PERACETIC ACID IN THE DISINFECTION OF A HOSPITAL WATER SYSTEM CONTAMINATED WITH LEGIONELLA SPECIES

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OBJECTIVE: To assess the efficacy of an alternative disinfection method for hospital water distribution systems contaminated with Legionella. METHODS: Disinfection with peracetic acid was performed in a small hospital contaminated with L. pneumophila serotype 1. The disinfectant was used at concentrations of 50 ppm (first three surveillance phases) and 1,000 ppm (fourth surveillance phase) for 30 minutes. RESULTS: Environmental monitoring revealed that disinfection was maintained 1 week after treatment; however, levels of recontamination surpassing baseline values were detected after approximately 1 month. Comparison of water temperatures measured at the distal outlets showed a statistically significant association between temperature and bacterial load. The circulating water temperature was found to be lower in the two wards farthest away from the hot water production plant than in other wards. It was thought that the lower water temperature in the two wards promoted the bacterial growth even after disinfection. CONCLUSION: Peracetic acid may be useful in emergency situations, but does not provide definitive protection even if used monthly (Infect Control Hosp Epidemiol 2005;26:490-493).

ABSTRACT

Contamination of hospital water systems with Legionella, and the risk of pneumonia associated with it, continues to pose a problem worldwide. To date, no occasionally performed disinfection method has offered long-term protection, but regular continuous disinfection has been reported effective. Many interventions fail because Legionella lives in the biofilm coating the inside surface of water pipes. This ecosystem barrier is difficult to eradicate with conventional chemical and physical disinfection agents. Superheating and hyperchlorination, the two most common methods, are widely recommended by guidelines applied in many countries and by those of the Centers for Disease Control and Prevention issued in 2004. Several alternative methods such as ozonation, copper–silver ionization, ultraviolet light, monochloramine, and chlorine dioxide have been evaluated, some of which demonstrate mid- and long-term efficacy. We report the results of a field trial conducted in a hospital where the control measure used peracetic acid. The hospital water distribution system was contaminated with L. pneumophila serotype 1.

METHODS

Peracetic Acid

Peracetic acid is a strong disinfectant with a wide spectrum of antimicrobial activity. Due to its bactericidal, virucidal, and sporicidal effectiveness demonstrated in various industries, peracetic acid as a disinfectant of waste water effluents has been drawing more attention in recent years. To date, no studies have been published on the use of peracetic acid as a disinfectant for decontaminating the water distribution systems of buildings or of hospitals in particular. In this field trial, we used an equilibrium mixture of peracetic acid (5%), hydrogen peroxide (27%), acetic acid (6%), and water.

The Hospital

The study hospital was a functional rehabilitation center with a central building and 2 wings with 5 inpatient wards (107 beds) located on 3 floors. Approximately 1,400 patients are treated annually. The average inpatient length of stay is 30 days, whereas the average length of outpatient treatment is 17 days. All patients undergo clinical surveillance for pneumonia. No cases of legionellosis had been reported in this facility.

The hospital receives its water from the metropolitan water supply system, whence it is collected in three large underground storage tanks (water reservoir). Hot tap water passes through a steam–water exchanger before it is mixed and then collected in a storage tank (55°C to 60°C) and distributed to distal outlets (36°C to 45°C). The month-
ly maintenance of the distal outlets (showers and faucets) consists of dismantling, washing, descaling, and disinfection of tap aerators. Installed some 22 years ago, the distribution system, almost completely in galvanized iron pipes, underwent installation changes during restructuring of the wards approximately 10 years ago, which probably created dead pipes in some sections.

In 2000, water samples taken from the faucets farthest away from the central hot water production plant showed *L. pneumophila* serotype 1 on culture. All samples were positive (bacterial loads of $10^{2}$ to $10^{3}$ colony-forming units/L), with the highest loads ($10^{3}$ to $10^{4}$) detected on two wards in one hospital wing. Disinfection by superheating proved unsatisfactory because it was effective for only 15 to 20 days.

In the current study, disinfection with a peracetic acid–based disinfectant (5%) and hydrogen peroxide (28%) was performed between August 2001 and April 2003. The agent’s in vitro activity was tested before evaluating its efficacy in this field trial (data not shown). The tests were performed according to European Standard EN 1276 and using *L. pneumophila* serotype 1 cultured from the environment as a test strain. In vitro tests have shown that the active concentration of peracetic acid against *Legionella* is 50 ppm for 5 minutes; therefore, this concentration for a prolonged exposure time was employed in the field trial.

**Protocol**

The study consisted of four phases in which one or more disinfection treatments were performed. The frequency of these treatments was determined empirically according to the results of the environmental survey.

Based on the in vitro test results, the disinfection agent was used at concentrations of 50 ppm for 30 minutes (phases 1 to 3) and 1,000 ppm for 30 minutes (phase 4). The latter conditions were adopted according to the French guidelines published during the trial.

Phase 1 consisted of one disinfection treatment with 50 ppm of peracetic acid. Phase 2 consisted of three disinfection treatments performed with 50 ppm of peracetic acid once a week for 3 weeks. Phase 3 consisted of five disinfection treatments with 50 ppm of peracetic acid performed monthly during 5 months. Phase 4 consisted of one disinfection treatment with 1,000 ppm of peracetic acid.

In each intervention, the water distribution system downstream from the storage tank was filled with an amount of peracetic acid such that the desired final concentration could be obtained. Taps and showers were opened to allow the agent to flow through the system. The flow was stopped for 30 minutes to permit disinfection. The system was then reopened and flushed. The entire procedure lasted approximately 4 hours.

During the disinfection and flushing phases, the concentration of the agent was continuously monitored using cards for titrating peracetic acid (Merckoquant, Merck KGaA, Darmstadt, Germany), and the temperature was measured at every sampling at each distal site.

**Verification of Efficacy**

Water (a 1-L sample harvested after a 1-minute flowthrough) and biofilm (obtained with a swab) were taken from the hot water production plant (recirculation line) and the faucets of the 5 wards (1 sample from each ward at the most distal faucets). At the time of sampling, the aerators had been removed. The sampling bottles contained sodium thiosulphate.

The sampling schedule was as follows: baseline collection at the start of each treatment cycle (phases 1, 2, 3, and 4); sampling at 1 week and 1 month after each treatment during phases 1 and 2; and sampling at 30 days after each treatment during phases 3 and 4 and only in the wards (red and lilac wards) that had demonstrated major criticality in the previous cycle. The green ward was taken as representative for two others (yellow and blue wards).

The staged sequence of sample collection was determined empirically from the previously obtained results.
Laboratory analyses for detection and identification of *Legionella* were performed in accordance with International Standard Organization norm 11731:1998.

**RESULTS**

In phase 1, samples collected at 7 and 30 days after a single treatment (50 ppm of peracetic acid) showed that the agent maintained its efficacy during the short-term (1 week after the treatment). However, at 1 month after disinfection, elevated levels of recontamination *L. pneumophila* serotype 1 were observed (Fig. 1).

In phase 2, almost no growth of *Legionella* was detected in the samples collected 1 week after each treatment (50 ppm of peracetic acid). However, at 1 month after the last treatment, recontamination with elevated bacterial loads (red and lilac wards) was observed (Fig. 2).

In phase 3, the results obtained in phases 1 and 2 (reproducible lack of growth after 7 days) prompted us to perform bacteriologic tests only 1 month after the treatment. At the end of five treatments at 1-month intervals, the pipes leading to two wards (red and lilac) had bacterial loads greater than those measured at the beginning of phase 3 (Fig. 3).

In phase 4, data demonstrated regrowth of *Legionella* 30 days after treatment with 1,000 ppm (Fig. 4).

The mean temperature was 38.6°C for the lilac ward, 40.1°C for the red ward, 42.0°C for the blue ward, 43.5°C for the green ward, and 46.7°C for the yellow ward. The difference between the mean temperature of the yellow, green, and blue wards (44.6°C) and that of the red and lilac wards (39°C) was statistically significant (*P* < .001). The table details the effect of temperature related to *Legionella* load in the water sampled at 1 month after the treatment.

**DISCUSSION**

The recontamination pattern in this hospital resembled the one observed in water distribution systems treated with conventional intermittent disinfection methods such as superheating and hyperchlorination in that peracetic acid produced good initial results but failed to maintain them over time.

One reason for this failure could have been the inability of chemical and physical agents to eliminate the biofilm that protects the contaminating microbes inside water pipes.

A possible concurring factor could have been the level of contamination at baseline, which was particularly high in two wards (red and lilac) of this hospital.

To clarify this issue, the results 30 days after disinfection were analyzed to determine the effect of water temperature on microbial growth. There was a clear association between water temperature and bacterial load. The circulating water temperature was lower in the two wards (red and lilac) that were the farthest from the central hot water production plant than in other wards.

Currently, there is no clear explanation for the regrowth to higher than baseline counts of *Legionella*. Dislodgment of biofilm, presence of peracetic acid as a carbon source for bacterial growth, temperature differences at the distal outlets, and a probable difference in iron concentration in the hospital water system (only the yellow ward was refitted with polypropylene pipes) all might have contributed to regrowth.

Because a single treatment can provide short-term
disinfection, peracetic acid may be used in emergency situations (outbreaks) but not for long-term protection against Legionella species, even if repeated monthly at high concentrations.

Positive aspects of peracetic acid include its lower ability to form potentially mutagenic compounds (chloramines and halomethanes) compared with chlorine, ease of use, handiness, and limited health risk to technicians. Moreover, the water supply system is shut off for 4 to 24 hours, depending on dosage and duration of treatment, for peracetic acid as well as heat and chlorine. In our study, the water supply was discontinued for only 4 hours.

Although galvanized iron is susceptible to reaction and corrosion with peracetic acid, we have observed no corrosive action at the concentration used. An unresolved issue is the cost-benefit ratio, as the management costs have not yet been analyzed.

REFERENCES