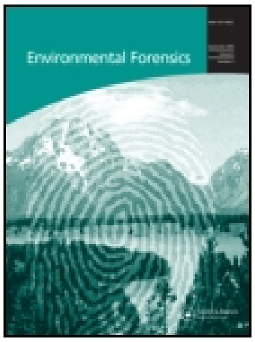

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The Hospital Tap Water System as a Source of Nosocomial Infections for Staff Members and Patients in West Bank Hospitals

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The number of nosocomial infections due to *Legionella pneumophila* and *Pseudomonas aeruginosa* is probably underestimated in many countries. This article discusses the risk of legionellosis due to *Legionella and P. aeruginosa* for patients and hospitals staff members from the water system in different Palestinian hospitals. A total of 134 water samples were collected in 2005 from six governmental hospitals located in the West Bank. *L. pneumophila* serogroup 2–14 was isolated from 33 of 53 samples, and *P. aeruginosa* was isolated from 17 of 81 before thermal disinfection. Thermal disinfection at 80°C and progressively flushing the hot water outlets around the system was successfully efficient to eliminate *Legionella* and *P. aeruginosa* pathogens in water distribution systems. The current study is an example of how microbiological methods and site history may be used to successfully track the source of bacterial water contamination and subsequently remediate it. Thorough contaminant characterization and forensic source identification is important for designing of appropriate management strategies.

Keywords: *Legionella*, *Legionella pneumophila*, *Pseudomonas aeruginosa*, hospital, water supplies, heat disinfection

Background

Water is one of the most effective vehicles to transfer pathogens. The water system within the hospital is the most frequent source of cases or outbreaks where patients may be at a higher risk for a severe infection. Contamination of the hospital water supply with potentially pathogenic organisms (*Legionella* and *Pseudomonas aeruginosa*) is very common worldwide and is a well-known risk factor for nosocomial infection (Visca et al., 1999; Borella et al., 2004; Leoni et al., 2005).

Point-of-use water (faucets and showers) may be the source of the transmission of waterborne microorganisms. The patient may be exposed to waterborne pathogens while showering, bathing, and drinking the water, and from exposure to medical equipment rinsed with potentially contaminated tap water or via the hands of medical personnel washed with contaminated tap water. The primary cause of poor water quality is the build-up of biofilm, corrosion of the distribution system and tank surfaces, aging systems, and water stagnation.

Legionella is a member of the family Legionellaceae. At least 42 species have been identified, and 22 currently known species have been linked to human diseases. All infections caused by *Legionella* species are covered by the general term *legionellosis*. *Legionella pneumophila* is the most pathogenic of the species, causing up to 90% of the cases of legionellosis. Fifteen serogroups of *L. pneumophila* have been identified, with serogroups 1, 4, and 6 being the primary causes of human disease. Serogroup 1 is thought to be responsible for 80% of the reported cases of legionellosis caused by *L. pneumophila* (American Public Health Association [APHA], 1998; Yang, 2004; Borella et al., 2004).

The distribution of *Legionella* is worldwide and has been found in fresh or brackish water, coastal waters, mud, soil at the banks of water courses, and putting mixes (Anaissie et al., 2003; Angelbeck, 2004). In its natural habitats, *Legionella* obtains its requirements for multiplication through interactions with other microorganisms such as algae, protozoa, and other bacteria and by the utilization of organic and inorganic material.

L. pneumophila and other species multiply in the temperature range of 20 to 45°C, but most rapidly between 30 to 43°C. They are freezing but die with increasing rapidity as temperatures rise above 45°C (National Environment Health Forum [NEHF], 1996).

The modern urban environment provides a wide diversity of sites for *Legionella* to colonize. These sites predominantly comprise equipment such as cooling towers, hot and warm water systems, and spa pools. *Legionella* proliferate in biofilms, which are slimy layers of bacteria, other microorganisms, and their byproducts as well as entrained matter.

In many central hot and cold water services, conditions are conductive for multiplications of these bacteria, especially when water remains at temperatures between 20 and 40°C. *Legionella* found in such services may multiply before the heater, within the heater, or near hot water outlets such as on tap washers or in showerheads (Figure 2). Biofilms also develop in these water systems and may be dislodged by hydraulic shocks and vibration on the walls of pipes and vessels, thus markedly increasing the numbers of bacteria in the water (NEHF, 1996).

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Illness resulting from infection with *Legionella* takes several forms: respiratory illness, which affects the lung, and Pontiac fever. Both diseases are transmitted through airway exposure, and there has been no report of human-to-human transmission. *Legionella* bacteria in airborne water droplets or mists from contaminated water sources are the primary source of human exposure. The incubation period for the disease is 2–10 days, with an average of 5–6 days, from initial exposure. Legionnaires' disease is caused by several species of *Legionella* bacteria. The disease is a form of pneumonia and includes symptoms of pneumonia. Legionnaire's disease affects mostly smokers, transplant patients, the elderly, and immunodeficient people. Usually < 5% of exposed people develop the disease. On occasion, mortality is likely if patients are not appropriately treated, and the fatality rate may reach 15% (Yang, 2004).

According to Centers for Disease Control and Prevention (CDC, Atlanta, GA) an estimation of 8,000–18,000 legionellosis cases occur each year in the United States, but only a fraction of these are reported (Attar et al., 2004).

Wellinghausen et al. (2001) studied the contamination of hospital water systems with *Legionella* at three different hospitals belonging to the University of Ulm, Germany. A total of 77 potable water samples were collected. The rates of detection of *Legionella* were 70.1%. Borella et al. (2005) studied *Legionella* contamination in hot water of Italian hotels. The hot water systems of Italian hotels were strongly colonized by *Legionella*. Contamination was found in 75% of the buildings examined and 60% of the water samples. Leoni et al. (2005) evaluated the prevalence of *Legionella* species in hot water distribution systems in Bologna, Italy. A total of 137 hot water samples were analyzed from private apartments, hotels, and hospitals. *Legionella* species were detected in 40% of samples, *L. pneumophila* in 33.3%. The highest colonization was found in the hot water systems of hospitals.

Pseudomonas aeruginosa was rarely considered as a real pathogen. In the 1970s, *P. aeruginosa* was recognized as the microorganism associated with bacteremia in the neutropenic host. Today *P. aeruginosa* is among the most common pathogens involved in nosocomial infections. In the United States, 1,400 deaths occur each year in hospitals as a result of waterborne nosocomial pneumonias caused by *P. aeruginosa* alone, which represented 9–11% of all nosocomial infections, with no clear guidelines for prevention of these infections (Anaissie et al., 2003).

Trautman et al. (2001) studied tap water colonization with *P. aeruginosa* in a surgical intensive care unit. Of 17 patients, 5 (29%) were infected with a genotype identical to that found in the tap water samples.

The number of nosocomial infections due to *L. pneumophila* and *P. aeruginosa* is probably underestimated in many countries. The objectives of the present study were 1) to estimate the risk of contamination due to *Legionella* and *P. aeruginosa* for patients and hospitals staff members from the water system in Palestinian hospitals; and 2) to assess the effect of thermal disinfection to reduce the contamination of *L. pneumophila* and *P. aeruginosa*.

The groundwater quality, which is the main source of water in Palestine, is showing trends of increasing nitrate contamination, even if the actual concentrations are below health standards. Combined with biological parameters and much anecdotal information, there are signs that health officials should be concerned about groundwater quality in public supplies, although hard evidence based on empirical data is largely absent (United Nations Environment Program [UNEP], 2003). Saving water, protection and augmentation of water supply rather than development of new water resources, and supply projects may prove to be in many cases the optimal policy. Cleaning and restoring groundwater is often technically problematic and costly, and finding alternative sources for water supply is not always possible. It is advisable also for environmental reasons to minimize leakage, to prevent pollution, and to reduce sensitivity to emergencies.

No study was performed previously in Palestine to determine hospital water contamination as a source of opportunistic pathogens that cause nosocomial infection. An exact forensic characterization of the contamination sources will further help in implementing an appropriate management system.

Materials and Methods

Sample Collection

A total of 134 water samples were collected in 2005 from six governmental hospitals located in the West Bank. The hospitals are Ramallah Hospital in Ramallah District, Alia Hospital in Hebron District, Beit Jalla Hospital in Bethlehem, Alwatani Hospital and Rafidia Hospital in Nablus District, and Jenin Hospital in Jenin District. The samples were collected and tested with the help of the Ministry of Health (Environmental Health Department and Central Public Health Laboratory).

For *Legionella* sampling, hot water samples (42–50°C) were drawn from the bathroom outlets (shower head or bathroom tap) in sterile 1-L glass bottles after a flow time (2–3 min) to eliminate any cold water present inside the tap or flexible shower pipe. Water flow was reduced to permit filling bottle without splashing. To neutralize the residual free chlorine, 10% sodium thiosulphate was added in sterile bottles for bacteriological analysis, whereas acid-preserved glass bottles were used for bacteriological analyses (APHA, 1998; Borella et al., 2004; Leoni et al., 2005).

Swab samples of biofilm on the interior surfaces in the faucets and showerheads were taken. The swab samples were resuspended and mixed with the water samples (APHA, 1998; Yang, 2004).

Bacteriological Analysis

Collection bottles were returned to the laboratory immediately after sampling for examination. If analysis would not begin within 24 h, samples were kept at above 4°C and processed within 48 h of collection. The samples were analyzed using different guidelines and standards published by APHA (1998), Borella et al. (2004), Bartie et al. (2001), Leoni et al. (2005), Alyssa et al. (1995), Leoni et al. (2005), and Yang (2004).

Statistical Analysis

Chi-square exact test was used to test contamination samples collected from selected hospitals. The test was chosen because of the limited sample size of water samples. Kruskal-Wallis and Mann-Whitney U were used to test the level of contamination measured by colony-forming unit (CFU). Statistical analysis was performed using Statistical Package for Social Sciences Version 12 (SPSS 12 SPSS Inc. Chicago, Illinois).

Results

All samples were uncontaminated with *L. pneumophila* serogroup 1. *L. pneumophila* serogroup 2–14 was isolated from 33 of 53 samples. In the positive samples, the mean number of *L. pneumophila* was 6.17×10^3 CFU/L (colony forming units/L). *P. aeruginosa* was isolated from 17 of 81, as shown in Table 1, with levels ranging from 1 to too numerous to count CFU/200 mL. Two water samples collected from the storage reservoirs of Rafidia and Al-Watani hospitals were uncontaminated with *L. pneumophila* serogroup 2–14 and *P. aeruginosa*, whereas the water from the distribution systems of two hospitals was contaminated. Therefore, the contamination is from the biofilm available on the interior surfaces of water distribution systems.

Legionella Pneumophila

All hospitals had at least two water samples tested positive for *L. pneumophila.* Chi-square exact test shows that there was significant difference in the number of positive samples between hospitals with significance level less than 1%. Although two thirds of tested samples were contaminated by *Legionella pneumophila*, there were variations in the level of contamination measured by the number CFUs. Results of Kruskal-Wallis showed that there was significant difference in the number of CFU with chi-square of 12.894 (d.f = 5) and significance level of 2.4%.

Pseudomonas Aeruginosa

Samples from Ramallah and Jenin hospitals tested positive for *P. aeruginosa.* Chi-square exact test shows significant difference between tested samples ($P < 0.001$). The level of contamination between the two hospitals could not be analyzed for all positive samples because the number of colonies was reported as too numerous to count. However, for the samples with reported number of colonies, there was not a significant difference in the level of contamination between the two hospitals using Mann-Whitney U test ($p = 0.21$).

Minimizing Hazards

Because *Legionella* bacteria are ubiquitous at low levels in surface water, it is impossible to prevent them from coming to the buildings and contaminating the water systems. Therefore, routine and systematic monitoring can serve as an alarm system to determine whether there is contamination and if remediation is necessary or not.

A number of methods exist for systemic treatment to manage *Legionella* contamination in the hospital water distribution system. These systems have variable levels of success, often providing a short-term reduction in *Legionella* contamination only to lead to recolonization within a few months (Table 2). *Legionella* persists in biofilms and inside amoeba, making systemic treatment far more challenging (Angelbeck, 2004).

The thermal eradication superheat and flush method was applied in this research. The goal is to raise the hot water temperature to at least 60°C, or preferably to 70°C or higher. The hot water serves to circulate and flush the entire water system and the outlets for a period of time. There is no standard duration for allowing the super-hot water to flush the system. Flushing for 5 to 30 min at 70°C or for at least 30 min at 60°C has been suggested. Where such thermal shock treatment is not possible, sodium hypochlorite may be added, preferably overnight, to maintain

Table 1. *Microbiological characteristics of hot water distribution systems in different hospitals*

Pseudomonas aeruginosa			*Legionella pneumophila* serogroup 2–14			
Concentration (range) CFU/200 mL	Contaminated samples, n	Samples, n	Concentration (range) CFU/100 mL	Contaminated samples, n	Samples, n	Hospital
1–45	7	24	200 to $6.6*10^3$	2	16	Ramallah
1–45	0	18	100 to $1.6*10^4$	13	18	Alia
1–45	0	13	1.2 to $6.5*10^3$	8	8	Beit Jalla
1–45	0	5	200 to $1.4*10^3$	3	3	Alwatani
1–45	0	11	100 to $200*10^3$	2	3	Rafidia
15–too numerous to count	10	10	$3.8*10^3$ to $2.8*10^4$	5	5	Jenin
	17 (21%)	81		33 (62.3%)	53	Total
	Exact test = 42.43 $P < 0.001$			Exact Test = 26.472 $P < 0.001$		

Table 2. *Methods for systemic treatment to manage* Legionella *contamination in the hospital water distribution system*

Method	Efficacy/advantage	Disadvantage
Thermal eradication superheat and flush	Can reduce *Legionella*; cheap; needs no special equipment; generally systemic treatment	Short-term benefit, but then recolonization occurs; time-consuming; scalding can occur
Hyperchlorination	Chlorine has been shown to inactivate *Legionella* in suspension; however, in biofilms and amoeba, *Legionella* are more resistant; generally systemic treatment	Recolonization can occur within 60 days with *Legionella*; corrosive to the pipes
Chloride dioxide	Effective at higher water temperatures and higher PH; a systemic treatment	Recolonization is likely to occur, *Legionella* in biofilms and amoeba may be resistant—one report shows failure to control *Legionella* after 18 months
Ultraviolet light	Focal treatment; easy to install; no adverse effects on the pipes; may be used closer to point of use	Unsuitable as a sole modality for a hospital, especially because *Legionella* persist in biofilms
Copper/silver ionization	Systemic treatment; can kill *Legionella* but may still not yield no *Legionella* for transplant units	Long-term treatment can theoretically cause resistance electrodes to accumulate scale and must be regularly cleaned; can impact water quality

a free chlorine residual of at least 2 mg/L. This will normally necessitate chlorination of the head tank at 20–50 mg/L (Angelbeck, 2004).

The thermal eradication superheat and flush method was applied in two hospitals—Beit Jalla Hospital and Jenin Hospital—because this method is the cheapest. For Beit Jallah hospital, 6 samples were collected after thermal disinfection at 80°C for 30 min. *L. pneumophila* serogroup 2–14 were detected in one sample (200 CFU/L). All samples were negative for *P. aeruginosa*.

For Jenin hospital, 5 samples were collected after thermal disinfection at 70°C for 30 min. *Legionella pneumophila* serogroup 2–14 were detected in all samples but with less concentration ($1.9*10^3$ CFU/L to $1*10^4$ CFU/L). All samples were negative for *P. aeruginosa*.

It was noticed that the thermal disinfection in Beit Jallah hospital is more effective than in Jenin hospital (the temperature in Beit Jallah hospital reached 80°C, whereas it reached 70°C in Jenin hospital).

Water services at buildings and grounds should be designed and operated to avoid conditions likely to encourage *Legionella* multiplication and to reduce contamination of systems. There is an opportunity of combining document review with monitoring in order to delineate bacterial sources to water and then design remediation systems to address the identified sources. The staff of the maintenance departments at all hospitals under this study was trained to take different measures, which include efficient remediation (discussed previously) and preventive measures, which include the following measures (NEHF, 1996) described in the following subsections.

Temperature Control

Systems should be regularly inspected to ensure thermostats are not malfunctioning. Where systems cannot be retrofitted with these devices, periodic raising of temperatures to at least 80°C or chlorination and flushing are recommended. Although the storage of water at or above 80°C is adequate for the control of *Legionella* in most storage situations, peripheral colonization of fittings such as taps and showerheads may still occur due to heat loss. A minimum return water temperature of 60°C is recommended.

Storage Time

Legionella growth can occur in storage tanks and pipes containing warm water that is not in use for a prolonged period. Long dead-legs in hot water piping systems should be avoided and recirculation loops incorporated as a design feature. New shower systems in large buildings and hospitals should be designed to ensure there is mixing of hot and cold water near the point of use such as the showerhead.

Nutrients

Dead and living microorganisms, biofilm, scale, and sediment may provide nutrient sources for *Legionella* and amoebae and multiplication may occur if conditions are suitable. Drainage facilities of adequate size at the lowest point of calorifiers will help remove accumulated sediment. Plumbing materials should not include natural rubber for gaskets and washers because there is evidence that *Legionella* multiplication is enhanced on this material.

Cleaning

A regular cleaning and inspection schedule should be prepared for hot and cold water services and an up-to-date log maintained.

Conclusions

Legionella species and *P. aeruginosa* are likely to be common inhabitants of hospital water distribution systems but may be unrecognized as a risk for patients for years because of lack of environmental surveillance. The study shows that the selected hospitals in the West Bank were contaminated with dangerous opportunistic pathogens that endanger the public. Thermal disinfection at 80°C and progressively flushing the hot water outlets around the system was successfully efficient to eliminate *Legionella and P. aeruginosa* pathogens in water distribution systems. An evaluation of prevalence of *Legionella* in domestic, hotels, and private hospital should also be performed. The success of the current study emphasizes the importance of initial forensic delineation of sources in the water management in Palestine and elsewhere. We hope that the publication of this study in *Environmental Forensics* will encourage the forensic approach as an initial stage when designing remediation management systems and illustrate the need for forensic studies outside the litigation arena.

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References

Alyssa, T., Janet, S., Victor, Y., and Marilyn, W. 1995. Comparison of culture methods for monitoring *Legionella* species in hospital potable water systems and recommendations for standardization of such methods. *Journal of Clinical Microbiology* 33(8):2118–2123.

Anaissie, E., Penzak, S. and Dignani, M. 2003. The hospital water supply as a source of nosocomial infections: A plea for action. *Archives Internal Medicine* 163(16):1483–922.

American Public Health Association (APHA). 1998. *Standard Method for Examination of Water and Wastewater*, 20th ed. New York, NY: APHA.

Angelbeck, H. 2004. *Legionella — A Waterborne Nosocomial Pathogen.* East Hills, NY: Pall Medical. Available at www.pall.com/pdf/ClinUpLegionella08.04.pdf (accessed May 13, 2006).

Attar, M., Shahmansouri, R., Neshat A. and Fazeli, M. 2004. Identification of *Legionella* in the hot water supply of a general hospital in Isfahan. *Journal of Research in Medical Sciences* 9(6):40–44.

Bartie, C., Venter, N., and Nel, H. 2001. Evaluation of detection methods for Legionella species using seeded water samples. Water SA. 27(4):523–528.

Borella, P., Montagna, T., Stampi, S., et al. 2005. *Legionella* contamination in hot water of Italian hotels. *Applied and Environmental Microbiology* 71(10):5805–5813.

Borella, P., Montagna, T., Vincenzo, R., et al. 2004. *Legionella* infection risk from domestic hot water. *Emerging Infectious Disease* 10(3):457–464.

Leoni, E., De Luca, G., Legnani, P., Sacchetti, R., Stampi, S., and Zanetti, F. 2005. *Legionella* waterline colonization: Detection of Legionella species in domestic, hotel and hospital hot water systems. *Journal of Applied Microbiology* 98(2):373–379.

National Environment Health Forum (NEHF). 1996. Guidance for the control of Legionella. *Water Series No. 1*. Canberra, Australia: NEHF.

Pall Medical. 2003. *Hospital Water: An Unrecognized Source for the Transmission of Waterborne Pathogens*. East Hills, NY: Pall Medical. Available at www.pall.com/pdf/Water_CU_August_2003.pdf (accessed May 13, 2006).

Trautmann, M., Michalsky, T., Heidemaire, W., Radosavljevic, V., and Ruhnke M. 2001. Tap water colonization with *Pseudomonas aeruginosa* in a surgical intensive care unit (ICU) and relation to *Pseudomonas* infections of ICU patients. *Infection Control and Hospital Epidemiology* 22:49–52.

United Nations Environment Program (UNEP). 2003. *Desk Study on the Environment in the Occupied Palestinian Territories*. United Nations Environment Program.

Visca, P., Goldoni, P., Lück, C., et al. 1999. Multiple types of *Legionella pneumophila* serogroup 6 in a hospital heated water system associated with sporadic infections. *Journal of Clinical Microbiology* 37(7):2189–2196.

Wellinghausen, N., Frost, C., and Marre R. 2001. Detection of *Legionellae* in hospital water samples by quantitative real-time light cycler PCR. *Applied and Environmental Microbiology* 67(9):3985–3993.

Yang, S. 2004. *Sampling and Controlling* Legionella *Bacteria in Domestic Water Systems*. Phoenix, AZ: Aerotech P&K. Available at: http://www.aerotechpk.com/Resources/PDF/TP_SamplingControlingLegionellaBacteriaInDomesticWater.pdf.