, popular for disinfecting DUWLs in the past, led to corrosion of handpieces and its use is mainly confined to 'shock treatment' for the eradication of microbiologically proven legionella contamination.<sup>7</sup> For a detailed review of the adverse reactions reported for a range of different biocides see Coleman *et al.*<sup>31</sup>

Continuously infused biocides used in the water line must be non-toxic and safe if imbibed or inhaled by the patient and staff. Commercial products for continuous infusion are less concentrated than those sold for intermittent purging of the system.<sup>24</sup>

#### Sterile water for surgical irrigation

Water from DUWLs should *never* be used as an irrigant in procedures involving breaches of the mucosa and bone exposure – instead use a sterile water supply and delivery system or sterile saline.

#### Point of use filters

Microbial point of use filters may be installed, for instance between the water line and the dental handpiece. These have no effect on the biofilm in the water lines, but will remove micro-organisms as the water is delivered to the patient. Disposable filters must be replaced daily, which can be expensive.<sup>3</sup>

#### Hot water plumbing:\*

- Avoid storage of water between 20–45°C
- Hot water should be stored at ≥60°C
- Aim is to achieve a hot water temperature of 55°C at all points of use within one minute of turning on the hot tap
- Maintain cleanliness of system, eg reduce scale and deposits
- Integral thermostatic mixer valves for hand wash basins set at 38–44°C to avoid scalding
- Flush infrequently used taps for several minutes on a weekly basis to reduce risks associated with stagnation and low water usage

#### Cold water plumbing:\*

- Site cold water tanks in a cool place with thermal insulation
- Aim is to achieve cold water temperature of below 20°C after running the taps for two minutes
- Introduce measures to reduce stagnation (eg remove or shorten length of dead leg pipes, remove redundant taps)
- Maintain cleanliness of the system, eg hard water areas, softening of the cold water supply to the hot water distribution system should be considered to reduce the risk of scale being deposited at the base of the calorifier and heating coils
- Keep the amount of water stored to a minimum, ie equivalent to no more than 12 hours of usage

**Table 3.** Basic principles for controlling growth of legionella in hot and cold water systems in the dental practice. \*Refer to HSG274 (part 2) and HTM 01-05 (2013) for detailed guidance and regulations.

### Water purification system

Water purification systems treat the water coming into the dental unit (source water). They kill or remove micro-organisms by methods such as filtration, electrolyzed water or ultraviolet light. One advantage of these methods is that they may delay biofilm formation on water lines or synergize other treatment methods. As they are not discharged in the effluent water, they are non-polluting and less likely to select for antimicrobial resistant species than biocides used in DUWLs.<sup>35</sup>

### Miscellaneous

Other, rather expensive methods, for delivery of quality water include the use of sterile water and autoclavable DUWL systems.

### Boil-water advisories

A 'boil-water' advisory notice is issued by authorities when the public water supply is likely to be contaminated with pathogenic organisms, eg *Cryptosporidium*, or the numbers of microbes in the public potable water supply system are above that which is compatible with health. A recent example occurred in Lancashire, UK during the summer of 2015. During such periods the following apply:

- Do not use potable to feed the DUWL or other dental equipment. Only reverse osmosis or distilled water should be used.<sup>3</sup>
- Do not use potable water for dental treatment, patient-rinsing or hand-washing. For the latter purpose, antimicrobial-containing products that do not require water can be used (eg alcohol-based hand rubs). If hands are visibly contaminated, use bottled water and soap for hand-washing or an antiseptic hand towel.
- Once the boil notice is cancelled, follow the detailed guidance specified in HTM 01-05<sup>3</sup> for DUWLs and other advice given by the local water utility. If no guidance is provided, flush dental water lines and faucets for at least three minutes before resuming patient care. Then disinfect dental water lines and in line filters as recommended by the manufacturer.

In the last two decades in response to the evidence base and publication of new regulations, dental

practices in the UK and around the world have responded to the challenge of the DUWL goal set by the ADA in 1996 and are routinely treating their patients in a safe and hygienic environment.

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