

Failure of *Legionella pneumophila* Sensitivities to Predict Culture Results from Disinfectant-Treated Air-Conditioning Cooling Towers

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The disinfection of cooling towers based on manufacturers' treatment protocols, as employed in units installed at various public gathering places in Dallas, Tex. (hotels, municipal auditorium), and at the city health department, was evaluated for effectiveness in controlling *Legionella pneumophila* and compared with previous laboratory studies. In specimens collected in September and December, 1978, *L. pneumophila* was isolated from 2 of 4 specimens from untreated cooling towers, 2 of 4 specimens from towers treated with agents deemed ineffective in earlier laboratory tests, 6 of 11 specimens from towers treated with putatively effective agents, and 0 of 4 specimens from towers treated with an agent of unknown efficacy. These results suggest the need for further studies to identify biocidal agents effective in eliminating *L. pneumophila* from air-conditioning cooling towers.

Legionella pneumophila is a well-known cause of respiratory illness (10, 11). The organism can be spread in the air from water in air-conditioning cooling towers (2, 4) and evaporative condensers (3, 11). Except for turning off air-conditioning units known to spread *L. pneumophila* (4, 11), effective measures for preventing legionellosis have not been identified. Preliminary studies of the effect of disinfectants on *L. pneumophila* suspended in tap water suggest that some agents (chlorine, 2,2-dibromonitripropionamide, and quaternary ammonium compounds) are effective in destroying viable cells, whereas others (isothiazolone, thiocarbamate, and chlorophenol) are not (15). These studies provided a basis for the recommendation of agents to inhibit growth in cooling-tower water, but few field trial results for these agents are available. Because air-conditioning systems are so widely used in the United States and because they can be a source of *L. pneumophila*, it is important to identify biocidal agents that can decontaminate them.

Of approximately 8,600 participants of the Veterans of Foreign Wars convention held 17 to 25 August 1978 in Dallas, Tex., 19 had Legionnaires disease 2 to 10 days later; 2 died. Risk of illness was greater for those who stayed at hotel A, the headquarters of the convention ($P < 0.001$; $\chi^2 = 13.2$; $df = 1$). For male participants who stayed elsewhere, risk of the illness was

greater with increased exposure to hotel A ($P = 0.05$, Wilcoxon rank sum, one sided). These findings suggested that the source of the outbreak was in or near hotel A. Infected participants at hotel A were more likely than those who were not infected to have stayed in rooms that received fresh air from vents located three floors above the hotel's air-conditioning cooling tower than in rooms that received fresh air from vents located on the side of the hotel away from a cooling tower ($P = 0.08$, Fisher's exact, one sided).

On 20 and 21 September 1978 we obtained information about equipment used in, and maintenance protocols for, the ventilation systems of the 10 hotels that housed conventioners, the municipal auditorium where conventioners met on 20 and 21 August, and the city health department building, where no convention activities had been held. Evaporative condensers were not used at any of these sites. The water temperature was measured in each cooling tower, and a water specimen was obtained at that time and again in the period from 5 to 7 December. Specimens were collected in sterile plastic 500-ml containers. From towers known to be treated with a chlorine-containing compound, a second specimen was collected in a similar bottle to which 0.4 ml of 10% sodium thiosulfate had been added as a neutralizer. Specimens were stored at 4°C and processed by established procedures

(13). Suspected *L. pneumophila* isolates were confirmed by observation for typical growth and morphology on charcoal-yeast extract (6) and Feeley-Gorman (7) agars, for browning on Feeley-Gorman agar, for lack of growth on 5% sheep blood agar, and for typical cellular fatty acid patterns by gas-liquid chromatography (14). Peak concentrations of disinfectants used in the cooling towers were estimated by the amounts of agents added and by cooling-tower basin, conduit pipe, and condenser capacities.

Thirteen cooling towers were surveyed (Table 1). All but one (cooling tower F-1) received makeup water from the Dallas municipal system. The cooling towers had been built by three different manufacturers and installed in the period 1957 to 1978; all contained wood, steel, or polyvinyl chloride as fill material. Zero to three of six classes of disinfectant agents were used. At least one agent was given at recommended peak concentrations in 9 of the 11 towers in which agents were used (cooling towers I-1 and J-1 were not treated), at the recommended frequency in 5 of 11, and in accordance with both recommendations in 4 of 11. All of these 11 towers were regularly treated with disinfectant agents (Table 2).

L. pneumophila was isolated from 7 cooling towers—6 of the 13 sampled in September and 4 of the 10 sampled in December (Table 3). Use of a disinfectant effective against *L. pneumophila* in laboratory tests did not predict the results of cooling-tower water cultures even when the recommended schedule of treatment was followed (Table 3). In all, 6 of the 11 specimens from towers treated with putatively effective agents were positive, as were 2 of 4 specimens from towers treated with agents deemed to be ineffective, 2 of 4 from towers not treated with any agent, and 0 of 4 from towers treated with an

agent of unknown efficacy. Three of five towers positive in September were also positive in December, whereas only one of five towers that was culture negative in September was culture positive in December. Basin temperatures in September ranged from 24 to 31°C, and in December they ranged from 7 to 27°C; water temperatures in culture-positive towers were similar to those in culture-negative towers. None of the physical characteristics listed in Table 1 distinguished culture-positive cooling towers from culture-negative towers.

It is important to identify biocidal agents effective against *L. pneumophila* in cooling towers and evaporative condensers for several reasons. First, as we observed in this investigation, *L. pneumophila* is a common environmental contaminant (8, 13). Second, cooling tower or evaporative condenser contamination occasionally presents an important public health hazard (3, 11). Third, cooling towers constantly expose tremendous volumes of air to recirculating water, creating aerosols (12). Studies of drift from a modern 18-m-tall mechanical-draft cooling tower with an exit velocity of 33 km/h have shown that approximately 75% of aerosolized particles are from 1 to 5 µm in diameter and that sentinel bacteria can be recovered 1,600 m downwind (1). Therefore, since *L. pneumophila* can be transmitted in air (9) and the seasons of cooling tower usage and legionellosis are similar (5), identifying disinfectant agents effective against *L. pneumophila* may provide a means of preventing some cases of legionellosis.

Until the present investigation, the only available information about the efficacy of biocidal agents against *L. pneumophila* was based on laboratory tests (15) and on chlorination of a cooling tower shown to be the source of a Legionnaires disease outbreak (2). In the labora-

TABLE 1. Cooling tower data^a

Cooling tower	Site	Manufacturer	Yr installed	Fill construction	Fan capacity (ft ³ /min)
A-1	Hotel A	Marley	1978	Wood	530,000
B-1	Hotel B	Flour	1958	Wood	160,000
C-1	Hotel C	Marley	1957	Wood	1,500,000
D-1	Hotel D	Marley	1958	Wood	44,000
D-2	Hotel D	Marley	1958	Wood	41,000
E-1	Hotel E	Baltimore Aircoil	1968	Galvanized steel	100,000
F-1	Hotel F	Marley	1976	Polyvinyl chloride	246,000
G-1	Municipal auditorium	Marley	1970	Redwood	2,300,000
H-1	City health department	Marley	Rebuilt 1978	Redwood	44,000
I-1	Hotel I	Marley	New basin 1977, new fill 1978	Wood	360,000
J-1	Hotel J	Marley	1961	Wood	121,000
K-1	Hotel K	Marley	1969	Wood	300,000
K-2	Hotel K	Marley	1969	Wood	300,000

^a All data obtained in 1978 from sites in Dallas, Tex.

TABLE 2. Actual and recommended use of biocides in cooling towers

Cooling tower	Biocide	Estimated peak concn (mg/liter)	Frequency of use (1978)	Days since last use before September specimen collection	Recommended use	
					Peak concn, (mg/liter)	Frequency (per wk)
A-1	Quaternary ammonium	26	Once/wk	5	6-13	Once
	Tri- <i>n</i> -butyl tin	5	Once/wk	5	1-3	Once
B-1	Chlorine	6	Once/wk	6	19	Once
	Quaternary ammonium	10	Once/wk	4	21	Once
C-1	Quaternary ammonium	18	Once/wk	2	6-13	Once
	Tri- <i>n</i> -butyl tin	4	Once/wk	2	1-3	Once
	Chlorine	3	Once/mo	<30	2-14	As needed
D-1, D-2	Quaternary ammonium	7-10	Once/wk	3	1-12	Twice or as needed
E-1	Quaternary ammonium	53	Once/yr	51	3-5	Twice or as needed
F-1 (until 15 November)	Alkyl propanediamine	10	Once/2 wk	<14	8-12	Once or as needed
	Quaternary ammonium	4	Once/2 wk	<14	3-5	Twice or as needed
F-1 (after 15 November)	Pentachlorophenol	13-53	Once/10 days	NA ^a	50	Once or as needed
G-1	Pentachlorophenol	1	Once/wk	<7	10-20	Once
H-1	Pentachlorophenol	60	Once/2 mo	64	10-20	Once
I-1	None	NA	NA	NA	NA	NA
J-1	None	NA	NA	NA	NA	NA
K-1, K-2	Methylene bis thiocyanate	3	Twice/yr	<180	1-6	Twice

^a NA, Not applicable.

tory, Skaliy and colleagues exposed the Philadelphia 1 strain of *L. pneumophila*, suspended in sterile tap water at a concentration of 10^5 to 10^6 viable cells per ml, to six disinfectants at three concentrations (corresponding to the manufacturer's recommended initial and maintenance concentrations and one half of the recommended maintenance concentration) for as long as 168 h (15). Three disinfectants (chlorine, 2,2-dibromonitropropionamide, and quaternary ammonium compounds) were rapidly effective at all concentrations tested (15). In the only instance of field testing of which we are aware, continuous chlorine treatment to maintain a free residual of at least 3 mg/liter was associated with a 7-day lag between initiation of treatment and elimination of *L. pneumophila* from the cooling-tower water (2), despite the observation that chlorine at a concentration of 3.3 mg/liter (free residual) immediately eliminated all viable *L. pneumophila* in the laboratory (15). This information further supports the need to identify

biocidal agents effective against *L. pneumophila* in cooling towers and evaporative condensers.

In the present investigation, we found no association between the isolation of *L. pneumophila* and the efficacy of disinfectant agents as determined in the earlier laboratory tests (15), despite the fact that 4 of 11 cooling towers had been treated according to the manufacturer's recommendations. Manufacturers' recommendations are based on empiric observation of the concentration needed to prevent interference by microbiological organisms with the efficient functioning of air-conditioning systems (12). In our investigation, *L. pneumophila* was isolated from towers treated with quaternary ammonium compounds alone, quaternary ammonium compounds in combination with chlorine, or quaternary ammonium compounds in combination with tri-*n*-butyl tin (an agent of unknown efficacy against this organism). Although the concentrations of *L. pneumophila* or biocides in the cooling-tower water specimens were not mea-

TABLE 3. Biocidal agents, water basin temperatures, and culture results of cooling towers

Cooling tower	Results for specimens collected in:			
	September		December	
	Basin temp (°C)	Culture result (serogroup)	Basin temp (°C)	Culture result (serogroup)
Effective^a biocidal agents, recommended schedule				
A-1	NA ^b	+ (1)	23	+ (1)
B-1	NA	+ (1, 5)	9	+ (1, 5)
C-1	31	—	11	—
D-1	25	+ (1, 5)	NA	NA
D-2	26	—	NA	NA
Effective^a biocidal agents, improper schedule				
E-1	27	—	7	—
F-1 (before 15 November)	24	+ (1)	NA	NA
Ineffective^a biocidal agents				
F-1 (after 15 November)	NA	NA	27	+ (1)
G-1	NA	—	NA	+ (1)
H-1	NA	—	NA	NA
No agent				
I-1	27	+ (1)	NA	—
J-1	NA	+ (1)	11	—
Agent of uncertain^a efficacy				
K-1	27	—	20	—
K-2	28	—	17	—

^a Based on laboratory studies (see text).

^b NA, Not available.

sured, the observation that three of six culture-positive cooling towers sampled in September had been treated in the preceding week with recommended concentrations of agents that had been effective in the laboratory suggests that these agents would not be effective in similar towers. Previous laboratory studies of *L. pneumophila* sensitivities of biocidal agents failed to predict culture results from treated cooling towers. It is clearly important to test potentially effective biocidal agents and combinations in the field to determine whether they prevent contamination with *L. pneumophila*.

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