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BSRIA

TOWARDS A STRATEGY FOR PREVENTING LEGIONNAIRES' DISEASE AND PONTIAC FEVER

by Dr Bryan Walker, Building Health Biologist, Oscar Faber Applied Research.

Abstract

While guidelines for minimising the risk of Legionnaires' disease already exist some established procedures, such as disinfection with 50 ppm of chlorine, are not sufficient to destroy the host organisms within which legionellae reproduce.

The relationship between Legionnaires' disease and Pontiac fever is discussed. Features of the biology of Legionella which are significant in relation to its control are highlighted.

INTRODUCTION

Many outbreaks of Legionnaires' disease and Pontiac fever are well documented but the biology of the bacteria which cause these infections is less appreciated. How and where these bacteria live and reproduce must be understood if the battle against legionellosis is to be won.

LEGIONNAIRES DISEASE

In July 1976 an explosive outbreak of pneumonia in members of the American Legion, attending a convention in Philadelphia, uncovered a previously unknown cause of pneumonia. The bacterium was hard to stain to make it visible under the microscope and it was difficult to grow on artificial media. Once described as Legionnaires' disease, the causal bacteria were found in natural waters, muddy banks, hot and cold water systems, showerheads, whirlpool baths, respiratory therapy equipment, air conditioning, cooling towers and evaporative condensers.

The first major outbreak in the UK occured at the Kingston Hospital in July 1980 where nine were infected and two died. In September 1981 two more patients at Kingston were infected. One patient died and four more became ill in August 1983 at the John Radcliffe Hospital in Oxford.

The worst outbreak in the UK occurred at the Stafford District General Hospital in April 1985 when thirty-one people died. Another man died in July of the same year in Ramsgate on the Haine Industrial Estate.

Legionella bacteria were found in nine operating theatres at Guys' Hospital at the end of 1985. Evidence for bacteria was discovered in 1987 at Ealing, Neasden and Ruislip tube depots. Two patients became seriously ill in May 1987 at the Charing Cross Hospital Kidney Unit. In the BBC Broadcasting House outbreak in April 1988 there were 70 confirmed cases of Legionnaires' disease, 3 of whom died.

In 1988 bacteria were discovered in the air-conditioning at Hammersmith Town Hall and a water-tank at the Heathrow control tower. There were other occurrencies in London and in Bolton. The West End became a major target in 1989 when twenty-six people people became ill and five people died. Over two hundred cooling towers were closed down for two weeks while investigations were carried out. Another died and five became ill at the Science Museum in March of the same year and another outbreak occurred nearby at Imperial College a month later.

Legionellae have subsequently been identified or blamed for outbreaks in old peoples homes and the the Dartford Grammar School for Girls and, at the end of 1989, at the Ashford Remand Centre where the water supply was found to be colonised.

Recently there has been a report of an outbreak of the disease from a greengrocer's store, where a nebuliser was used to generate an aerosol to maintain a mist over one section of the display (Ref 1). Infection follows inhalation of water droplets containing *Legionellae* but only rarely can infection be transferred from person to person (Ref 2).

About 200 cases are reported each year in England and Wales where about 3% of all cases of pneumonia are the result of it. The majority of reported cases are sporadic and not associated with any other case of Legionnaires' disease. In these circumstances it is almost impossible to trace the source of infection. Illness develops mainly in elderly individuals after an incubation period of 2-10 days. Mortality is high, but has been reduced from about one fifth to one tenth of infected people as the diagnosis of the disease becomes more rapid and the use of antibiotics more effective. Healthy and fit young people are unlikely to suffer anything more than a mild illness.

Legionnaires' disease is unfortunately named, because it has nothing to do with military activity nor does it affect men specifically. The disease particulary affects people whose immune systems are weak, such as:

*** Those already experiencing cancer, AIDS or transplant operations.**

*** Those who smoke 20 cigerettes or more a day are four times at risk.**

*** Those who drink alcohol equivalent to 2 pints a day are twice at risk.**

*** Older males (see figure 1)**

*** Those who have been on sunshine holidays are also in higher risk categories and the disease has been identified in all parts of the world.**

Re-examination of stored blood samples shows that the disease has certainly been in existence since the 1940's.

Variations in seasonal conditions which favour the growth of *Legionella* species and the distribution of aerosol droplets containing them, may be reflected in the distribution of cases of the disease during the year (see figure 2).

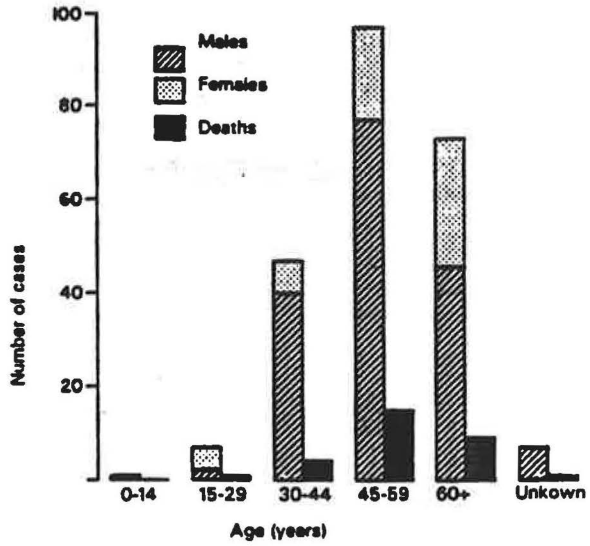

Figure 1: Sex and age distribution of cases of Legionnaires' disease, England and Wales, 1989.
(Weekly Epidemiological Record, vol. 22, 171)

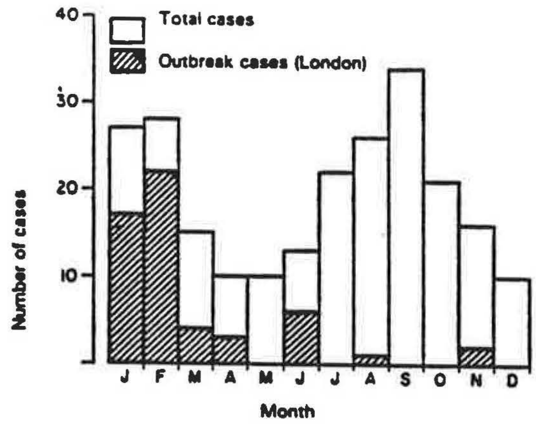

Figure 2: Seasonal distribution of cases of Legionnaires' disease, England and Wales, 1989.
(Weekly Epidemiological Record, vol. 22, 171)

PONTIAC FEVER

Before outbreaks of Legionnaires' disease were identified, an explosive epidemic of a 'flu-like' illness occurred in a county health department in Pontiac, Michigan in 1968. Patients experienced a short-lived self-limiting illness, characterised by a high temperature, muscle pain, head and chest ache, cough and other symptoms. Like humidifier fever the illness is not associated with pneumonia. Studies ten years later confirmed that this illness was caused by the same organism *Legionella pneumophila* which had been identified frequently in Legionnaires' disease. At the time there was no explanation for why the infection could manifest itself either as Pontiac fever (high attack rate and no mortality) or as *Legionella* pneumonia (low attack rate and significant mortality) (Ref 4).

Pontiac fever can affect previously healthy people, the incubation period is usually thirty-six to forty-eight hours and the illness resolves spontaneously, normally within two to five days. Deaths have not been reported. Some patients do experience generalised symptoms for longer periods of time. Of those who recovered from the original outbreak, 14% experienced a recurrent illness when they were re-exposed to the building but this is unusual.

An explanation for some of these problems begins to unfold as the biology of the organism becomes apparent. Recently discovered knowledge may also lead to the rational development of guidelines to control and monitor the incidence of legionellosis arising from domestic water supplies and environmental control systems.

THE BIOLOGY OF LEGIONELLA

About 50 species of *Legionella* have now been identified, of which *L. pneumophila* is just one. At least 14 of these species are able to cause human disease, but *L. pneumophila* is the most common cause. However, the biggest outbreak in the UK was caused by a different species, *Legionella micdadei.*

Depending on the kind of reaction which *L. pneumophila* produces in the blood stream, this species can be further sub-divided into more than 14 serogroups. In turn these serogroups may be further divided into sub-types which are given names. Rather like the address system of a town with a road, a house number and a flat, an example of a particular *Legionella* bacterium may be called *'Legionella pneumophila* serogroup 1 sub-type Pontiac'.

In a recent lecture to a meeting of the Institute of Occupational Safety and Health, Dr Tim Rowbotham explained that some organisms are able to inhibit the growth of legionellae. Others are essential for its reproduction and growth; these are the microscopic amoebae, which are among the most common single-celled animals on this planet in both numbers and species.

Legionellae have an extraordinary association with several common freshwater amoebae including three species in particular *(Acanthamoeba, Hartmannella* and *Naegleria)*. Some of these single-celled animals are able to cause diseases in man. In turn they can be infected with legionellae which first bind to the surface of the amoebae. The bacteria then enter and multiply inside. If the temperature is low the amoebae can digest the bacteria and survive the infection; if the temperature is high the bacteria will reproduce until the entire animal is filled with bacteria (see figure 3). Eventually this bacterial growth kills the amoebae which bursts to release as many as 1500 bacteria into the surrounding water where they become ready to infect more amoebae.

The amoebae feed on algae, fungi, bacteria and other particles which may accumulate in sludge. They live particularly in deposits, biofilms, foam and scum. They thrive on surfaces and in muck, and are frequently found at the bottom of tanks, or on rotten washers in shower heads and water systems. If their nutrients become scarce they are able to go into a dormant state in which they round up and become inactive. And the *Legionella* inside can survive this. These tough encysted forms of amoebae (each about the size of a white blood cell) can be blown about and withstand dessication carrying their bacteria with them. When favourable aquatic conditions are found, the amoebae return to their normal living state and the bacteria continue with their cycle.

Whilst *Legionella* normally infects and reproduces only within other single-celled animals, the bacteria can also survive in water independent of their host (Ref 5). In view of this it is essential to understand the factors which influence the survival of both bacteria and their hosts.

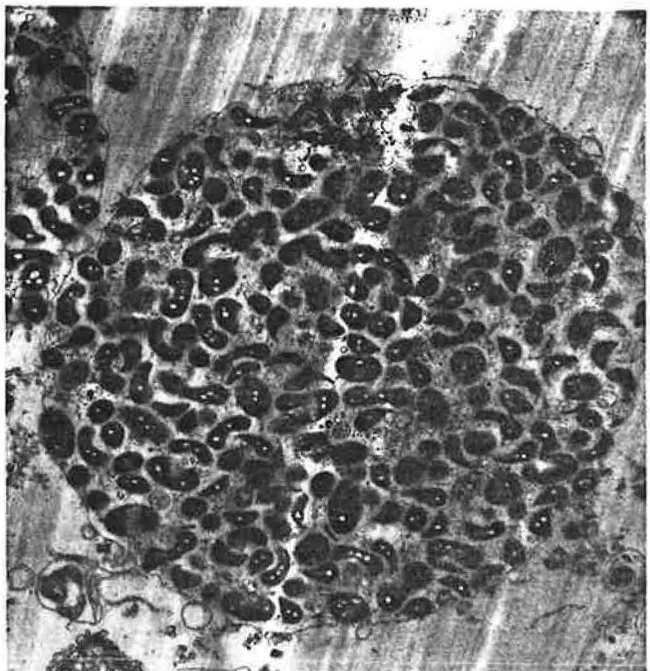

Figure 3: Highly magnified slice through an amoeba heavily infected with *Legionella pneumophila.*
(Photograph by courtesy of Mr G E Bellamy and Dr T J Rowbotham, Leeds Public Health Laboratory).

Recent work by Kilvington and Price (1990) (Ref 6) showed that although legionellae are killed by 50 ppm of chlorine, *Ananthamoeba* cysts can survive higher concentrations of chlorine for 18 hours and they are resistant to a wide range of biocides. This means that legionellae within amoebic cysts may survive cooling tower disinfection and later burst out to re-seed the system. There is also good evidence that amoebae will survive in conditions of temperature and pH which would otherwise kill the free-living bacteria, or at least be unfavourable to their survival, but these circumstances may permit the survival of the bacteria within their hosts. The temperature and pH conditions influencing the survival of *Legionella pneumophila* are summarised in figures 4 and 5.

Although little is known of the ecology of legionellae in natural waters, it is clear that air-borne amoebic cysts could be capable of reinfecting cooling towers and by this means, even towers which have been decontaminated and sterilised, can readily become recolonised by legionellae again. But legionellae are not confined to wet cooling towers in buildings (see table 1).

THE SPREAD OF LEGIONELLOSIS

It is now well established that *Legionella* infects humans by being transported through the air in minute water droplets which become inhaled. Any factors which favour the production and duration of aerosol droplets will increase the hazard of legionellosis.

Within the human body (and other animals) are wandering cells which can move about in the tissues, such as lungs, engulfing foreign particles. These macrophages (Greek meaning 'big eaters') look much like amoebae under the microscope. Their job is to protect the body against infection by eating infective bacteria and other particles. However, while the macrophages can cope with low numbers of bacteria and leave the body disease free, higher numbers are not so readily overcome and the bacteria may win the battle for a time when transient disease sets in. If the numbers are higher still the macrophages and other body defence mechanisms may be swamped and disease of a more serious nature become established which can lead to death. (If the association between the bacteria and the macrophages is similar to the relationship between the bacteria and the amoebae this would explain why antibiotics are only effective in treating Legionnaires' disease if they are of the kind which can act inside cells, such as *erythromycin* and *rifampicin).*

An appreciation of the fact that an aerosol droplet may contain a few free living legionellae or hundreds packaged within a

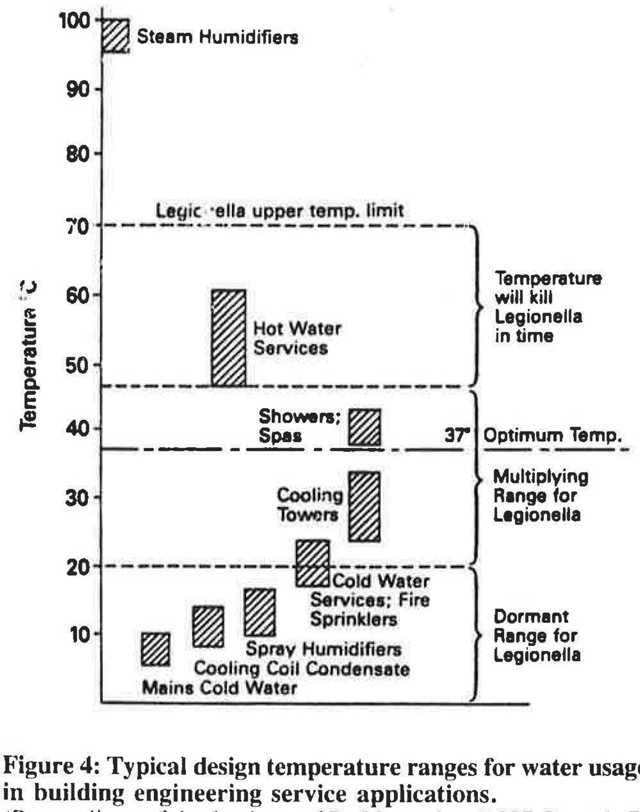

Figure 4: Typical design temperature ranges for water usage in building engineering service applications.
(Proceedings of the Institute of Refrigeration (1987-8), vol. 7, 4).

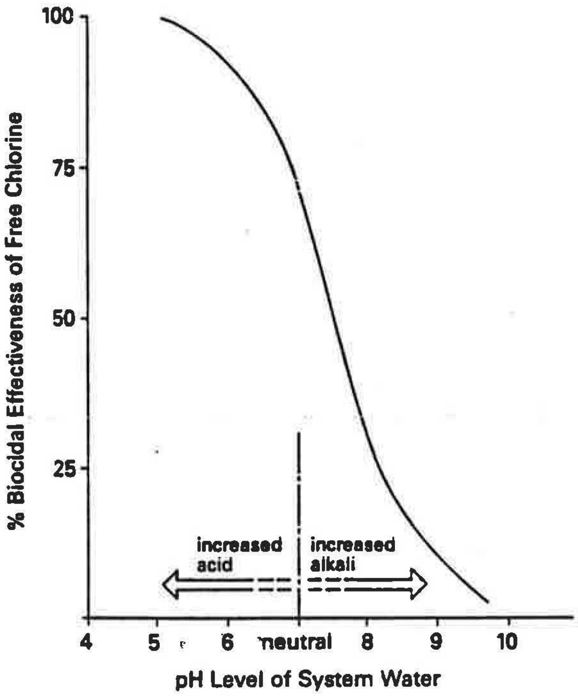

Figure 5: Biocidal effectiveness of free chlorine in water as a function of pH.
(Proceedings of the Institute of Refrigeration (1987-8), vol. 7, 6).

Building	Services	Number of Establishments sampled	Positive traces of legionellae found in establishments (%)
Hotels	Hot and Cold water	104	53
	Cooling water systems	9	67
Hospitals	Hot and Cold water	40	70
	Cooling water systems	13	38
Business Premises	Hot and Cold water	17	75
	Cooling water systems	24	54
Residential Establishments	Hot and Cold water	3	67

(PHLS Report for the DHSS, 1986)

Table 1: The presence of *Legionella* in buildings
(Health Estate Journal (1990), vol. 44, no. 3, 6).

single amoebae or cyst could explain how the same bacteria may cause either Pontiac fever or Legionnaires' disease. Free bacteria produce the relatively mild disease of Pontiac fever while heavier infections might give rise to Legionnaires' disease in susceptible people.

CONTROL OF LEGIONELLOSIS

While it is impossible to wipe out legionellae or to stop reinfection of water completely, it is clearly imperative to remove the conditions which favour the growth of amoebae and other hosts for legionellae within buildings and, as far as possible, to reduce aerosol production. There must be a recognition that lives may be lost through ineffective treatment of water systems. These include wet cooling towers, sprayed coils in air humidifying domestic hot and cold water systems, water used for cooling industrial processes, whirlpool spas, and water-based lubricants and coolants. Guidelines for minimising the risk of Legionnaires' disease are contained in CIBSE TM 13 (1987) and Guidance Note EH 48 from the Health and Safety Executive.

When should water samples be tested for legionellae and which tests should be used? Rapid assays may only provide an indication that *Legionella pneumophila* serogroup 1, subtype Pontiac is present but no distiniction is made between living and dead organisms. Culture techniques will detect living bacteria of the 53 species known so far. However, Dr Rowbotham has discribed a group of six Legionella-like amoebal pathogens which are identical in appearance to known legionellae but which do not grow on standard culture media. Furthermore, exposed water systems are likely to become reinfected with legionellae so that may account for the fact that several surveys have shown as many as 80% of cooling towers to contain this organism. This means that while routine cleaning and disinfection are essential, routine testing of the same water system for legionellae is a waste of time and money; some public health laboratories have now refused to employ routine testing for these reasons. However, testing should be carried out whenever structural or maintenance procedures are changed in water systems that present a risk to ensure that the hazard of infection has not been reintroduced.

STRATEGY

1. The dose of legionellae required to cause Pontiac fever or Legionnaires' disease is not known, but people will differ in their susceptibility to infection. The variations between individuals and the pathogenicity of the different strains are not fully understood.

2. Samples of water which contain low numbers of legionellae or which appear to be legionella-free may be obtained from a system that contains high numbers of the bacteria entrapped in their hosts. Some types or strains of legionellae may not be exposed by some test procedures. Such negative results can lull the engineer into believing a water system to be less of a hazard than it really is.

3. Water samples for testing should be taken from the location in a system most likely to contain legionellae i.e. from the biofilm, foam or sediment in a wet cooling tower. This approach may need to be reinforced by swab-sampling from taps, washers and shower heads in domestic water systems.

4. Appropriate emphasis needs to be placed on the importance of keeping water systems free of scale, sludge and biofilm i.e. those conditions which favour organic growth and the survival of legionellae hosts within which the bacteria can reproduce in a protected environment.

5. Legionellae testing is best limited to monitoring the effects of changes to the structure of a water system or changes in cleansing procedures. Routine testing for legionellae is of little use beyond checking the efficiency of a water treatment regime.

6. Cleaning procedures should be preceded and succeded by disinfection. A detailed record should be kept of testing, maintenance, disinfection and cleaning procedures.

7. Disinfection procedures, such as the use of 50 ppm of chlorine or the use of other cleansing devices, may eradicate legionellae from the main body of water but may not be sufficient to destroy legionellae within a biofilm of those engulfed within other host organisms.

8. Designers of buildings and services and installers of services should give proper thought to the access around and within systems which require regular cleaning and to the use of materials which may discourage organic growth. Aerosol formation should be reduced to a minimum and ventilation systems safeguarded from aerosols where they may exist. Although it is not always the case, many water systems associated with outbreaks of legionellosis are either poorly designed or poorly maintained.

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MAINTENANCE

News digest

New guideline to control CFC emissions

The American Society of Heating, Refrigerating and Air Conditioning Engineers, Inc. has published a guideline for controlling the release of chloroflurocarbons (CFCs) from air conditioning and refrigerating systems.

ASHRAE Guideline 3-1990, *'Reducing Emission of Fully Halogenated CFC Refrigerants in Refrigeration and Air Conditioning Equipment and Applications,'* recommends procedures for reducing emissions during manufacture, installation, testing, operation, maintenance, and disposal of refrigeration and air conditioning equipment and systems. The guideline covers all refrigeration and air conditioning equipment and systems that use CFC refrigerants.

In the USA the 1989 estimated use of CFC-11 and CFC-12 in air conditioning and refrigeration applications (not including automobiles) was 92 million pounds.

Approximately 80% of that is used for replacing refrigerant which has been released, either through leakage or during service.

The guideline contains a section covering the design of air conditioning and refrigerating systems and components and identifies sources where refrigerants escape. The section covers compressors, water-cooled condensers and evaporators, piping and connections, shutoff valves, access valves, relief devices, air purgers, and pump-down capability.

Other sections address the manufacture of equipment; installation and servicing; systems operation and maintenance; refrigerant recovery, reuse and disposal; alternative refrigerants; training of personnel; and handling and storage of refrigerants.

The guideline contains two appendices. One lists halocarbon refrigerants' relative estimated atmospheric lifetimes and ozone depletion, chlorine loading and global warming potentials. The other presents outlines of training courses in refrigerant emission control for equipment and system design engineers, installers and service technicians and end users.