Epidemiol. Infect. (1990), **104**, 29–38
Printed in Great Britain

Maintenance of cooling towers following two outbreaks of Legionnaires' disease in a city

R. S. BHOPAL[1] AND G. BARR[2]

[1] *Division of Community Medicine, The Medical School, Framlington Place, Newcastle upon Tyne, NE2 4HH, UK*

[2] *Glasgow District Council, 23 Montrose Street, Glasgow, G1 1RN, UK*

(*Accepted 24 August 1989*)

SUMMARY

This survey assessed the maintenance of evaporative cooling towers in Glasgow, following two Legionnaires' disease outbreaks. Information was obtained from 76 of 81 premises and a maintenance score was calculated for each of 174 towers. The quality of maintenance was extremely varied (range of maintenance scores, 8–30; mean, 22 (S.D., 5·0); median, 23; maximum possible, 33) and some towers were neglected. Breaches of maintenance principles were mainly structural and organizational, e.g. inadequate drift control, rather than failure to use chemicals. Low maintenance scores were associated with no log book, no guidelines, no change in procedures in last 5 years, solitary cooling towers, and towers on industrial premises. Despite intense publicity the standard of cooling tower maintenance in Glasgow remained a concern. Information campaigns directed at those responsible for cooling-tower maintenance are necessary.

INTRODUCTION

Evaporative cooling towers provide an ideal environment for legionellae to grow, i.e. warm, recirculated water containing inorganic and organic solute and sludge harbouring a wide range of microorganisms (1–3). In a recent survey legionellae were grown from 52% of cooling towers (2). Cooling towers have been the source of many outbreaks both worldwide (4) and in Britain (5–8). Good maintenance of cooling towers is associated with a lower frequency of contamination with legionellae (3).

Despite the production of guidelines on cooling tower maintenance (2, 9–14) (which have been publicized in journals, conferences and the mass media) Legionnaires' disease outbreaks continue to occur. Community physicians have been urged to ensure that the recommendations of the second report on the Stafford District General Hospital (15) are acted upon in their districts (8). Some local authorities have developed questionnaires to assess risk at premises (15).

As the location of cooling towers is often unknown, statutary organisations cannot ensure that information has been provided or that maintenance programmes are in operation. Following an outbreak of Legionnaires' disease in 1984 in Glasgow (5) the need to know the addresses of premises with cooling towers became clear, and the Environmental Health Department of the Glasgow District Council started a register. In 1985 a nosocomial outbreak in Glasgow was linked to a cooling tower (7). Circumstantial evidence emerged that sporadic cases of Legionnaires' disease in Glasgow might be associated with cooling towers (17). Hence the present survey to assess the maintenance of cooling towers in Glasgow.

METHODS

Identification of cooling towers

In 1985 Environmental Health Officers sought out premises with cooling towers in their areas. Simultaneously, a letter asking about cooling towers was sent to many large premises in Glasgow. Also, information about cooling towers was obtained from the City's Planning Department, particularly about new buildings. By 1987, 144 premises were registered.

The managing director (or equivalent) was sent a letter seeking cooperation with the survey and a copy of the questionnaire for information. If permission was gained, those in charge of cooling towers were interviewed using a semi-structured questionnaire. Towers were also inspected visually. The survey took place between September 1987 and April 1988.

The questionnaire

The questionnaire was designed to assess whether established maintenance procedures were being followed (4, 9–12). Information on the following aspects of cooling towers or their maintenance was collected: administration/organization, structure, function, cleaning and chemicals. (The questionnaire is available from the authors.)

Analysis

Numerical data were analysed with the SPSS pc statistical package (18) on an IBM PS/30 microcomputer. Maintenance scores were calculated for each cooling tower by giving points for the features listed in Table 1.

The Mann–Whitney *U* test was used to test for sub-group differences in maintenance scores (19). If the variable of interest in sub-group analysis was a component of the maintenance score the score was recalculated after excluding that variable, e.g. when cooling towers with and without log books were compared, the maintenance score excluded log books. The maximum score was 33.

Analyses were done on all operative towers and on a sample of one tower from each premise. The results were similar. Hence the latter analyses are not usually given in this report. Table 2 indicates the closeness of the two sets of analyses.

RESULTS

General

Of 144 premises on the register 63 had no evaporative cooling tower (some had air cooling, others had removed towers and some premises had been demolished.) Five premises with towers did not participate (two had had outbreaks and

Table 1. *Features included in the maintenance-score calculation*

	Feature	Score
1.	Water supply is from the mains	1
2.	A log book or other record is maintained	1
3.	A named person is responsible for maintenance	1
4.	There is no serious structural damage to the tower	1
5.	The tower is made of non-porous material	1
6.	The air intake is by the induced method	1
7.	The tower is in continuous operation	1
8.	Shutdowns are for 48 hours or less	1
9.	When not in use, the tower is drained	1
10.	Prior to recommissioning after shutdown the tower is treated	1
11.	Drift eliminators are fitted	1
12.	Drift does not bypass the tower via faults in the tower body or drift eliminator	1
13.	Drift eliminators are cleaned	1
14.	Drift eliminators are of non-porous material	1
15.	The fillpack is of non-porous material	1
16.	There is no air intake near the tower	1
17.	Plumbing connections have an air-break	1
18.	The tower can be completely drained	1
19.	Routine checks for equipment are made	1
20.	Total dissolved solids are checked	1
21.	Chlorination is done before cleaning towers	1
22.	Anti-corrosives are added:	
	once a week or more *or*	2
	at least annually	1
23.	Anti-scale agents are added:	
	once a week or more *or*	2
	at least annually	1
24.	Anti-fungal agents are added:	
	once a week or more *or*	2
	at least annually	1
25.	Biocides are added:	
	once a week or more *or*	2
	at least annually	1
26.	Sludge is removed:	
	once a week or more *or*	2
	at least annually	1
27.	Foaming does not occur	1
28.	Anti-legionella agents additional to the above are added	1

apparently took stringent precautions). In the remaining 76 premises studied (94% response) there were 174 functioning cooling towers (range 1–8). Where several towers were at one site their maintenance was usually similar but at one extreme was a premise where one tower was fully treated, another not at all. Access to several towers was difficult and the location of some towers posed physical hazard.

At fifty-four (71%) premises respondents recalled receiving guidelines on cooling-tower maintenance from one or more sources; mostly from commercial organizations (48/54 premises) rather than statutory organizations (18/54 premises).

Maintenance procedures had changed in the previous 5 years at 59% of

Table 2. *Proportion (%) of premises and cooling towers with organizational arrangements recognized as part of good maintenance*

Variable	Premises ($n = 76$)	Cooling towers ($n = 174$)
Log book/record of maintenance was kept	74	82
A named person was in charge of maintenance	93	90
Routine check of equipment was done	91	86
Total dissolved solids were measured	53	51
Towers were not out of action for 48 h or more	38	42
When not in use the towers were drained	36	37
Before re-commissioning the towers were treated chemically	81	82

premises. Publicity associated with the Dennistoun outbreak (5) (20 mentions) was a major spur to changes such as the chemical treatment of water, cleaning of towers, involvement of water treatment firms, and bacteriological testing.

In 70% of premises bacteriological tests for legionellae had been done though irregularly or on a single occasion in some places. In 9 of 116 cooling towers tested legionellae had apparently been detected.

Only 27 premises gave estimates of costs of maintenance which ranged from nil to £6100 per cooling tower (median £660). Most costs were not specific to Legionnaires' disease.

Organizational features

Table 2 shows the proportion of premises with some organizational features recommended for the maintenance of cooling towers.

Structure and function of towers

The age of the towers ranged from a few months to 27 years (median, 7 years). Fifty-five percent were supplied directly from mains water, 36% from storage tank water (17% had a second storage tank at a height, a break tank) and 8% from both. Severe rust or other forms of corrosion affected eight towers and some had inoperative components such as autodosing units (in which case manual dosing took place). At some premises the drift blew, or was drawn, towards areas where people were working.

Table 3 summarizes data on structural and functional aspects of towers. Drift control was poor. Although about two-thirds of towers had drift eliminators, in 29% of these drift was observed to exit from cracks or other spaces in the body of the tower (50% of the towers had apparently effective drift eliminators). Only three respondents knew the manufacturer's figures for water lost as drift and drift loss had never been measured. For almost 50% of towers a fresh-air inlet was visible in the immediate vicinity.

Table 3. *Some structural and functional aspects of cooling towers of importance in the prevention of Legionnaires' disease*

Variable	Number (%) of towers
Tower construction ($n = 173$)	
Wood	7 (4)
Steel	102 (59)
Plastic or fibreglass	63 (36)
Two of the above	1 (1)
Drift eliminator was fitted ($n = 159$)	111 (70)
Drift exits only via drift eliminator ($n = 109$)	77 (71)
Construction of drift eliminators ($n = 105$)	
Wood	10 (10)
Steel	34 (32)
Plastic or fibreglass	60 (57)
Other	1 (1)
Construction of fillpack ($n = 167$)	
Wood	10 (6)
Steel	28 (17)
Plastic or fibreglass	129 (77)
Tower was ($n = 173$)	
Induced draught	73 (42)
Forced draught	100 (58)
Breaktank was present ($n = 173$)	29 (17)
Cooling tower drainage was separated from other drainage by air break ($n = 174$)	168 (97)
Tower could be completely drained ($n = 173$)	118 (75)
No air intake existed in vicinity of discharge point ($n = 174$)	93 (53)

Commonly, respondents did not know about the capacity of the tower (no information was readily available in 61% of premises), if plumbing had been altered to meet Water Research Centre standards (20) (53% don't know, 7% yes, 40% no) or if the plumbing met Water Research Centre standards (39% yes, 2% no, 58% don't know).

Chemical and non-chemical maintenance procedures

Table 4 shows that most cooling towers received chemical and non-chemical treatment on a routine basis. Numerous commercial agents were in use (list available from authors). Anti-legionella activity was claimed for many of these agents but 48 towers received additional treatment which was used specifically to help control legionellae; the commonest was hypochlorite (44). Foaming occurred in 25% of towers and was usually ascribed to the maintenance chemicals.

Maintenance scores

Maintenance scores for the 174 towers, shown in the figure, ranged from 8–30 with mean, median and mode values of 22 (standard deviation, 5·0), 23 and 24 respectively. Table 5 shows that lower maintenance scores were associated with the following: no log book; no recall of receiving guidelines; solitary cooling towers; cooling towers on industrial premises; and no change in procedures in the

Table 4. *Chemical and mechanical cleaning of cooling towers**

Cleaning/treatment method	% of cooling towers treated	% of cooling towers treated, which receive treatment weekly or more
Anticorrosive agent	82	91
Antiscale agent	80	90
Fungicidal agent	76	80
Biocidal agent	84	77
Sludge removal	94	20
Control of total dissolved solids	68	N/A
Chlorination prior to cleaning the towers (n = 167)	39	N/A
Drift eliminators cleaned (n = 111)	68	N/A

* n = 174 unless otherwise stated.

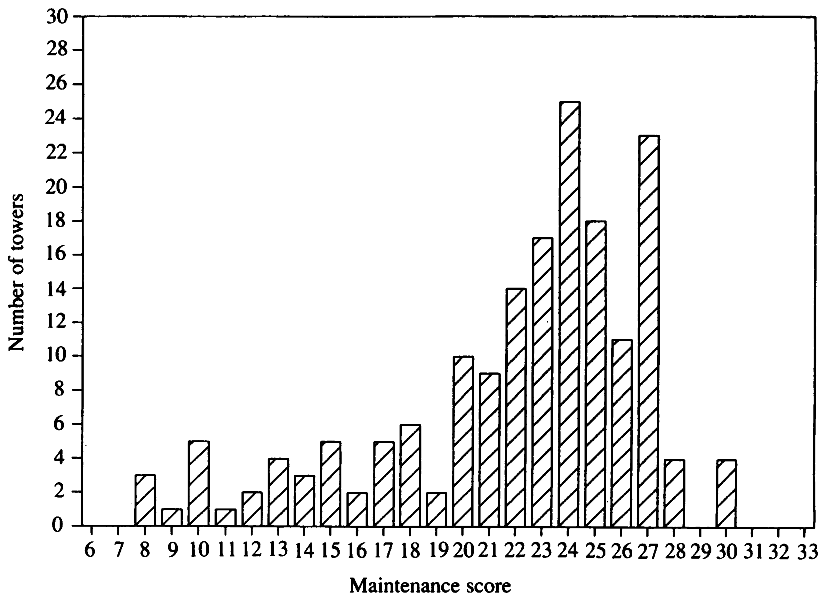

Fig. 1. Distribution of maintenance scores.

last 5 years. These associations remained statistically significant when one tower from each premise was selected for analysis. Low maintenance scores were not associated with having a named person in charge or undertaking routine checks.

DISCUSSION

Methods and scope of this study

Forty-four percent of the premises on the cooling tower register had no towers. Clearly, a knowledgeable person needs to check towers prior to their registration.

Table 5. *Relationship of maintenance scores to characteristics of premises and cooling towers*

Hypothesis	Categories (n = no. of cooling towers)	Maintenance score and statistics: Range	Mean (S.D.)	Median	P value*	P value for analysis of 76 towers*
1. Where a maintenance log is kept standards will be higher	(*a*) Log book is kept ($n = 143$)	14–29	22·6 (3·2)	23·0	< 0·001	< 0·001
	(*b*) Log book is not kept (31)	8–24	14·5 (4·7)	13·0		
2. Where guidelines have been received the maintenance standards will be higher	(*a*) Received guidelines ($n = 139$)	8–30	23·3 (3·8)	24·0	< 0·001	< 0·001
	(*b*) Not received guidelines ($n = 29$)	8–28	14·9 (4·6)	14·0		
3. For solitary cooling towers maintenance standards will be lower	(*a*) Solitary cooling tower ($n = 33$)	9–28	20·1 (5·3)	22·0	0·007	0·045
	(*b*) more than one cooling tower ($n = 141$)	8–30	22·4 (4·9)	24·0		
4. Cooling towers on industrial premises have lower maintenance standards than others	(*a*) Hospitals ($n = 12$)	21–30	25·3 (2·8)	24·5	< 0·001	0·005
	(*b*) Other public buildings ($n = 40$)	11–26	23·0 (2·4)	23·0		
	(*c*) Offices (30)	18–30	25·0 (2·9)	25·5		
	(*d*) Industrial premises (92)	8–28	20·2 (5·8)	21·0		
5. Where procedures have been changed in the last five years maintenance standards will be higher	(*a*) Procedures have changed ($n = 113$)	8–30	23·3 (3·8)	24·0	< 0·001	0·007
	(*b*) No change in procedures ($n = 56$)	8–28	19·1 (6·1)	20·5		
6. Where a named person has responsibility maintenance standards will be higher	(*a*) Named person (157)	7–29	21·0 (4·9)	22·0	0·038	N.S.
	(*b*) No named person (17)	10–27	22·3 (6·2)	24·0		
7. Where cooling towers are routinely checked maintenance standards will be higher	(*a*) Routine checks are done ($n = 150$)	7–29	21·3 (4·6)	22·0	0·879	N.S.
	(*b*) Routine checks are not done ($n = 24$)	8–27	20·0 (6·7)	24·0		

* Based on Mann–Whitney U test.

Self-administered questionnaires, as previously suggested (16), probably will not suffice. Possibly, some premises with cooling towers remained unregistered. However, complete ascertainment, though desirable, would be difficult to achieve.

Respondents were usually engineers, and many were extremely knowledgeable about cooling towers. Except for the questions on costs, capacity of the tower, drift loss and whether plumbing met Water Research Centre standards, they had little difficulty in providing information. The validity of the answers was not cross-checked (except when possible during the visual inspection) and the true quality of maintenance may be lower than reported.

Maintenance scores were based on a simple, arbitrary system. Arguably, some features are of greater value than others, e.g. an effective drift eliminator may be of great importance (1, 15). However, weighting each factor would also have been arbitrary, and on present knowledge probably unjustifiable. The use of maintenance scores as indicators of risk and to allow comparative studies, merits further development. Towers identified as 'high risk' could then be investigated in further detail.

Bacteriological investigation would have been of interest but was not done for reasons of cost and fear of non-cooperation. Guidelines emphasize that cooling towers need to be maintained irrespective of whether legionellae have been cultured. On the basis of past experience it must be assumed that in many towers legionellae will be present (2, 3). Our objective was to show whether cooling towers were maintained, not whether they were contaminated.

Maintenance

In a city which has endured two major outbreaks of Legionnaires' disease (5, 7) which led to intense publicity on the potential hazards of cooling towers, a high standard of cooling tower maintenance would be expected. Encouragingly, media publicity and other information had led to improvement of maintenance procedures at nearly two-thirds of premises. Some towers were well maintained (though, not surprisingly, none attained our 'gold' standard of a maintenance score of 33), most moderately so, but a significant minority were improperly maintained or neglected. Problems such as severe corrosion, failure to drain cooling towers during shutdown, no chlorination prior to cleaning, poor drift control and the presence of air intakes close to cooling towers were causes for particular concern.

Compliance with guidelines was best in the use of chemicals, perhaps because they are necessary for efficient funtioning of towers. However, at most premises respondents remembered receiving commercially produced information from water treatment companies. Such literature emphasizes the role of chemicals in the control of legionellae. The balanced view of non-commercial guidelines needs wider dissemination (2, 3, 6, 9–15). These emphasize the structural and organizational aspects of maintenance (particularly drift control, the use of approved materials, and the proper handling of towers during shutdown) and general hygiene.

In the past, information has been directed mainly to hospitals (2, 9–11, 13). However, the drift from all cooling towers is a potential hazard and may affect the passerby (15, 17). At present, the source of 75% of cases of Legionnaires' disease is unknown (4, 15). The view that the principle source of sporadic infection is domestic water is plausible (4, 15) but unproven and the possible role of cooling towers must not be forgotten (17). Cooling towers should be maintained to prevent outbreaks and possible sporadic infection (15–17).

The statistical associations between maintenance scores and certain characteristics of premises can help to decide priorities for information campaigns, e.g. the emphasis might now be on industrial premises, those without a log book and those where guidelines have not been received. A full report on this survey and the leaflet EH48 (12) has been sent to premises in Glasgow with cooling towers and further action is planned. Other cities should consider similar surveys to assist in the investigation of outbreaks, assess the potential hazard from inadequately maintained cooling towers and guide information campaigns.

ACKNOWLEDGEMENTS

We thank the Serious Infections Group (Glasgow City Environmental Health Department), Dr R. J. Fallon, Dr R. Donaldson, and Mr D. Nicholson for invaluable advice at the planning stage. Dr R. J. Fallon, Dr A. E. Wright and Mr B. Kelly provided helpful criticism of an earlier manuscript. The study was supported by grants from the Greater Glasgow Health Board and the Pneumonia Research Trust while the Environmental Health Department released Mr G. Barr to work on the project. We thank Mrs Karen Ferguson for clerical support and Mrs Eileen Williams for preparing the manuscript. Lastly, we thank those who took part in the survey.

REFERENCES

1. Miller PR. Cooling towers and evaporative condensers. Ann Intern Med 1979; **90**: 667–70.
2. DHSS and the Welsh Office. The control of *Legionella* in health care premises. London; HMSO, 1988.
3. Department of Health and Social Security. Report of the Expert Advisory Committee on Biocides. London: HMSO, 1989.
4. Bartlett CLR, Macrae AD, Macfarlane JT. Legionella infections. London: Edward Arnold, 1986.
5. Ad hoc Committee. Outbreak of Legionellosis in a community. Lancet 1986; ii: 380–3.
6. Committee of Inquiry. First report of the Committee of Inquiry into the outbreak of Legionnaires' Disease in Stafford in April 1985. London: HMSO, 1986.
7. Timbury MC, Donaldson JR, McCartney AC, et al. Outbreak of Legionnaires' disease in Glasgow Royal Infirmary: microbiological aspects. J Hyg 1986; **97**: 393–403.
8. Communicable Disease Surveillance Centre. Communicable Disease Report: April to June 1988. Community Med 1988; **10**: 358–62.
9. Department of Health and Social Security. Legionnaires' Disease and hospital water systems. Circular No. HN (80) 39, 1980.
10. Department of Health and Social Security. Legionnaires' Disease: Engineering guidance note 3. Circular No. HN (86) 16, 1986.
11. Department of Health and Social Security. Legionnaires' Disease: Engineering guidance note 4. Circular No. HN (87) 16, 1987.
12. Health and Safety Executive. Legionnaires' Disease. Guidance note EH48. Environmental Hygiene Series 48. London: HMSO, 1987.
13. Department of Health and Social Security. Health Services Management. The control of Legionellae in health care premises. Circular No. HL (88) 47 and HN (FP) (88) 19, 1989.
14. Chartered Institute of Building Service Engineers. CIBSE code of practice. Minimising the risk of Legionnaires' Disease.

15. Committee of Inquiry into the outbreak of Legionnaires' Disease in Stafford, April 1985. Second report. London: HMSO; 1987 (Cmnd 256).
16. Baxter D. Legionnaires' Disease. A comprehensive description and contemporary bibliography. Occasional paper No. 9. Manchester University, Department of Community Medicine, 1985.
17. Bhopal RS, Fallon RJ. Geographical epidemiology of Legionnaires' Disease in Glasgow: a preliminary report. Communicable Diseases (Scotland) Unit Weekly Bulletin. 1988 No. 17 (pp. 7–11) and No. 18 (p. 2).
18. SPSS Inc. Marija J. Norusis. SPSS/PC plus. Chicago: SPSS Inc, 1986.
19. Siegel S. Nonparametric statistics for the behavioural sciences. New York: McGraw Hill, 1956.
20. Water Research Centre. Water fittings and materials directory 1988/89. Water Research Centre, Marlow, 1988.