

# Surveillance of Legionellosis and *Legionella* Bacteria in the Built Environment in Singapore

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## Abstract

During the period 1986 to 1996, a total of 258 sporadic cases of community-acquired legionellosis was reported, giving a mean annual morbidity rate of 0.9 per 100 000 population. Majority of the cases (91.5%) was serologically diagnosed by the indirect fluorescent antibody (IFA) test against *Legionella pneumophila* based on single sera with a titre of  $\geq 1:1024$ . The others were confirmed by a four-fold increase in IFA titre to a minimum of 1:128 (7.4%) and by culture (1.1%). Cases were reported predominantly among males, ethnic Indians, the elderly and those with concurrent medical conditions. The overall case-fatality rate was 14.7%, with the rate significantly higher among those aged  $\geq 45$  years (21%), smokers (20.4%) and those with concurrent medical conditions (22.5%). Seroepidemiological studies among the healthy population based on an IFA titre of  $\geq 1:32$  showed a prevalence of between 10.3% and 21.9%. Of the various occupational groups investigated, high seroprevalence rates were found in foreign construction workers (52.4%) and occupants of a building investigated for an unusual building-related illness (76.1%). Environmental surveillance of *Legionella* bacteria showed that 36% of cooling towers, 15% to 19% of decorative fountains and waterfalls and 2% of spa pools were positive. The majority (85%) of environmental isolates was identified as *Legionella pneumophila*: 54.8% of serogroup 1 and 5% of Pontiac subtype.

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**Key words:** Code of practice, Cooling towers, *Legionella pneumophila*, Legionnaires' disease, Seroprevalence

## Introduction

The first reported outbreak of Legionnaires' disease with 182 cases and 29 deaths occurred in Philadelphia in 1976.<sup>1</sup> Since then, several other outbreaks of legionellosis associated with cooling towers,<sup>2-7</sup> whirlpool spas,<sup>8,9</sup> evaporative condensers<sup>10</sup> potable and hot water supply,<sup>11-14</sup> decorative fountain,<sup>15</sup> and excavation and construction<sup>16-21</sup> had been reported. Media publicity on these outbreaks with high case-fatality gave rise to much public health concern.

Legionellosis has two distinct clinical manifestations: Pontiac fever, a self-limiting flu-like syndrome; and Legionnaires' disease, a more severe multi-system disease with lung infection. Legionnaires' disease is of major concern because it is potentially life-threatening.

Most of the epidemiological studies on legionellosis have been conducted in temperate countries. To find out whether or not the disease occurs in Singapore, legionellosis was made administratively notifiable in June 1985. Guidelines on the clinical diagnosis, laboratory investigation and management of Legionnaires' disease were issued to all registered medical practitioners. All clinically diagnosed and laboratory confirmed cases are to be notified to the Quarantine and Epidemiology Department, Ministry of the Environment. In June 1985, *Legionella* bacteria was first detected in water samples taken from air-conditioning cooling towers,<sup>22</sup> and in March 1986, the first local case of Legionnaires' disease was reported.<sup>23</sup>

We report here our epidemiological surveillance of

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legionellosis and the distribution of *Legionella* bacteria in the tropical urban environment of Singapore for the period 1986 to 1996.

## Materials and Methods

### Epidemiological Investigation

As soon as notification was received, a thorough epidemiological investigation was carried out by a trained environmental health officer using a standard questionnaire form. The investigation entailed an interview with the patient, or the immediate family members (if the patient had died), and a review of the clinical case notes. Information collected included demographic profile of the case, such as age, sex, ethnic group, residential address, place of work, date of onset of illness, signs and symptoms, results of laboratory and radiographic investigations, presence of concurrent medical illness and duration of hospitalisation. To determine the possible sources of infection, enquiries were made into recent travel history, and exposure to cooling towers, fountains, spa baths and other artificial water systems at the place of residence and place of work.

The cases included in the analysis were all clinically diagnosed and verified by culture or serology based on the indirect fluorescent antibody (IFA) test that utilised polyvalent reagents against *Legionella pneumophila* serogroups 1-6 (MarDx Diagnostics Inc, USA) conducted at the Serology Section, Department of Pathology, Singapore General Hospital and the Microbiology Department, National University Hospital. A case is laboratory-confirmed if *Legionella* bacteria were cultured from respiratory secretions, or there was a four-fold increase in *Legionella* antibody titre to  $\geq 1:128$  between acute- and convalescent-phase serum specimens. If the serological test was based on a single IFA titre of  $\geq 1:1024$ , it was considered a presumptive case.

### Seroprevalence Surveys

To determine the actual extent of *Legionella* infection, seroepidemiological surveys were conducted for the period 1992 to 1995 among the general population and selected occupational groups such as sewage workers and cooling towers maintenance personnel. In an investigation into an unusual building-related illness, occupants of the building were also tested. For the general population, the sera were obtained from the 1993 national seroepidemiological survey on vaccine-preventable diseases. Seropositivity was based on an IFA titre of  $\geq 1:32$ .

### Surveillance Of *Legionella* Bacteria in the Environment

Water samples were routinely collected from cooling towers and other artificial water systems at the place of residence, place of work or in the neighbourhood of the reported cases and submitted to the Food and Water

Laboratory, Pathology Department, Singapore General Hospital, for culture of *Legionella* bacteria.<sup>24,25</sup> Since September 1991, extensive nationwide surveys of cooling towers, fountains and spa baths were conducted to determine the distribution of *Legionella* bacteria in the built environment. About 500 ml of water sample was taken from the pond of the cooling tower or fountain using a pump, disinfected with sodium hypochlorite and neutralised with sodium thiosulphate.

The species and serogroups of *L. pneumophila* isolated were determined by direct fluorescent antibody technique, using polyvalent and monovalent DFA conjugates from MarDx Diagnostics, USA, DFA monoclonal antibody reagent from Sanofi Diagnostics, Pasteur, France and /or slide agglutination using the Denka Seiken Kit, Japan. All unidentified *Legionella* were sent to the Centre for Applied Microbiology and Research, Salisbury or to the Oxford Public Health Laboratory, United Kingdom, for identification using the Oxford panel.

### Data analysis

All clinical, epidemiological and laboratory data collected were analysed using the microcomputer-based Dbase IV, Microsoft Excel 7.0 and Statistical Package for Social Science (SPSS).

## Results

### Epidemiology

During the period 1986 to 1996, a total of 258 cases of legionellosis (comprising 237 cases of Legionnaires' disease and 21 cases of Pontiac fever) were reported, giving a mean annual morbidity rate of 0.9 per 100 000 population (Table I). Only twenty-two (8.5%) cases were labo-

TABLE I: INCIDENCE, MORTALITY AND CASE-FATALITY RATES OF REPORTED LEGIONELLOSIS IN SINGAPORE, 1986 TO 1996

| Year  | No. of cases | Morbidity rate per 100 000 | No. of deaths | Mortality rate per million | Case-fatality rate (%) |
|-------|--------------|----------------------------|---------------|----------------------------|------------------------|
| 1986  | 3            | 0.1                        | 1             | 0.4                        | 33.3                   |
| 1987  | 5            | 0.2                        | 2             | 0.8                        | 40.0                   |
| 1988  | 9            | 0.3                        | 1             | 0.4                        | 11.1                   |
| 1989  | 33           | 1.2                        | 4             | 1.5                        | 12.1                   |
| 1990  | 32           | 1.2                        | 3             | 1.1                        | 9.4                    |
| 1991  | 14           | 0.5                        | 2             | 0.7                        | 14.3                   |
| 1992  | 58           | 2.1                        | 6             | 1.8                        | 10.3                   |
| 1993  | 17           | 0.6                        | 4             | 1.4                        | 23.5                   |
| 1994  | 33           | 1.1                        | 9             | 3.1                        | 27.3                   |
| 1995  | 22           | 0.7                        | 2             | 0.7                        | 9.1                    |
| 1996  | 32           | 1.1                        | 4             | 1.3                        | 12.5                   |
| Total | 258          | 0.9*                       | 38            | 1.3*                       | 14.7                   |

\* Mean annual rate based on the 1990 census of population (Source: Department of Statistics)

ratory confirmed (three or 1.1% by culture and 19 cases or 7.4% by a four-fold rise in IFA titre). The other 236 cases (91.5%) were presumptive cases. Of the reported cases, 18 (7%) gave a history of recent travel 2 to 10 days prior to their onset of symptoms and were classified as imported.

There was a male predominance with a male to female ratio of 2.4:1. The highest morbidity rate was among the elderly aged 65 years and above. Of the three major ethnic groups, Indians had the highest mean annual morbidity rate (1.4 per 100 000 population), which was significantly higher than that of the Chinese (0.8 per 100 000 population) and the Malays (0.6 per 100 000 population) ( $P = 0.003$ ) (Table II). The occupations of 227 cases reported during the period 1989 to 1996 included retirees (28.6%), housewives (16.6%), construction labourers (9.5%), armed forces personnel (7.5%) and clerical workers (5.0%).

No clustering of cases by person and place was observed. Cases occurred singly and sporadically throughout the year in all parts of the island. A discernible peak was noted in December 1989 and again in January 1992, both following a spell of heavy rainfall (Fig. 1). However, there was no significant correlation between cases and rainfall in the other years.

Majority of the cases (145/241; 60.2%) had concurrent medical conditions especially diabetes mellitus, hypertensive and ischaemic heart disease, chronic obstructive pulmonary disease, asthma, pulmonary tuberculosis, neoplasms and renal failure (Table III). The main clinical presentations were fever with chills and rigors, cough, dyspnoea, and chest pain/discomfort (Table IV).

### Case Fatality

A total of 38 cases died, giving an overall case-fatality rate of 14.7%. Factors significantly associated with a higher case-fatality rate included age  $\geq 45$  years, concurrent medical conditions and smoking history (Table V).

### Seroprevalence

The seroprevalence of the general population to *L. pneumophila* was between 10.3% and 21.9% with IFA titres of  $\geq 1:32$  and between 1.1% and 7.8% with titres of  $\geq 1:256$  (Table VI). Among various occupational groups, a higher seroprevalence was observed in foreign construction workers (52.6% with titres of  $\geq 1:32$  and 36.8% with titres of  $\geq 1:256$ ). In an investigation into a building-related illness in a centrally air-conditioned shopping complex, the seroprevalence of the occupants (76.1% and 17.4%, respectively) was found to be significantly higher than that of the general adult population (21.9% and 1.1%, respectively) ( $P < 0.0001$ ).

### Surveillance of the Environment

For the period September 1991 to 1996, the overall isolation rate of *Legionella* bacteria was 36% (1107/3095) for cooling towers, 33% (2/6) for public showers, 29% (30/103) for indoor decorative fountains, 15% (10/68) for outdoor decorative fountains, 15% (4/26) for outdoor man-made decorative waterfalls, and 2% (1/48) for spa pools (Table VII). The isolation rate was not correlated with rainfall. The majority of isolates (992 or 85.6%) belonged to the serogroup *L. pneumophila*. Of these, 544 (54.8%) belonged to serogroup 1. Further subtyping of a total of 233 isolates showed that 180 (77%) belonged to OLDA, 41 (18%) to Bellingham, and 12 (5%) to Pontiac

TABLE II: EPIDEMIOLOGICAL FEATURES AND CASE-FATALITY RATE OF 258 REPORTED LEGIONELLOSIS CASES IN SINGAPORE, 1986 TO 1996

| Characteristic | No. of cases |        |            | Mean annual rate<br>per 100 000* | No. of deaths | Case-fatality<br>rate (%) |
|----------------|--------------|--------|------------|----------------------------------|---------------|---------------------------|
|                | Male         | Female | Both sexes |                                  |               |                           |
| All            | 181          | 77     | 258        | 0.9                              | 38            | 14.7                      |
| Age group:     |              |        |            |                                  |               |                           |
| 0 to 4         | 0            | 0      | 0          | 0                                | 0             |                           |
| 5 to 14        |              | 0      |            | 0.02                             | 0             | 0                         |
| 15 to 24       | 26           | 5      | 31         | 0.6                              |               | 3.2                       |
| 25 to 34       | 16           | 8      | 24         | 0.4                              | 0             | 0                         |
| 35 to 44       | 19           | 7      | 26         | 0.5                              | 0             | 0                         |
| 45 to 54       | 19           | 9      | 28         | 1.0                              | 4             | 14.2                      |
| 55 to 64       | 29           | 14     | 43         | 2.1                              | 9             | 20.9                      |
| 65+            | 71           | 34     | 105        | 5.9                              | 24            | 22.9                      |
| Ethnic group:  |              |        |            |                                  |               |                           |
| Chinese        | 122          | 52     | 174        | 0.8                              | 23            | 13.2                      |
| Malay          | 17           | 8      | 25         | 0.6                              | 6             | 24.0                      |
| Indian         | 19           | 10     | 29         | 1.4                              | 6             | 20.7                      |
| Others         |              |        | 10         | 3.1                              |               | 10.0                      |
| Foreigner      | 16           | 4      | 20         |                                  | 2             | 10.0                      |

\* Based on the 1990 census of population (Source: Department of Statistics)

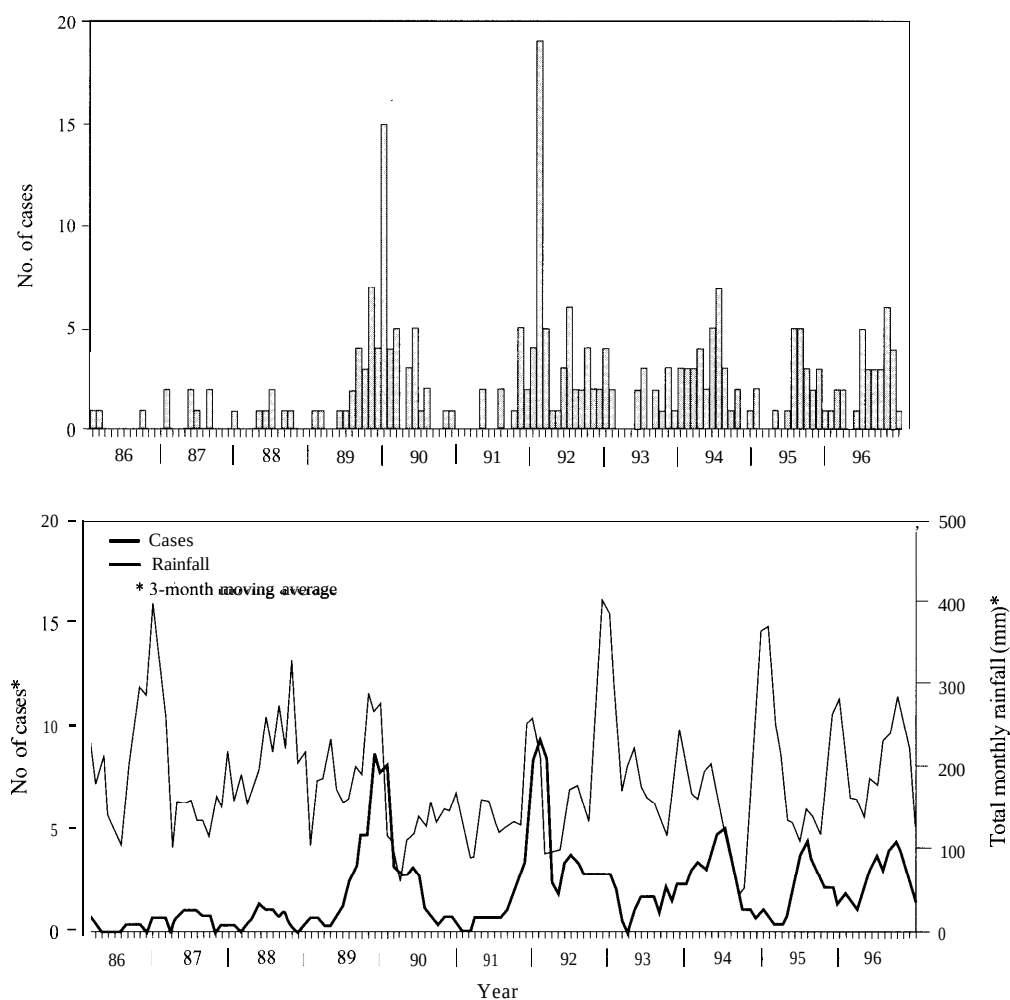


Fig.1 Monthly distribution of reported cases (based on date of onset) of legionellosis and its relationship with rainfall, 1986 to 1996. In analysing the correlation between the seasonal distribution of cases and rainfall, three-month moving average, of the preceding, current and the following months 'parameters, was used to smoothen the wide monthly variance.

TABLE III: FREQUENCY OF MAIN CONCURRENT MEDICAL CONDITIONS\* AND CASE-FATALITY RATE OF 241 REPORTED CASES OF LEGIONELLOSIS, 1989 TO 1996

| Medical condition                          | Case<br>n = 241 |      | Death<br>n = 34 |                        |
|--------------------------------------------|-----------------|------|-----------------|------------------------|
|                                            | No.             | (%)  | No.             | Case-fatality rate (%) |
| Any medical condition                      | 145             | 60.2 | 33              | 22.8                   |
| Diabetes mellitus                          | 38              | 15.8 | 12              | 31.6                   |
| Diseases of the circulatory system:        |                 |      |                 |                        |
| - hypertensive disease                     | 37              | 15.4 | 10              | 27.0                   |
| - ischaemic heart disease                  | 34              | 14.1 | 11              | 32.4                   |
| - cerebrovascular disease                  | 16              | 6.6  | 7               | 43.8                   |
| Diseases of the respiratory system:        |                 |      |                 |                        |
| - chronic obstructive pulmonary disease    | 21              | 8.7  | 7               | 33.3                   |
| - asthma                                   | 19              | 7.9  | 2               | 10.5                   |
| Pulmonary tuberculosis                     | 22              | 9.1  | 2               | 9.1                    |
| Neoplasms                                  | 9               | 3.7  | 4               | 44.4                   |
| Renal failure                              | 6               | 2.5  | 2               | 33.3                   |
| Cholecystitis, cholangitis, cholelithiasis |                 | 2.9  | 0               | 0                      |

\* Cases may have more than one concurrent medical conditions

TABLEIV: CLINICAL PRESENTATION\* OF 258 CASES OF LEGIONELLOSIS, 1986 TO 1996

| Clinical presentation       | No. | %    |
|-----------------------------|-----|------|
| Fever                       | 196 | 76.0 |
| Chills and rigors           | 65  | 25.2 |
| Excessive perspiration      | 9   | 3.5  |
| Respiratory symptoms:       |     |      |
| - cough (productive)        | 161 | 62.4 |
| - cough (non-productive)    | 47  | 18.2 |
| - dyspnoea                  | 109 | 42.2 |
| - chest pain/discomfort     | 55  | 21.3 |
| - haemoptysis               | 16  | 6.2  |
| - hoarseness and sorethroat | 11  | 4.3  |
| Gastrointestinal symptoms:  |     |      |
| - anorexia                  | 28  | 10.9 |
| - nausea/vomiting           | 23  | 8.9  |
| - diarrhoea                 | 16  | 6.2  |
| - abdominal pain/discomfort | 12  | 4.7  |
| Neurological symptoms:      |     |      |
| - headache                  | 11  | 4.3  |
| - confusion                 | 3   | 1.2  |
| Constitutional symptoms:    |     |      |
| - malaise and lethargy      | 14  | 5.4  |
| - myalgia/arthralgia        | 11  | 4.3  |

subtype.

In the environmental investigation of the centrally air-conditioned shopping complex with a building-related illness, it was found that the fresh air intake into the building was sited near the cooling towers which were heavily colonised by *L. pneumophila*, serogroup 1, subtype OLDA, and serogroup 7.<sup>26</sup>

## Discussion

In Singapore, Legionnaires' disease has emerged as an important public health problem with an annual incidence rate of 0.1 to 2.1 per 100 000 population and a case-

fatality rate of 14.7%. There appears to be a general increase in incidence after 1988, probably due to better case-detection resulting from increased awareness among medical practitioners. The possibility of over-notification cannot be ruled out as majority of reported cases were presumptive and not laboratory confirmed by culture or four-fold increase in IFA titre. Nevertheless, the reported incidence rate of legionellosis in Singapore is lower than that of the USA (12 per 100 000 population)<sup>27</sup> and Scotland (5.1 per 100 000 population) and comparable to that of Denmark (1.8 per 100 000 population), Germany (1.6 per 100 000 population) and England and Wales (0.2 per 100 000 population).<sup>28</sup> The wide range of incidence rates could be accounted for by differences in case definition and laboratory methods of diagnosis.

The epidemiological features of legionellosis in Singapore are similar to those of temperate countries i.e. the disease affects mainly the elderly, males, and those immunocompromised by concurrent medical conditions. However, gastrointestinal (5% to 11%) and neurological (1% to 4%) symptoms are lower than those observed in temperate countries.<sup>29</sup> Also, unlike temperate countries, where a large proportion of the cases were hospital acquired<sup>30</sup> or associated with foreign travel (23% in USA, 45% to 65% in England and Wales),<sup>31-33</sup> majority (93%) of the reported cases in Singapore were community acquired. Our surveillance noted the association of cases following two seasons of heavy rainfall; the reason for the association in these years and the lack of association in the following years remains unknown.

Cooling towers provide ideal reservoirs for the growth and multiplication of *Legionella* bacteria, if they are not properly or regularly maintained, and sludge, scale, rust, algae and organic particles are allowed to accumulate. As the water is constantly subjected to agitation, bacteria-laden aerosols of respirable size are dispersed

TABLEV: FACTORS SIGNIFICANTLY ASSOCIATED\* WITH CASE-FATALITY RATE OF 258 REPORTED LEGIONELLOSIS CASES, 1986 TO 1996

|                               | Case | Death | Case-fatality rate (%) | Odds ratio | (95% CI)     | P value |
|-------------------------------|------|-------|------------------------|------------|--------------|---------|
| Age:                          |      |       |                        |            |              |         |
| - <45 years                   | 82   | 1     | 1.2                    | 21.6       | (3.1 - 94.4) | <0.0001 |
| - 45+ years                   | 176  | 37    | 21.0                   | 1          |              |         |
| Concurrent medical condition: |      |       |                        |            |              |         |
| - present                     | 160  | 36    | 22.5                   | 13.9       | (3.2 - 46.1) | <0.0001 |
| - absent                      | 98   | 2     | 2.0                    | 1          |              |         |
| Smoking history:              |      |       |                        |            |              |         |
| - yes†                        | 113  | 23    | 20.4                   | 2.2        | (1.0 - 4.7)  | 0.04    |
| - no                          | 145  | 15    | 10.3                   | 1          |              |         |

CI: confidence interval

\*  $\chi^2$  test using Yates' continuity correction

† Includes smokers and ex-smokers

TABLE VI: SEROPREVALENCE OF INDIRECT FLUORESCENT ANTIBODY TO *LEGIONELLA PNEUMOPHILA* IN SELECTED POPULATION GROUPS, 1992 TO 1995

| Population group                                                                    | No. tested | ≥1:32 |      | ≥1:256 |      |
|-------------------------------------------------------------------------------------|------------|-------|------|--------|------|
|                                                                                     |            | No.   | (%)  | No.    | (%)  |
| Construction worker:                                                                |            |       |      |        |      |
| - Singaporean (1992)                                                                | 19         | 2     | 10.5 | 1      | 5.3  |
| - Foreigner (1992)                                                                  | 38         | 20    | 52.6 | 14     | 36.8 |
| Sewage worker (1992)                                                                | 600        | 94    | 15.7 | 29     | 4.8  |
| Dumping ground worker (1992)                                                        | 43         | 6     | 14.0 | 3      | 7.0  |
| Cooling tower maintenance personnel (1992)                                          | 230        | 44    | 19.1 | 18     | 7.8  |
| Quarry worker (1992)                                                                | 76         | 8     | 10.5 | 3      | 3.1  |
| Cemetery worker (1992)                                                              | 64         |       | 10.9 | 3      | 4.7  |
| Zoo keepers (1992)                                                                  | 150        | 22    | 14.7 | 5      | 3.3  |
| Occupants of a building investigated for an unusual building-related illness (1995) | 46         | 35    | 76.1 | 8      | 17.4 |
| Healthy population (1993)                                                           |            |       |      |        |      |
| - <20 years                                                                         | 271        | 28    | 10.3 | 0      | 0    |
| - ≥20 years                                                                         | 448        | 98    | 21.9 | 5      | 1.1  |

into the environment. Conditions in a hot, tropical urban environment could pose a higher public health risk of the disease than that of a temperate country. This is because, firstly, the increased usage of cooling towers throughout the year and in some buildings, throughout the day, and the high ambient temperature (ranging from 23°C to 33°C) impose considerable heat load on the systems. These in turn increase the degree of *Legionella* colonisation and multiplication.<sup>34</sup> Secondly, once disseminated out of the cooling towers, the viability of the bacteria in the contaminated aerosol is well supported by our consistently high relative humidity, “enabling the droplet to remain suspended longer. The risk is further enhanced by the close proximity of centrally air-conditioned buildings with human populations. Finally, the sheer density of high-rise buildings prevents lateral spread and thus traps emissions from the cooling towers.”<sup>36</sup>

The environmental isolation rate of *Legionella* bacteria in Singapore is comparable with those in temperate countries: 37% in Japan,<sup>37</sup> 83% in Paris, France,<sup>38</sup> 42% to 54% in England and Wales,<sup>39</sup> and 42% in Victoria, Australia.<sup>40</sup> Serological surveys confirmed the high level of exposure of the general population with a quarter positive for IFA (≥1:32) to *L. pneumophila*. However, no common source outbreaks have been detected, nor cases traced to any cooling tower or other artificial water system. This could be because environmental isolates were predominantly of the non-pathogenic strains, as only 54.8% of all *L. pneumophila* isolated belonged to serogroup 1, of which 5% were of the pathogenic Pontiac subtype. In the investigation into a building-related illness in a centrally air-conditioned shopping complex,

the significantly higher seroprevalence among the occupants was probably due to the proximity of fresh air intake to the contaminated cooling towers. This incident showed that if the cooling towers were contaminated by the more pathogenic subtype, outbreaks could occur.<sup>41</sup> The reason for the significantly higher seroprevalence among foreign construction workers compared with local workers is unknown. One possibility could be the higher exposure of foreign workers to construction dust compared to local workers who worked predominantly as supervisors and overseers.

Building owners and managers are educated on the disease and the importance of proper and regular maintenance of cooling towers. This has been carried out through joint site inspections and face-to-face education by environmental health officers in the course of water sampling. A Code of Practice<sup>42</sup> on the prevention and control of *Legionella* bacteria in cooling towers was published in 1992 to provide a source of reference for building owners and management corporations on the maintenance and servicing of cooling towers. The Code includes sections pertaining to cleaning, disinfection, and chemical treatment. It highlights the importance of monitoring the effectiveness of treatment by monthly testing for *Legionella* for hospitals, and six-monthly testing for other buildings. Building managers are responsible for keeping proper records of details of servicing and maintenance in a log book for random checks by environmental health officers. Seminars targeted at building managers and water treatment companies are also held periodically to update them on the disease situation and the latest developments in the prevention and control of *Legionella* in cooling towers. It is encouraging to note that

TABLE VII: ISOLATION RATE OF *LEGIONELLA* BACTERIA IN THE ENVIRONMENT BY TYPE OF PREMISES AND WATER SYSTEM, 1991 TO 1996

| Type of premises                   | No. positive/No. tested (%) |               |              |             |
|------------------------------------|-----------------------------|---------------|--------------|-------------|
|                                    | Cooling tower               | Fountain      |              | Waterfall   |
|                                    |                             | indoor        | outdoor      |             |
| Hospital                           | 261/115 (22.6)              |               |              |             |
| Office                             | 137/486 (28.2)              | 0/2 (0.0)     | 0/1 (0.0)    | 1/3 (33.3)  |
| Shopping complex                   | 42/113 (37.2)               | 0/6 (0.0)     | 2/3 (66.7)   | 0/4 (0.0)   |
| Office/shopping complex            | 117/321 (36.6)              | 4/11 (36.4)   | 3/19 (15.8)  | 1/2 (50.0)  |
| Hotel                              | 135/316 (42.7)              | 4/36 (11.1)   | 4/29 (13.8)  | 1/16 (6.3)  |
| Factory                            | 414/1206 (34.3)             | 1/1 (100.0)   | 0/6 (0.0)    | 1/1 (100.0) |
| Club/recreational centre           | 19/35 (54.3)                | 0/1 (0.0)     |              |             |
| Training centre                    | 9/19 (47.4)                 | 0/2 (0.0)     | 0/2 (0.0)    |             |
| Restaurant                         | 17/36 (47.2)                |               |              |             |
| Supermarket                        | 21/46 (45.7)                |               |              |             |
| Cinema                             | 12/24 (50.0)                |               |              |             |
| Residential building               | 3/11 (27.3)                 | 0/1 (0.0)     |              |             |
| Place of worship                   | 0/7 (0.0)                   |               |              |             |
| Institute of higher learning       | 62/138 (44.9)               |               |              |             |
| School/college/technical institute | 3/16 (18.8)                 |               |              |             |
| Research institution/laboratory    | 20/35 (57.1)                |               |              |             |
| Sewerage treatment works           | 0/21 (0.0)                  |               |              |             |
| Food catering building             | 9/12 (75.0)                 |               |              |             |
| Library                            | 4/7 (57.1)                  |               |              |             |
| Airport                            | 30/42 (71.4)                | 17/136 (47.2) | 0/3 (0.0)    |             |
| Convention centre                  | 11/37 (29.7)                | 0/1 (0.0)     | 1/5 (20.0)   |             |
| Others                             | 16/73 (21.9)                | 4/6 (66.7)    |              |             |
| Total                              | 1107/3095 (35.8)            | 30/103 (29.1) | 10/68 (14.7) | 4/26 (15.4) |

TABLE VII: cont.

| Type of premises                   | No. positive/No. tested (%) |            |                       |            |              | Total            |
|------------------------------------|-----------------------------|------------|-----------------------|------------|--------------|------------------|
|                                    | Pond                        | Spa pool   | Evaporative condenser | Shower     | Sewage water |                  |
| Hospital                           |                             |            |                       |            |              | 26/115 (22.6)    |
| Office                             | 0/3 (0.0)                   |            |                       |            |              | 138/495 (27.9)   |
| Shopping complex                   |                             |            |                       |            |              | 44/126 (34.9)    |
| Office/shopping complex            |                             |            |                       |            |              | 125/353 (35.4)   |
| Hotel                              | 0/4 (0.0)                   | 1/24 (4.2) |                       |            |              | 145/425 (34.1)   |
| Factory                            | 0/1 (0.0)                   |            | 5/10 (50.0)           |            |              | 421/1225 (34.4)  |
| Club/recreational centre           |                             | 0/20 (0.0) |                       |            |              | 19/56 (33.9)     |
| Training centre                    |                             |            |                       |            |              | 9/23 (39.1)      |
| Restaurant                         |                             |            |                       |            |              | 17/36 (47.2)     |
| Supermarket                        |                             |            |                       |            |              | 21/46 (45.7)     |
| Cinema                             |                             |            |                       |            |              | 12/24 (50.0)     |
| Residential building               |                             | 0/1 (0.0)  |                       | 2/6 (33.3) |              | 5/19 (26.3)      |
| Place of worship                   |                             |            |                       |            |              | 0/7 (0.0)        |
| Institute of higher learning       |                             |            |                       |            |              | 62/138 (44.9)    |
| School/college/technical institute |                             |            |                       |            |              | 3/16 (18.8)      |
| Research institution/laboratory    |                             |            |                       |            |              | 20/35 (57.1)     |
| Sewerage treatment works           |                             |            |                       |            | 0/21 (0.0)   | 0/21 (0.0)       |
| Food catering building             |                             |            |                       |            |              | 9/12 (75.0)      |
| Library                            |                             |            |                       |            |              | 4/7 (57.1)       |
| Airport                            | 4/6 (66.7)                  | 0/3 (0.0)  |                       |            |              | 51/90 (56.7)     |
| Convention centre                  |                             |            |                       |            |              | 12/43 (27.9)     |
| Others                             |                             |            |                       |            |              | 20/79 (25.3)     |
| Total                              | 4/14 (28.6)                 | 1/48 (2.0) | 5/10 (50.0)           | 2/6 (33.3) | 0/21 (0.0)   | 1163/3391 (34.3) |

despite the absence of legislation, building managers have always been prompt in taking remedial actions whenever unsatisfactory water sampling results are reported. We are monitoring the performance of water treatment specialists and only those found to have consistent results will be recommended to building owners and management corporations. In the absence of point source evidence of infection among reported cases, preventive measures aimed at cooling towers is empirical and based on the experience of other countries.

In Singapore, *Legionella* pneumonia ranks well below the main pathogens, accounting for 1.7% to 6.7% of community-acquired pneumonia among hospitalised patients.<sup>43,44</sup> Nevertheless, as the presenting signs and symptoms, chest radiography and laboratory tests do not discriminate between legionella and other more common causes of community-acquired pneumonia, such as mycoplasma and pneumococcus, medical practitioners should always bear a high index of suspicion and investigate every case of pneumonia for Legionnaire's disease. It is known that the existing epidemiological system tends to pick up the more severe cases of acute bacterial infection and milder cases of flu-like syndrome are not reported as they do not require hospitalisation or laboratory investigations. It is therefore important to notify every confirmed case to the Ministry of the Environment so that possible sources of infection can be traced and appropriate prevention and control measures implemented to prevent the risk of outbreaks. As the mortality rate is significantly associated with age (45 years and above), concurrent medical illness and smoking history, early diagnosis and appropriate treatment among these high-risk persons may prevent or reduce mortality.

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