CONTROL OF *LEGIONELLA* IN LARGE BUILDINGS THROUGH COMMUNITY-WIDE INTRODUCTION OF MONOCHLORAMINE

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Monochloramine may be more effective than chlorine at reducing *Legionella* colonization of potable water systems in large buildings, which are key sources of community- and hospital-acquired Legionnaires' disease. Monochloramine has previously been shown to penetrate biofilms better than chlorine (1) and to be associated with a lower risk of Legionnaires' disease in healthcare settings (4, 5). Regulations issued by the Environmental Protection Agency require that U.S. water utilities reduce concentrations of trihalomethanes, carcinogens created through the combination of chlorine and organic compounds. Because monochloramine use is associated with lower concentrations of trihalomethanes, many utilities are converting their residual disinfectant from chlorine to monochloramine. In a small study, we observed that monochloramine conversion was associated with decreased *Legionella* colonization of buildings served by the municipal water system (6). To determine whether this decreased risk was sustainable over a longer period of time and at a larger number of distal sites, we performed a larger colonization survey in San Francisco before and after conversion to monochloramine (3).

We sampled water from 53 large (≥3 stories) buildings (24 government, 29 private [hotels, offices]) in San Francisco, Calif., every 4 months during February 2003 to September 2004; monochloramine conversion occurred in December 2003. During each of the six rounds of sampling, bulk water was collected from central hot water heaters and four distal sites (e.g., showers, taps) in each building; biofilm swabs were also collected from each distal site. Temperature, pH, and free and total residual chlorine concentrations were measured at the time of collection. *Legionella* were isolated from water samples and biofilm swabs, speciated, and serogrouped using standard methods (2). Laboratory staff were blinded to the identity of buildings in each round. Predictors of colonization were identified using a multivariable model that adjusted for residual disinfectant, building size, temperature, and disruptions in service. We conducted enhanced surveillance for laboratory-confirmed Legionnaires' disease in San Francisco before and after the conversion to monochloramine.

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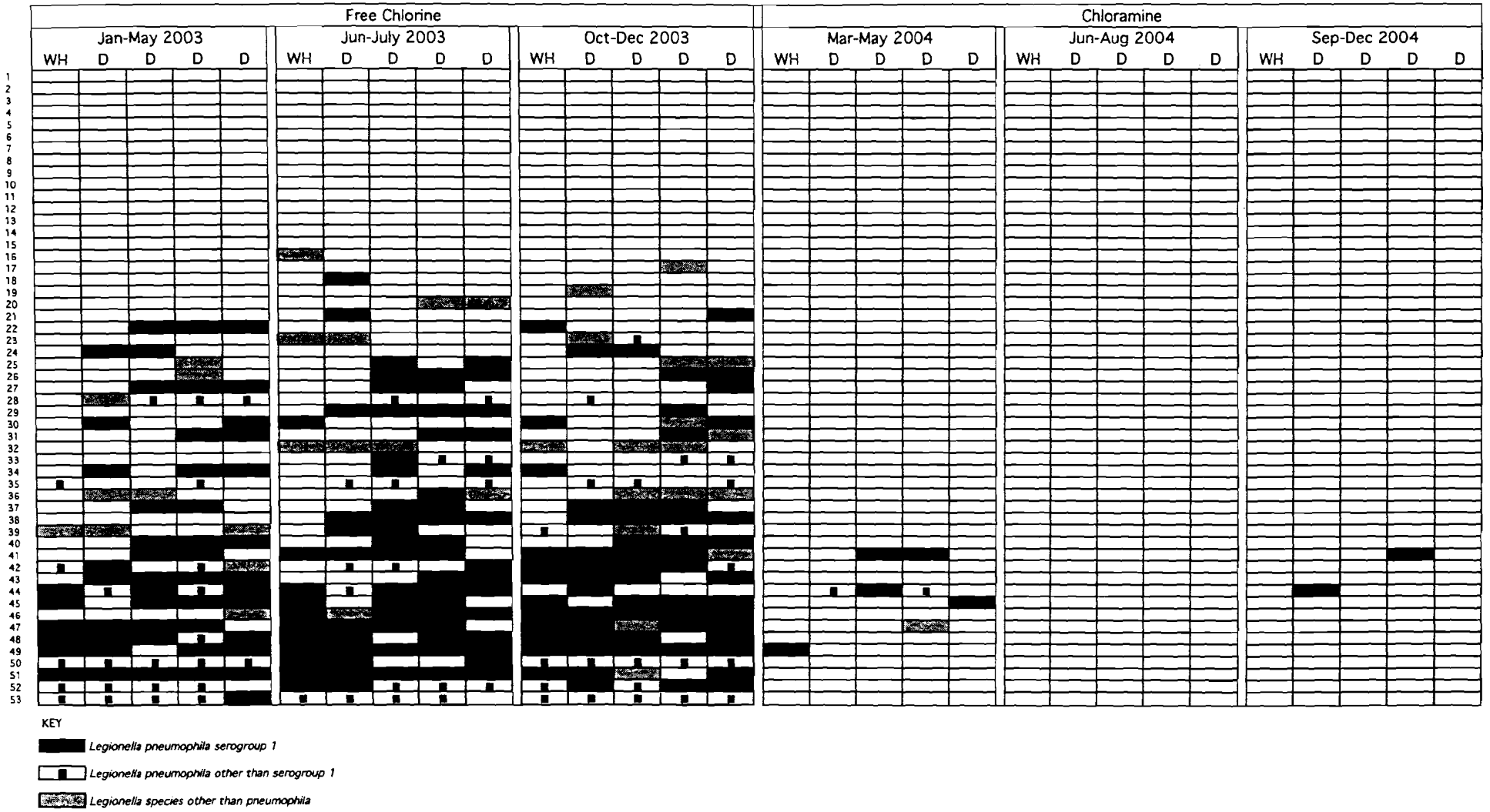

FIGURE 1 *Legionella* colonization of water heaters and distal sites sampled in San Francisco buildings (in rows), by residual disinfectant and sampling interval. *Legionella* species are represented by different patterns. Each row represents a single building and each cell, the results of *Legionella* culture for a site within the building. WH, water heater; D, distal site.

In the chlorine phase, 37 (70%) buildings were colonized at least once in ≥1 sampling site. In the monochloramine phase, 5 (9%) buildings were colonized ($P < 0.001$), and all had been extensively colonized during the chlorine phase. The overall prevalence of *Legionella* in samples collected was reduced from 25% (352 of 1,405 samples) in the chlorine phase to 0.9% (12 to 1,417) in the monochloramine phase ($P < 0.001$) (Fig. 1). *L. pneumophila* serogroup 1 (sg 1) accounted for 63 and 67% of isolates in the chlorine and monochloramine phases, respectively.

In the chlorine phase, 29% (45 of 157) of samples collected from water heaters yielded *Legionella*; fewer than 1% (1 of 159) of water heaters sampled during the monochloramine phase were positive ($P < 0.001$). After controlling for water heater temperature, building height, and disruptions in service, monochloramine use was associated with a 96% reduction in the prevalence of water heater colonization ($P < 0.001$). We observed decreased risk of colonization of hot water heaters with increasing temperature, from 21 to 24% when the temperature was below 39°C, to 18% at 40 to 49°C, to 1% when the temperature was ≥50°C ($P = 0.001$ for trend). Controlling for other factors, *Legionella* colonization of water heaters was 3 times more likely in buildings >10 stories tall than in buildings 3 to 10 stories tall ($P = 0.002$) and 2.3 times more likely when disruptions in water supply were reported in the 3 months before sampling ($P = 0.003$). *Legionella* colonization of water heaters increased the likelihood of colonization at distal sites 1.7-fold, ($P < 0.001$) and independently, taller buildings were 1.8 times more likely to have *Legionella* recovered from distal sites ($P < 0.001$). Similar to our findings with hot water heaters, the use of monochloramine was associated with a 96% reduction in the risk of colonization at distal sites ($P < 0.001$).

Conversion of the residual disinfectant to monochloramine in San Francisco's municipal water system virtually eliminated *Legionella* colonization in large buildings served by the system. This occurred despite over half of the buildings being colonized in at least one site and despite many buildings being persistently colonized at multiple sample points before the introduction of monochloramine.

Few cases of Legionnaires' disease were diagnosed during our study: 1 case in 2002 (the year before our study), 0 cases during the chlorine phase, and 1 case during the monochloramine phase. Review of requests for *Legionella* diagnostic testing at local clinical laboratories revealed few urine antigen tests and 40 to 60 *Legionella* culture requests each month at 2 laboratories. We were unable to show an impact on Legionnaires' disease in San Francisco due to the low number of diagnosed cases.

Monochloramine holds promise as a measure to prevent community-acquired Legionnaires' disease. Because of the association between *Legionella* colonization of potable water systems in hospitals and increased risk of healthcare-associated Legionnaires' disease, direct introduction of monochloramine into hospital water systems might offer another intervention for prevention of healthcare-associated Legionnaires' disease.

REFERENCES

1. **Cunliffe, D. A.** 1990. Inactivation of Legionella pneumophila by monochloramine. *J. Appl. Bacteriol.* **68**:453–459.
2. **Fields, B. S., R. F. Benson, and R. E. Besser.** 2002. Legionella and Legionnaires' disease: 25 years of investigation. *Clin. Microbiol. Rev.* **15**:506–526.
3. **Flannery, B., L. B. Gelling, D. J. Vugia, J. M. Weintraub, J. J. Salerno, M. J. Conroy, V. A. Stevens, C. E. Rose, M. R. Moore, B. S. Fields, and R. E. Besser.** 2006. Reduction of Legionella colonization after conversion to monochloramine for residual disinfection of municipal drinking water. *Emerg. Infect. Dis.* In press.
4. **Heffelfinger, J. D., J. L. Kool, S. Fridkin, V. J. Fraser, J. Hageman, J. Carpenter, and C. G. Whitney.** 2003. Risk of hospital-acquired Legionnaires' disease in cities using monochloramine versus other water disinfectants. *Infect. Control Hosp. Epidemiol.* **24**:569–574.
5. **Kool, J. L., J. C. Carpenter, and B. S. Fields.** 1999. Effect of monochloramine disinfection of municipal drinking water on risk of nosocomial Legionnaires' disease. *Lancet* **353**:272–277.
6. **Moore, M. R., M. Pryor, B. Fields, C. Lucas, M. Phelan, and R. E. Besser.** 2006. Introduction of monochloramine into a municipal water system: impact on colonization of buildings by Legionella spp. *Appl. Environ. Microbiol.* **72**:378–383.