

Risk Assessment of Dental Unit Waterline Contamination

Caroline L Pankhurst

Biofilms form rapidly on dental unit waterlines. The majority of the organisms in the biofilm are harmless environmental species, but some dental units may harbour opportunistic respiratory pathogens. This paper describes a risk assessment approach to analysing the hazard from biofilm organisms contam-

inating dental unit waterlines on the respiratory health of both the dental team and patients.

The health risk from the respiratory pathogens *Legionella spp*, *Mycobacterium spp* and *Pseudomonads* was found to be low. Nevertheless, in order to satisfy water regulations and com-

ply with health and safety legislation dentists should institute infection-control measures to maintain the dental unit water at the standard of less than 200 colony-forming units per ml of aerobic bacteria.

KEY WORDS: DENTAL UNIT WATERLINES, CROSS-INFECTION, RISK ASSESSMENT, WATER MICROBIOLOGY

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Introduction

Effective infection control is one of the cornerstones of good practice and clinical governance. Due to a combination of negative publicity and an increased scientific knowledge of dental unit waterlines' (DUWL) biofilms and their associated risks, contamination of dental unit waterlines has become a prominent infection-control issue. The perceived threat to public health from DUWL contamination comes from opportunistic and respiratory pathogens such as *Legionella spp* (causative agent of the pneumonia, legionnaires' disease), *Mycobacteria spp* and *Pseudomonads*. These organisms can be amplified in the biofilm to reach infective concentrations, with the potential for inhalation or direct contamination of surgical wounds.¹

During the last five years the American Dental Association (ADA) has specifically targeted DUWL, promoting research and technical developments.² The ADA recommended to their members that den-

tal unit water should comply with drinking water standards and contain <200 colonies/ml of bacteria (equivalent to that permitted for drinking water). This standard has been adopted by other national dental organisation as being acceptable and achievable. To control contamination of DUWL, the British Dental Association recommends flushing, independent bottled water systems, anti-retraction valves on handpieces, and use of sterile water for minor oral surgery. Dental equipment manufacturers have in turn responded with a variety of approaches to this complex problem. There are a plethora of automated flushing systems, filters, water disinfectants, independent bottle water systems, and even fully detachable autoclavable DUWL on the market.

In the UK, water authority enforcement of European drinking water directives has focused on the prevention of back siphonage from dental surgeries into the mains water supply. Additional safety recommendations can be found in the Health and Safety Commission 2001 *Legionnaire's Disease. The Control of Legionella Bacteria in Water Systems. Approved Code of Practice*

and Guidance.³ For the first time the code of practice, which applies to all premises covered by the *Health and Safety at Work Act 1974*, includes dental surgeries. All dentists are required to conduct a statutory risk assessment in their practices. To comply with their legal duties employers must identify and assess sources of risk and prepare a scheme for preventing and controlling the risk. This paper will focus on the relative risk associated with contaminated dental waterlines of respiratory health and the factors that should be taken into account when conducting a risk assessment of DUWL. Detailed analysis of different methods of water decontamination is outside the scope of this paper.

Respiratory Health Risks—Sources of Infection

In order to assess the risk from contaminated DUWL one must first establish the source and reservoir of infection. The major source of organisms is environmental and derives from the incoming mains water. The DUWL and surgery plumbing act as

CL Pankhurst PhD, MSc, BDS, MRCPATH.
Specialist in Oral Microbiology, London, UK.

a reservoir of continuing infection. More than 25 different bacterial species as well as several species of fungi, and protozoa have been isolated from DUWL; the actual species depends on the geographic location.⁴ Predominant are the environmental Gram-negative bacteria. DUWL may also harbour smaller numbers of opportunistic pathogens which are responsible for respiratory disease, namely *Pseudomonas aeruginosa*, *Legionella spp* and non-tuberculous *Mycobacterium spp*.

Contamination is not thought to be entirely environmental, as retrograde flow from the oral cavity may contribute to a lesser degree to the microbial biofilm in the waterlines. In the past, oral bacteria such as Streptococci were commonly isolated from dental waterlines due to retrograde movement of irrigant water and saliva into the handpiece on releasing the foot pedal, whereas modern handpieces normally incorporate an anti-retraction valve, which prevents suck-back of oral microbes and hence reduces the risk of contamination from this source. If the valve is not fitted or is malfunctioning it is estimated that approximately 1 ml of fluid containing 25,000 oral bacteria could contaminate the handpiece each time the air turbine is stopped with the risk of these organisms being transmitted to subsequent patients, unless further precautions are taken.⁵ Bloodborne viruses such as Hepatitis B and HIV that are secreted in the saliva have been shown experimentally to be sucked back into the handpiece and have been recovered distally in the dental waterlines.⁶ However, they are unable to proliferate outside the human host and are rapidly diluted out and removed by flushing the waterline and by autoclaving of the handpiece between patients. Therefore, the species that are important with respect to DUWL contamination are those which can divide and grow within the biofilm. Flushing and autoclaving the handpieces will also aid removal of other contaminants

from the oral cavity.⁷ Routine maintenance of handpieces should include checking the function of the anti-retraction valve.

The third potential source of bacterial contamination is from independent bottled water systems. These systems are not particularly user-friendly. If they are not used with sterile water, or the bottles and waterlines are not disinfected on a daily basis and then stored dry, the interior of the bottle becomes colonised, with both skin and water microbes.⁸ The microbes in the bottle proliferate in the stagnant, room temperature water and contaminate the waterline. The major advantage of bottled water systems is they are unlikely to be contaminated by respiratory pathogens such as *Legionella* found in the mains water. Their introduction reduces the risk of microbial contamination from the mains water but adds additional risks associated with handling and storage. Methods

microbore tubing that comprises the DUWL, permitting unheeded growth and proliferation of the bacterial micro-colonies within the biofilm.⁹ This rapid amplification may result in pathogens that originally occurred only in very low concentration in the mains reaching their infective dose for humans.

The main route of transmission for most of the pathogenic respiratory pathogens is by aerosolisation of the dental unit water. Dental handpieces generate 5 µm particles, which are large enough to transport microbes but small enough to bypass the nasal baffle and pass into the alveoli of the lungs. The numbers of microbes in aerosols generated by air turbines are considerably higher than from conventional speed handpieces. Finally, to complete the route of infection, the host has to be susceptible. When conducting a risk assessment the dentist has to take into account those people who might

Table 1: Risk assessment: a five-stage process

Step 1	Look for hazards.
Step 2	Decide whom might be harmed, and how.
Step 3	Evaluate the risks rising from the hazards and decide whether existing precautions are adequate or more should be done.
Step 4	Record your findings.
Step 5	Review your assessment at regular intervals and revise it if necessary.

Modified from: *Five Steps To Risk Assessment*. London: Health & Safety Executive, INDG163(rev1). Website: www.hse.gov.uk

and instructions on the cleaning of independent reservoirs should form part of the risk management of DUWL.

Organisms entering from one of the three main routes described above colonise the dental waterlines to form a biofilm along the length of the tubing. The biofilm acts as a reservoir for continued long-term contamination of the waterline. Counts of up to 10⁴⁻⁶ cfu/ml are commonly detected in the water from poorly maintained waterlines. A mature biofilm will form in a new dental unit plumbed to the mains within a few weeks. This process occurs due to stasis and stagnation of the water in the

be affected by the hazard (*Table 1*). Dentists are now treating a more susceptible and vulnerable population than in the past. Age, inhaled and systemic steroids, diabetes, gastrectomy, antibiotics, smoking, cancer and chronic diseases medically compromise increasing numbers of people.

Finally, when assessing the risk posed by contaminated DUWL, the degree and length of exposure to the contaminated aerosols is an important factor in determining the appropriate course of action to reduce and manage the risk. Unlike the situation in which patients who are exposed to inhalation risks on an occasional short-term basis, dental

Table 2: Risk assessment scores

Hazard severity score	Likelihood of occurrence score
1 = Minor delay not requiring first aid.	1 = Very unlikely (eg yearly or less often).
2 = Minor injury, first aid only.	2 = May happen (eg quarterly).
3 = Time off work: up to three-day injury or illness.	3 = Likely to happen (eg monthly).
4 = Major injury/disabling illness.	4 = Very likely (eg weekly).
5 = Death.	5 = Almost certain (eg daily).

Risk = hazard severity x likelihood of occurrence.
Risk rating scores: High risk = 16-25 Medium risk = 9-15 Low risk = <8

healthcare workers experience a daily cumulative occupational exposure to contaminated DUWL aerosols throughout their working lives. Assessing the risk of occupational exposure is governed under COSHH regulations.

Risk Assessment

The five stages of risk assessment are shown in *Table 2*. Risk is expressed as an equation:

$$\text{Risk} = \frac{\text{hazard severity}}{\text{likelihood of occurrence}} \times \text{likelihood of occurrence}$$

The severity of the hazard and likelihood of it occurring can be assigned numerical values (*Table 2*) and the numbers entered into the equation. The level of risk will fall into one of three bands: high, medium or low. The aim of the statutory risk assessment is to eliminate the risk or, if this is not practical, to reduce it to the low risk category by appropriate management. In order to determine the 'risk', data are required on hazards posed by infection or colonisation by the different respiratory pathogens found in dental water and the number of cases of infection, and hence the likelihood of occurrence of these infections.

Prospective case-controlled studies on infection risks from DUWL are non-existent and would probably now be deemed unethical, therefore we have to rely on indirect data extrapolated from surveillance studies. Much of our current knowledge derives from comparable studies of hospital outbreaks of waterborne infections. Analysis of the outcomes of exposure to respi-

ratory pathogens in contaminated waterlines is further complicated by the fact that these organisms are also commonly detected in domestic water supplies, drinking fountains and mineral waters.¹⁰

Infection Risk from Respiratory Pathogens

Non-tuberculous Mycobacterium
 Non-tuberculous *Mycobacterium spp* (NTM) are opportunistic pathogens causing pneumonia, cutaneous, and disseminated disease. AIDS patients are highly susceptible to opportunistic NTM. Worldwide, there is an increasing incidence of infection in non-compromised patients, which is thought to be acquired from environmental sources such as drinking water. NTM can be isolated from up to 50% of municipal water supplies, in low numbers. In hospital outbreaks of NTM infection, the source of

the organism was tracked back to contaminated taps and shower-heads. Fortunately, most NTM infection is asymptomatic; studies suggest that approximately 12% of the population in the USA has been infected by the NTM, *M. avium*.¹⁰ Priming of the immune system by exposure to environmental NTM is thought to be beneficial as it helps to maintain the BCG vaccine (anti-tuberculin) immune response.¹¹

There are only a small number of studies evaluating the risk from NTM in DUWL. They are commonly isolated from DUWL and have been shown to proliferate in the biofilm. Significantly, the numbers of NTM in DUWL exceeded those in drinking water by a factor of 400.¹² The obvious concern is that high numbers of NTM may be swallowed, inhaled or alternatively be inoculated into oral wounds during dental treatment with the potential for colonisation and infection. Gargling with water containing NTM resulted in respiratory colonisation. A small number of cases of NTM infection have been associated directly with dental treatment. One report described a prosthetic heart valve infection with *M. gordonae* and another two cases of NTM cervical lymphadenitis following dental extractions.^{13,14} The true extent of the risk posed by NTM in DUW to the immunocompromised patient has yet to be fully elucidated. So although the severity of the 'hazard' associated with diagnosed cases of NTM infection is of major disabling

Table 3: Risk assessment of infection in an immunocompetent patient from exposure to contaminated dental waterlines. The 'severity of infection' may be higher for an immunocompromised patient depending on exactly which immune cells or function were deficient.

Risk of infection from exposure to waterlines contaminated with low levels of the organism	Severity of infection (immunocompetent patient)	Likelihood of occurrence	Risk category and range
<i>Legionella pneumophila</i>	4 or 5 (pneumonia) <i>Usually no infection</i>	1	Low risk (1 to 4-5)
Atypical <i>Mycobacterium spp</i>	1 (colonisation*)	1-2	Low risk (1-2)
<i>Pseudomonas aeruginosa</i>	1 (colonisation*)	1-2	Low risk (1-2)

* Colonisation of mouth or gastrointestinal tract more likely than infection.

illness or death, the likelihood of it occurring is considered to be very low for otherwise healthy patients and staff, giving an overall low level of risk (Table 3).

Pseudomonas aeruginosa

Pseudomonas aeruginosa is highly resistant and can grow in dilute disinfectants such as chlorhexidine, and iodophors. It is able to thrive in low nutrient environments such as distilled water; the latter water source is often used by dentists to fill independent reservoir water systems.

Unfortunately, risk assessment data on waterborne opportunistic pathogens in DUWL are not yet available and data have to be extrapolated from those on drinking water. Colonisation of the gut is the initial step in *P. aeruginosa* infection. The infective dose for colonisation in healthy human volunteers is $>1.5 \times 10^6$ cfu/ml. Such high concentrations are rarely encountered in DUWL. Antibiotic treatment makes a patient more susceptible to opportunistic pathogens and markedly lowers the required infectious dose. The estimated risk of colonisation to daily exposure to water with low levels of *P. aeruginosa* is 1.7×10^{-8} . Therefore the risk for a healthy person becoming colonised is very low.¹⁰

The only proven evidence for DUWL-associated infection during dental treatment is due to *P. aeruginosa* and was published in 1987. Two patients with solid tumours were unwittingly exposed to DUWL contaminated with *P. aeruginosa*. Both patients subsequently developed gingival abscesses which typing confirmed matched the strains of *P. aeruginosa* isolated from the airturbine waterlines. In a follow-on prospective study, 78 non-compromised patients treated in one of six *P. aeruginosa* contaminated dental units were transiently colonised for 3-5 weeks with *P. aeruginosa*, but no infection ensued.¹⁵

More recently, a Danish study¹⁶ by Jensen *et al* evaluated the risk of acquisition of *Pseudomonas spp* in highly susceptible cystic fibrosis

patients. Disease-induced changes in the cystic fibrotic lung result in sequential colonisation of the lung with pathogenic bacteria including *P. aeruginosa*. The cohort of patients was treated in multiple dental clinics and 103 water samples from patient treatment sessions were analysed. The recovery rate of *P. aeruginosa* varied according to the clinic, from 2.9%-5%. In a single case a genotypically identical *Pseudomonas* isolate was recovered from both the patients' sputum and their matched water sample. The authors concluded that there was only a small risk of acquiring *P. aeruginosa* from a dental treatment session.¹⁶ For comparison the annual acquisition rate *P. aeruginosa* is 1-2% in cystic fibrosis patients. Mirroring the situation with NTM infection, the overall risk for both patients (including highly susceptible patients) and staff from acquiring pseudomonas infection from contaminated dental waterlines is low.

Legionnaires' disease

Legionellaceae are ubiquitous in the environment and are found in all types of water. Transmission is via inhalation of contaminated aerosols; there is no case-to-case transmission. Large outbreaks of infection have been associated with aquarium, cooling towers, showers, taps and humidifiers. Six to thirty per cent of domestic hot water systems harbour *Legionellae*, in the majority cases without causing disease.¹⁷ Clinical infection presents as pneumonia or as a milder, self-limiting, flu-like illness, Pontiac fever. In the UK, the annual incidence of reported cases of legionnaires' disease is approximately 250/year but this is likely to be an underestimate. Most are due to *Legionella pneumophila* serogroup 1, although other species in the genus can also cause pulmonary illness.

People at particular risk are male, over 50 years of age and smokers. The infective dose for legionellosis in humans is not known. Outbreaks of infection

have been associated with bacterial counts $>10^5$ cfu/l. Recovery rates for *Legionella spp* in DUWL are in the range of 10^2 - 10^5 cfu/ml.^{18,19} Data on the prevalence of *Legionella spp* in DUW vary widely from 0-60% with a prevalence of *L. pneumophila* serogroup 1 of approximately 8%.²⁰ A recent survey of dental practices in the South West of England found that only one out of 55 dental units was contaminated with *Legionella spp*.²¹ There appear to be marked geographic variations in the prevalence of *Legionellae* in dental waterlines, though overall the prevalence rate in most of the UK is low. Once established, however, *Legionella* colonisation can persist for years in waterlines.²²

There is no published evidence indicating that a patient has ever contracted legionnaires' disease in a dental chair. A nationwide survey performed by the Legionella Reference Laboratory, CPHL, looking at risk factors in notified cases of legionnaires' disease, failed to find any direct association with prior dental treatment.²³ Even allowing for under-reporting of mild cases of Pontiac fever or clinical misdiagnosis of the cause of pneumonia, the risk is vanishingly small. This may be explained by the combination of low prevalence rate and bacterial load of *Legionella spp* in DUW in the UK.

Evidence of Occupational Exposure to *Legionella*

The risk assessment of the hazard to employees varies from that of the patient population due to sustained and daily contact with DUWL aerosols. Evidence of occupational exposure was first described in the 1960s. Dental personnel demonstrated an abnormal nasal flora corresponding to that isolated from the biofilms lining DUWL.²⁴

Studies investigating occupational exposure to *Legionellae* in the dental surgery found higher titres of *Legionella* antibodies among

dental personnel compared to the general population. The magnitude of *Legionella* antibody titres correlated directly with the length of time spent in clinical dentistry. Dentists had a higher incidence of antibodies than other members of the dental team.^{25,26} However, two dental schools in London reported *Legionellae* in the waterlines but found no correlation with respiratory illness in their staff.^{27,28}

A single fatal case of *Legionella* pneumonia in a dentist attributed to *L. dumoffi* has been reported. The evidence linking the disease to DUWL is only circumstantial. *L. dumoffi* and other *Legionella spp* were recovered from the dentist's surgery waterlines, although not from his domestic water supply. Unfortunately, the isolates were not available for molecular typing which would have definitively confirmed the link to the source.²⁰ Epidemiological surveillance data have uncovered a small number of dentists who contracted legionnaires' disease but investigation of their DUWL was not performed. All had other known risk factors for *Legionella* infection and no causal occupational association could be made.

Thermal Control of *Legionella*

The Health and Safety Commission (HSC) has issued *Legionnaire's Disease. The Control of Legionella Bacteria in Water Systems. Approved Code of Practice and Guidance*,³ which came into effect in January 2001. The document gives practical advice in accordance with implementation of the *Health and Safety at Work Acts* and COSSH regulations. Dentists are particularly required to assess whether conditions are present that will encourage *Legionella* to multiply, become aerosolised or lead to exposure of susceptible people to contaminated aerosols.

Legionellae can tolerate a wide range of temperatures. Although survival occurs at temperatures below 20 °C the organism prefer-

entially grows between 20-45 °C. Thus, storage of water between these temperatures should be avoided. The average temperature of most DUWL is 23 °C. Water temperature or thermal control can therefore be used as an effective method of infection control and risk management for both the hot and cold water sides of the dental surgery plumbing. A résumé of the main thermal recommendations stated in the approved code of practice can be found in *Table 4*.

Table 4: Thermal control

Hot water thermal control

- Avoid storage of water between 20-45 °C.
- Hot water should be stored at 60 °C.
- Aim is to achieve hot water at 50 °C at all points of use within one minute of turning on the hot tap.
- Infrequently used taps should be flushed for several minutes on a weekly basis.

Cold water thermal control

- Cold water tanks should be sited in a cool place and thermally insulated.
- The amount of water stored should be kept to a minimum and be equivalent to one day's usage.
- The water temperature should be below 20 °C after running the taps for two minutes.

The specific HSC guidelines on dental equipment state that they should be 'drained down and cleaned at the end of each working day'. In-depth safety guidance on all aspects of surgery plumbing and the monitoring programme can be found in the *Code of Practice*. If taste and odour problems are noted then a microbiological investigation may be required as this could signal development of conditions that could promote growth of *Legionellae*.

Environmental Gram-negative Bacteria

The environmental aerobic Gram-negative bacteria that comprise the bulk of the bacterial load found in the DUWL biofilm are non-pathogenic. To date, no clinical cases of environmental bacterial infections have been associated with dental procedures. The bacterial cell wall of Gram-negative bacteria is a potent source of endotoxin. Endotoxin can cause localised inflammation, fever and shock. Endotoxin has been detected in dental water

with reported mean counts of 80 endotoxin units/ml.²⁹ For comparison the USA *Pharmacopeia* sets a limit for endotoxin for irrigation sterile water of 0.25 endotoxin units/ml. A recent paper³⁰ has suggested that the endotoxin in DUWL may stimulate pro-inflammatory cytokines in gingival tissue during surgery and adversely affect healing. Guidelines recommend the use of separate sterile water supplies for surgical procedures, which should eliminate this potential haz-

ard. Similarly in medical equipment prone to biofilm and endotoxin build-up, such as humidifiers, a hypersensitivity pneumonitis to endotoxin is described. Further research is required to establish whether endotoxin at levels found in DUWL also represents a health hazard. Based on current data the respiratory health risk assessment score for environmental Gram-negatives is low. However, the dentist is obliged to comply with drinking water regulations and provide safe water for irrigation. In fact the majority of decontamination systems and published guidelines are aimed specifically at reducing and maintaining the environmental Gram-negatives at an acceptable level (<200 cfu/ml) in the DUWL.

To complete parts four and five of the risk assessment (*Table 1*) the dentist must then prepare a scheme of planned implementation, management, monitoring and record-keeping to prevent and control the risks. There is a recommended hierarchy of control options, with complete elimination of the risk being the ideal through to

Table 5: Hierarchy of control options

1. **Elimination of risk from DUW** = detachable fully autoclavable waterlines and independent water reservoir system filled with sterile water; autoclaved handpiece.
2. **Substitution** = independent water system, drain down waterlines and store bottles dry, disinfect bottles and waterlines.
3. **Prevent access to the hazard:**
 - **Enclosure** = point of use microbiological filters on waterline, handpiece anti-retraction valves.
 - **Guarding** = rubber dam, high volume suction, good surgery ventilation.
4. **Safe system of work** = flushing at start of day and between patients, fit and maintain anti-retraction valves, employ thermal control of hot and cold water systems.
5. **Written procedures** = provide infection-control policy on waterline management Daily check-sheet to be filled out to show waterlines have been flushed, waterlines and bottles drained down at end of day.
6. **Ensure adequate supervision** = train nurse and hygienist on waterline management.
7. **Identification of training needs** = train new staff, involve practice manager.
8. **Information/instruction** = ask staff to sign to say they have read infection control manual.
9. **Personal protective equipment** = masks, goggles.

personal protective equipment, an action of last resort. A brief list of the type control options suitable for the management of dental waterlines is outlined in *Table 5*. In most surgeries a combination of infection-control procedures that aim to minimise the hazard coupled with appropriate staff training will be required to achieve the microbiological standard of less than 200 cfu/ml aerobic bacteria in DUWL.³¹ Patients and dental staff can be reassured that the risk to respiratory health from bacterial contaminants in dental unit waterlines is very low (*Table 3*).

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Correspondence: C Pankhurst,
10 Glasfryn Court, Roxeth Hill,
Harrow, Middlesex HA2 0LD.
E-mail: caroline@pankhurst.freereserve.co.uk