

Two outbreaks of Legionnaires' disease in Bolton Health District

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SUMMARY

In 1988, there were two outbreaks of legionellosis in Bolton Health District. Altogether 37 cases of Legionnaires' disease and 23 cases of non-pneumonic legionellosis were identified. Twenty-five patients with Legionnaires' disease were associated with an engineering plant, 4 with Bolton town centre, and 8 with both the plant and town centre. Twenty-two people with non-pneumonic legionellosis were linked with the engineering plant and one with the plant and the town centre. A case-control study carried out among 37 employees with legionellosis and 109 control subjects at the plant showed that infection was associated with one of the 15 cooling towers on the site. *Legionella pneumophila* indistinguishable by serological and genetic typing methods was isolated from this cooling tower and from sputum samples from two patients. In the town centre, no one tower was linked with infection and *L. pneumophila* was not cultured from any of the nine towers identified. Control measures were implemented and to date there have been no further cases of legionellosis associated with Bolton Health District.

INTRODUCTION

In late September and early October 1988 two patients with confirmed Legionnaires' disease and one in whom the diagnosis was suspected were admitted to Bolton General Hospital. All three worked at an engineering plant on an industrial estate situated about five miles from Bolton, and had been admitted to hospital in the previous fortnight. The engineering plant employed 2700 people and had 15 cooling towers on the site which were used for cooling equipment and for air conditioning (Fig. 1). On 27 October, as a result of case searching two patients with confirmed Legionnaires' disease were identified who had not been in

the vicinity of the engineering plant but who had walked near the open market in Bolton during the first 2 weeks of October. This suggested a second source of infection in or near the town centre. Action Committees were established to document the extent of each of the outbreaks, determine the source and route of infection and institute control measures. This paper describes the results of these investigations.

METHODS OF INVESTIGATION

Epidemiological

A case of Legionnaires' disease was defined as an individual with a primary pneumonia diagnosed by a physician, and one of the following: isolation of *Legionella pneumophila* from respiratory secretions or other body tissues; serological confirmation of recent infection with *L. pneumophila*, with a fourfold rise in titre on immunofluorescent antibody test (IFAT) or rapid micro-agglutination test (RMAT), a single titre of 64 or greater on IFAT or a single titre of 32 or greater on the RMAT; or detection of *L. pneumophila* by direct immunofluorescent antibody examination by use of a monoclonal reagent of respiratory secretions or tissue.

A case of non-pneumonic legionellosis was defined as an individual who suffered from an influenza-like illness and who had *L. pneumophila* isolated from respiratory secretions or who had serological confirmation of recent infection with *L. pneumophila* as defined above.

A case of suspected Legionnaires' disease was defined as an individual with a primary pneumonia or chest infection diagnosed by a physician without microbiological confirmation of legionella infection.

A case search was carried out among employees of the factory and neighbouring firms by requesting information on recent and current sickness absences and following up reports of illness. In addition, hospital physicians and general practitioners in Bolton Health District were contacted and requested to report any suspected cases of legionella infection. Medical Officers for Environmental Health in neighbouring areas were informed. The case notes of patients with atypical pneumonia who were admitted to hospitals in Bolton during September and October were reviewed. Convalescent serum samples for *L. pneumophila* antibodies were requested, if this test had not been carried out. Cases of Legionnaires' disease identified in this way were interviewed.

Preliminary interviews conducted with those affected among the factory staff suggested that many worked in the western part of the factory and the location of cooling tower A (Fig. 1) suggested that exposure to aerosol from this tower might be associated with legionella infection. A case-control study was carried out to test this hypothesis.

Three control subjects were selected from staff for each case. Control subjects were matched with affected employees for work location, age, and sex. A questionnaire was administered by trained interviewers. Information was obtained on symptoms after 1 September 1988, underlying illnesses, long-term medication and smoking. Subjects were asked in detail about time spent in different parts of the plant and the use of toilet facilities. Information was also requested on nights

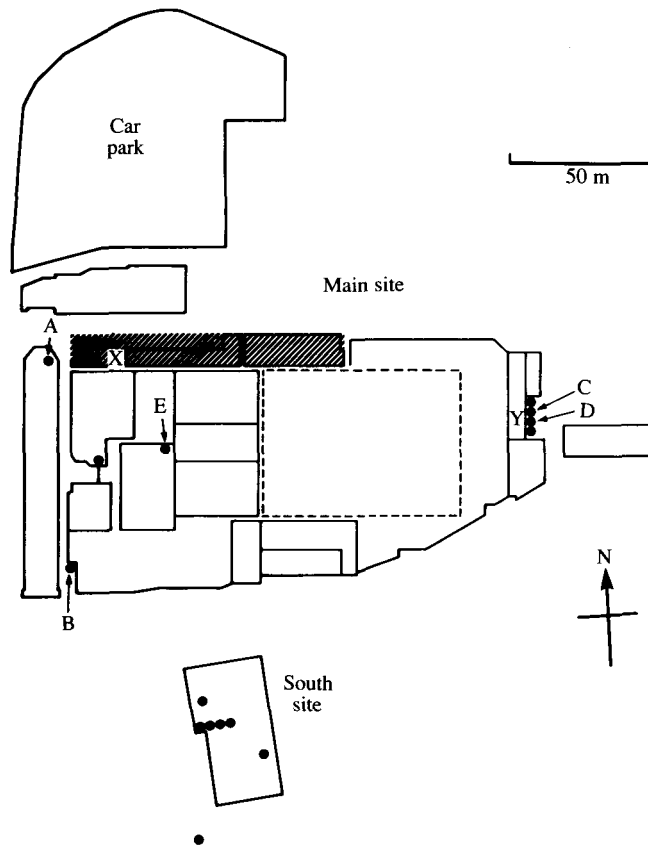


Fig. 1. Plan of the engineering plant site. *Key*: ●, cooling tower, ▨, 'north-west' area; X, cash dispenser; Y, toilet facilities.

spent away from home, visits to Bolton town centre and areas near the factory. After the interviews if control subjects were noted to have had an illness with fever and a cough since 1 September they were excluded from the study and a replacement control obtained. All control subjects were requested to donate a blood sample for the detection of antibodies to *L. pneumophila* serogroup 1. They were excluded from the analysis if they had an IFAT titre of 16 or greater.

The initial analysis was carried out by observing associations between illness and six main areas within the factory; in the second stage of the analysis two of these areas were subdivided. The statistical tests used were χ^2 with Yates's correction and Fisher's exact test. Significant associations were examined using variable matched-pair analysis.

It was not possible to do an analytical study to test the hypothesis that visiting the open market was associated with infection since the number of such people with Legionnaires' disease who had no contact with the factory was too small.

Microbiological

Serum samples were examined using the RMAT and IFAT methods, and clinicians were requested to obtain sputum samples for culture for *L. pneumophila*.

Water samples (5 and 1 litre) were collected from calorifiers, water storage tanks, as well as from other points in the water distribution system on the factory site and from machines using water and oil formulations. Samples were also taken from cooling tower ponds in the factory and nearby premises, as well as from those within a 500 m radius of the market. These samples were examined for temperature at the time of sampling, pH, total bacterial load, and the presence of *Legionella* species by direct fluorescent antibody microscopy and culture. *Legionella* strains were sent for serogrouping and typing by restriction fragment length polymorphism (RFLP) to the PHLs Legionella Reference Unit, Colindale.

Environmental

The factory site was inspected and a thorough review of the ventilation, cooling towers, and water distribution system was undertaken. Cooling tower A was inspected in detail and preliminary smoke tests were carried out to test the potential direction of drift from the tower. Subsequently gas tracer studies using sulphur hexafluoride were conducted on cooling tower A by Dr D. J. Dickson, of the Electricity Council Research Centre. Local meteorological data for the months of August and September were obtained.

Information was sought on the maintenance and water treatment regimens of cooling towers in other premises in the vicinity of the plant and within a 500 m radius of the market in Bolton town centre.

RESULTS

Descriptive epidemiology

A total of 37 cases of Legionnaires' disease and 23 cases of non-pneumonic legionellosis was identified. Of the 37 cases of Legionnaires' disease, there were 31 men and 6 women, and of the 23 cases of non-pneumonic legionellosis there were 20 men and 3 women. The age range for patients with Legionnaires' disease was from 27 to 77, median 48 years and for those with non-pneumonic legionellosis was from 22 to 64 years, median 47 years. Altogether 31 patients with Legionnaires' disease were admitted to hospital. There were no deaths, although one man with Legionnaires' disease had a very severe illness and was in an intensive therapy unit for about 5 weeks. Chest X-ray examinations were carried out on 36 patients and of these 28 had evidence of pneumonia and in 8 the result is not known. None of those with non-pneumonic legionellosis was treated in hospital and no abnormality was detected in 14 of these patients who had a chest X-ray examination.

Of the 37 people with Legionnaires' disease, 33 had contact with the factory or its vicinity. Twenty-two of the 33 were employees and of the remaining 11 non-employees, 3 had been in the vicinity of the factory but not in the town centre and 8 had visited both areas in the 10 days before the onset of their illness. Of the three non-employees with Legionnaires' disease who had been in the vicinity of the factory, one had visited the factory car park on one occasion, the second worked at a nearby firm, and the third lived near the factory. Four of the 37 affected were associated only with the town centre.

Of the 23 individuals with non-pneumonic legionellosis, 21 worked at the factory, one other had visited the site and the remaining one had contact with

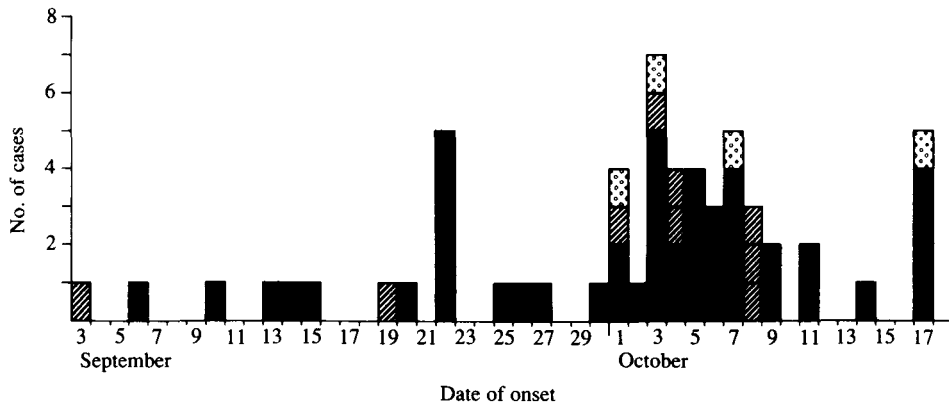


Fig. 2. Dates of onset of illness for 37 cases of Legionnaires' disease and 21 cases of non-pneumonic legionellosis. ■, Contact with factory or its vicinity; ▨, contact with factory and town centre; ▩, contact with town centre. (Date of onset unknown for two cases of non-pneumonic legionellosis.)

Table 1. Case-control study. Visiting town centre of Bolton in the 10 days before the onset of symptoms

	Cases		Controls		Yates corrected chi-squared P value*
	Visited	Not visited	Visited	Not visited	
Shopping centre	4	31	39	49	0.001
Open market	4	29	28	61	0.05
Square	7	29	44	47	0.005

* All associations protective.

both the factory and the town centre. The attack rate among the factory staff for Legionnaires' disease was 0.8% (22/2700). For the non-pneumonic legionellosis it was also 0.8%.

The dates of onset of legionellosis in people associated with the factory ranged from 6 September to 17 October, in those associated with both the factory and the town centre, from 3 September to 17 October, and in those who had only visited the town centre, from 1 October to 17 October (Fig. 2).

Fifteen people of whom one died, were identified as suspected cases of Legionnaires' disease by the case search. Microbiological confirmation of legionella infection was not obtained for these 15 patients. In addition, the review of hospital admissions identified 35 patients with pneumonia who were admitted to local hospitals in September and October. Five of the 35 patients died. Altogether 10 had paired serum specimens and 11 had a single specimen tested for legionella antibodies and, of these 21, only one had evidence of legionellosis and this patient is included in the total number of cases in the Descriptive Epidemiology section.

Case-control study

Altogether 37 people with legionellosis (20 cases of Legionnaires' disease and 17 cases of non-pneumonic legionellosis) and 109 control subjects were interviewed.

Table 2. *Case-control study. Factors found to be significantly associated with illness*

	Cases		Controls		Yates corrected chi-squared <i>P</i> value
	Yes	No	Yes	No	
Working in or visiting north western part	27	10	44	48	0.02
Smoking cigarettes	23	14	27	65	0.001
Using cash dispenser	21	16	26	66	0.005
Visiting toilet facilities in eastern part	5	32	2	90	0.04*

* Fisher's exact test (2 tailed).

Of the 109 control subjects, 107 donated a blood sample and 10 had IFAT titres of 16 or greater and were excluded from the analysis. Confusion was the only symptom which was reported more frequently by patients with Legionnaires' disease than by people with non-pneumonic legionellosis ($P = 0.04$). The duration of illness up to the time of interview ranged from 7 to 65 days, with a median of 42 days, and no difference was observed between the two forms of legionellosis. Of the 37 individuals with legionellosis, three suffered from asthma or bronchitis and one reported kidney disease; none were on immunosuppressive therapy.

The results of the study showed that employees with legionellosis were less likely to have visited Bolton town centre than the control subjects (Table 1), but were more likely to have worked or visited an area in the north western part of the factory, which was in the vicinity of cooling tower A (Fig. 1; Table 2). This area included offices on the ground floor and first floor, all of which had windows facing north. Those affected were also more likely than control subjects to have visited the toilet facilities at the eastern part of the factory (Y, Fig. 1) and to have used an automatic cash dispenser situated on the internal road way in the north western part of the factory (X, Fig. 1 and Table 2). Staff who smoked cigarettes had a higher risk of contracting legionellosis than non-smokers (Table 2). People with Legionnaires' disease were no more likely than those with non-pneumonic legionellosis to be smokers, to be older, to have underlying disease, or to have visited different areas of the site. The matched pair analysis confirmed the association of illness with the north western part ($P = 0.006$), and smoking cigarettes ($P = 0.0003$); it also showed an independent association of illness with using the cash dispenser ($P = 0.01$) and visiting the toilet facilities in the eastern part of the site ($P = 0.003$).

Microbiological

L. pneumophila serogroup 1 subgroup Philadelphia RFLP type 5 was isolated from sputum samples from two patients with Legionnaires' disease. In the remaining 35 cases of Legionnaires' disease, the diagnosis was made on the basis of serology: 27 with a fourfold rise in antibody titre and 8 with a single high titre. The diagnosis in 5 cases of non-pneumonic legionellosis was based on a fourfold rise in titre and in the other 18 a single high titre. Large numbers (3×10^7 c.f.u./l) of

Table 3. Microbiological examination of pond water from 15 cooling towers at engineering plant site

Cooling tower	Water temp. (°C)	pH	TVC (c.f.u./l)	DFA (org/field)	Legionella culture (c.f.u./l)
A	17.7	6.9	1.8×10^7	3×10^7 *	<i>L. pneumophila</i> SG1 3×10^7
B	10.8	6.5	2×10^4	2-5	NI
C	10.9	6.5	5×10^3	1	NI
D	10.8	6.4	1×10^5	10-20	NI
E	16.1	6.5	2×10^3	NS	<i>L. anisa</i> 6×10^5
F	10.7	6.7	1×10^6	NS	NI
G	10.6	6.6	2×10^4	NS	NI
H	10.6	6.4	7×10^4	NS	NI
I	13.5	8.4	13×10^6	NS	NI
J	12.5	8.2	< 10	NS	NI
K	11.1	6.8	9×10^4	NS	NI
L	10.1	8.6	2.4×10^5	NS	NI
M	10.7	8.1	1.8×10^5	NS	NI
N	11.0	7.1	3×10^2	NS	NI
O	11.4	6.5	8×10^4	NS	NI

TVC, Total viable count at 30 °C; DFA, direct fluorescent antibody examination for *L. pneumophila* serogroup 1; c.f.u./l, colony-forming units/litre; org/field, organisms/field; NS, Not seen; NI, Not isolated.

* Organisms/litre.

L. pneumophila serogroup 1 were detected both by direct fluorescent antibody (DFA) examination and culture of the microflora concentrated from pond water from tower A (Table 3). This strain was indistinguishable from the patient strains on serogrouping and RFLP typing.

Although low numbers of *L. pneumophila* serogroup 1 were seen by DFA examination of deposit from three other towers (B, C and D, Fig. 1 and Table 3) in the factory, the organism was not cultured from these towers. *L. anisa* was recovered from cooling tower E (Fig. 1 and Table 3). Legionellae were not detected by either method in the pond samples from the other ten cooling towers on site (Table 3). *L. pneumophila* serogroup 5/8 was cultured from one of the calorifiers where the water temperature was 31 °C at sampling. A further 16 samples from calorifiers or hot water taps and 7 samples of cold water collected from header tanks and cold taps were negative for legionellae. In addition, samples from machines using water and specimens of different oil formulations did not yield legionellae on culture.

Legionellae were not cultured from samples collected from the two cooling towers in the vicinity of the factory or from water samples taken from the cooling towers in the town centre.

Environmental

There was a combination of natural and artificial ventilation in the factory. Although 12 areas with specialist function were fully air conditioned, the main machine shop had a variety of ventilation systems including mechanically

operated louvres, five main air circulation plants and a large number of small heater units which provided fresh air and/or heating.

Cooling towers in the factory

Of the 15 cooling towers, 8 were on the main site and 7 on the South Site of the factory; 3 were used for air conditioning and the remaining 12 for compressor cooling (Fig. 1). Only six towers were subject to regular antiscaling and biocide treatment. Monitoring was carried out by two different companies, each responsible for three units. All towers had been cleaned and disinfected approximately 13 weeks before recognition of the outbreak. Cooling tower A was a forced draught cooling tower and it was reported that it was treated with biocide on a fortnightly basis and was said to have been dosed on 12 and 26 September 1988. However, it could not be ascertained if the biocide had been added correctly to the pond. No checks had been carried out on the quality of the water in cooling tower A since it was cleaned and disinfected in July.

On inspection on 4–5 October 1988 all towers were structurally in good condition except that three of the baffle plates above the drift eliminators on tower A could not close. These baffle plates and the louvres on the tower extract had been damaged in a severe storm in October 1987. There was a continual high cooling demand on tower A but often not sufficient to require the operation of the fan. The pond water was cloudy or discoloured in four towers, including towers A and B.

Smoke tests carried out on cooling tower A when the fan was not in operation showed that smoke emerged from the air-intake which was located some 12 ft from the ground. Gas tracer studies on tower A were conducted on a day with a moderate (wind speed 14–20 miles/h) west to northwest wind blowing: similar conditions as prevailed on several occasions in September and early October. With the fan running, emissions from tower A were detected throughout the main building up to 300 m downwind of the tower, and, as a consequence of wind eddies, at points on the roadway adjacent to the tower base. The highest concentrations of gas being at the latter point and along the internal roadway at the north western part of the building (Fig. 1). With the fan off, the concentrations measured near the base of the cooling tower were up to twice those measured with the fan on.

The meteorological data revealed that there were several warm and humid days in the last week of September, followed by a couple of cloudy days with moderate SSW and WNW breezes.

Water distribution and other water systems in the factory

All water used on site originated from the town main water supply. Hot water was provided from 17 calorifiers of varying size situated around the site. Some of the calorifiers were also poorly lagged and in the largest tanks temperature stratification was found. The temperature at the take off point was greater than 50 °C after 2 min run off in all but two, and in one of these the temperature was only 31 °C at sampling. All calorifiers were examined twice yearly and good records of the inspection were kept. The condition of the holding and header tanks varied but several were in poor condition, unlagged and/or uncovered.

There were two wet blast processing machines as well as approximately 300 machines which used cutting oils, made up on site and comprised of about 95% water.

Other cooling towers in the vicinity of the factory

There were two other cooling towers within 500 m of the factory. One was in good condition and had been cleaned and disinfected the weekend the outbreak was recognized. The second cooling unit was used to cool a vacuum pump system and on inspection the water was brown and there was foaming on the pond surface.

Cooling towers in Bolton town centre

Nine cooling tower units were identified in the town centre. Seven were covered by twice yearly cleaning and disinfectant regimens. Regular monitoring of the chemical and bacterial composition (pH and total dissolved solids) of the pond water was established practice. The water was cloudy brown in two units and foaming on the surface of the pond was present in another two towers. One tower had been cleaned and chlorinated following the recognition of the factory outbreak.

In two of the nine towers, cleaning and disinfection were only carried out on an annual cycle and, biocide was only added when the bacteriological load as measured by dip-stick exceeded 10^5 organisms/ml. The pond water in these two towers was green and there was a considerable amount of slime on the pack and external surface of the structure. According to a log book, these towers had not been dosed with biocide for 2.5 years as the bacteriological load had not exceeded 10^5 organisms/ml.

Control measures

On Tuesday 4 October, all 15 cooling towers at the factory were shut down and between 5 and 10 October all were chlorinated, drained and cleaned, then refilled and rechlorinated. After disinfection, towers were brought into use and a minimum level of 5 ppm free chlorine was maintained. Samples from all towers collected on 13 October were negative for legionella organisms. Automatic monitoring and biocide and antiscalc dosing of all towers was introduced on 27 November and samples collected from the towers on 14 December 1988 and 1 March 1989 did not yield legionella. All of the calorifiers were drained and cleaned, and subsequently the water temperature was raised to 70 °C for a period of several hours.

The two cooling towers in Bolton town centre which were in poor condition were cleaned and chlorinated on 29 October.

DISCUSSION

The results of the epidemiological investigation suggested that there were two outbreaks of Legionnaires' disease in Bolton in September and October 1988. There were no deaths among patients with confirmed Legionnaires' disease. This

finding is in contrast with case fatality rates of 4.3% in a large outbreak associated with an identified contaminated cooling tower in London [1] and 32.4% in the Stafford outbreak [2]. This finding may be attributable in part to early and appropriate treatment of patients because of the high level of awareness among local physicians. Another factor which may have contributed to the low fatality rate was that many of those affected were previously healthy, fit employees at the engineering plant.

Between 1978 and the end of September 1988, there was a total of 32 outbreaks of Legionnaires' disease recorded in England and Wales (PHLS, CDSC unpublished data). Of these, only four incidents were associated with industrial premises and the largest of these outbreaks was one linked with a cooling water system in a power station under construction where six cases of pneumonia occurred [3]. Thus, the present outbreak of Legionnaires' disease is the largest associated with industrial premises reported to date and was unusual because the attack rates were the same for non-pneumonic legionellosis and Legionnaires' disease. The attack rate for Legionnaires' disease was similar to that reported in other outbreaks such as those in Stafford [2] and Brighton [4] whereas that for non-pneumonic legionellosis was lower than reported from a previous outbreak associated with an engineering plant [5]. It was of interest that there were no differences between patients with Legionnaires' disease and those with non-pneumonic legionellosis in terms of age, smoking or underlying illnesses or exposure to different parts of the factory.

Within the plant there was an association between illness and the frequency of visiting the north western part of the factory. The gas tracer studies carried out on the cooling tower A showed that it was possible for aerosol from the tower to be disseminated throughout the main building but particularly high concentrations were found in the north western part. In addition, the tests showed that because the baffle plates were damaged there was potential for reverse flow of air through the tower when the fan was not operating and for contaminated aerosol to be released only 12 ft from ground level. These results suggested that tower A was the most likely source of infection and the microbiological results confirmed that the strain identified in sputum from two patients was also present in the water samples collected from cooling tower A. Three towers had samples which were positive on DFA but negative on culture and these may have been seeded by contaminated aerosol from tower A. These towers could not be completely excluded as sources of infection. There was a statistical association with the use of one toilet facility; this area was close to towers C and D but was visited by only five of those affected and they had also been in the vicinity of tower A. There was no other evidence that these towers were associated with illness.

There was epidemiological evidence that drift was carried some distance beyond tower A as at least two cases did not enter the site. The warm days during the last week of September provided conditions in which legionella could grow, followed by a period when there was cloud, high humidity, and moderate wind speeds which would have favoured survival of the organism in an aerosol.

The isolation of *L. anisa* from one cooling tower and *L. pneumophila* serogroup 5/8 from one of the calorifiers were unlikely to be important findings because all

cases of legionellosis were due to *L. pneumophila* serogroup 1. In addition, there was no evidence to suggest that coolants, which have been implicated in one outbreak of Legionnaires' disease in the USA [5] or high pressure water jets were associated with infection in this outbreak.

The second outbreak came to light because of extensive case finding. Following the identification of four patients with Legionnaires' disease who could not be linked to the factory site, but had visited the open market in Bolton, the data on other patients were reviewed. For eight people it was not possible to determine whether the infection was acquired from the factory or another source near Bolton open market. Legionellae were not detected in any of the nine cooling towers within 500 m of the open market. This does not exclude one of these towers from having caused the outbreak because at least one was treated as a precautionary measure at the time of the first outbreak and because the number of organisms in a cooling tower pond may both increase, and decrease to undetectable levels, over a very short period of time.

Although contaminated aerosol from cooling towers has been implicated in two community outbreaks of Legionnaires' disease in the United Kingdom, it has not always been possible to identify which tower was responsible. In the Reading outbreak in 1983 and 1984, legionellae were detected in four cooling towers in the town centre, and although results of the case-control study implicated one of the four towers, it could not be proved that this was the source [6]. In another outbreak associated with the town centre in Gloucester in 1986, legionellae were isolated from one of 22 well-maintained, biocide treated towers and from 20 of 27 towers which were less well maintained and not regularly treated with biocide [7].

Despite the publicity given to a number of outbreaks of Legionnaires' disease in the past, these two incidents in Bolton highlighted continuing problems in the maintenance and treatment of cooling towers in many buildings. Although guidance has been available from the Health and Safety Executive [8], which is responsible for the inspection of factories and other premises, it would appear that the implications of inadequately specified water treatment regimens are not always appreciated. Within the engineering plant, there were separate contracts with two water treatment companies to provide biocide treatment to some but not all cooling towers and the water treatment schedules were different for the two companies. It appears that although cooling tower A was regularly treated with biocides, the monitoring procedures for this cooling water system were inadequate. When cleaning and maintenance is carried out by outside contractors there may be difficulties in ensuring that regular checks by local engineers take place unless this is written into the contract. Since the outbreaks in Bolton, the Expert Advisory Committee on Biocides have reported their recommendations to help prevent such deficiencies [7]. The Committee gave guidance on the points which should be incorporated in water treatment contracts, including the cleaning schedule required, the biocide dosages, as well as other actions to be taken by the groups who sign the contract. It is hoped that this approach will reduce the number of outbreaks of Legionnaires' disease.

Since the introduction of control measures there have been no reports of further cases associated with either the factory or the town centre.

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