The cost of Legionellosis and technical ways forward

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Abstract

Legionnaires' disease in the UK could cost around £100M/annum (£1B/annum for the European Union) for healthcare and lost working days. The cost of monitoring *Legionella* in the Domestic Hot Water (DHW) systems of UK non-domestic building stock is around £140M/annum. Further, the methods of control employed depend on maintaining high water temperatures which result in high energy consumption. Research is currently being undertaken at Brunel University to assess the effectiveness of controlling *Legionella* in DHW systems with an electrochemical device which should allow hot water to be distributed at lower temperatures with estimated savings of 0.41MtCO_2 per annum for the UK. It is also hoped that such device would reduce both the costs of monitoring and the risk of contracting the disease.

Keywords: *Legionella Pneumophila*, legionellosis, Domestic Hot Water systems (DHW), electrochemical disinfection

1.0 Introduction

Legionella was at the centre of a media uproar in July 1976 when 221 members of the American Legion, attending a conference in a hotel in Philadelphia, developed a form of pneumonia from which 34 died [i]. Speculations about the cause of the outbreak ranged from lethal chemicals to terrorists attack and panic spread around the globe. Finally, in January 1977, the United States Center for Disease Control claimed that the cause of the outbreak was an unrecognised bacterium which they consequently named *Legionella Pneumophila.* The bacterium had been breeding in the cooling towers and was spread around the building by the air conditioning system. The illness caused by the bacterium became known as Legionnaires' disease, (LD), and was soon identified in outbreaks world-wide. Today many countries have developed codes and regulations to reduce risks from this bacterium and require suspected cases of LD to be reported. However, the symptoms are indistinguishable from other forms of pneumonia, a common illness, so that significant under-reporting almost certainly occurs [ii]. The elderly, those with existing respiratory problems and those who are immuno-compromised are most susceptible to the bacterium, developing either LD or the less severe Pontiac fever, a flu-like illness that usually does not require treatment. Both are contracted by inhaling an aerosol of water contaminated with the bacteria. Collectively, LD and Pontiac Fever are known as Legionellosis.

The *Legionella* bacterium is widespread in the environment, found suspended in water or co-existing with other microorganisms in biofilms. There are 48 species of the bacteria divided into 70 serogroups but it is Legionella Pneumophila serogroup 1 that accounts for 84% of legionellosis cases [iii]. The requirements for its growth include temperatures between 25˚C and 42˚C, nutrients (such as scale and sediments) and stagnating water. Legionella species are also parasites able to colonise protozoa where they find shelter from disinfectants [iv]. Whilst larger outbreaks of Legionnaires' disease are generally associated to cooling towers, the more frequent smaller outbreaks and individual cases are attributed to hot water distribution systems and spas where the temperature is suitable and where nutrients and protozoa are abounding [v]. In hot water systems, showers are the most obvious source of water droplets but any hot water tap could potentially create an aerosol.

Legionella control in domestic hot water (DHW) systems becomes of paramount importance in buildings such as hospitals, schools, nursing homes, leisure centre, health clubs and hotels. Typically, such buildings store and distribute hot water at 55˚C and above to prevent Legionella proliferation [vi]. To prevent scalding, mixing valves must be provided at the point of use. In addition to the high capital and maintenance costs, this also leads to large heat losses and so high running costs and CO_2 emissions. (In new hotels it is estimated that 62 % of the total energy demand is for DHW [vii]. In order to achieve the 2019 zero carbon target for new non-domestic buildings set by the UK government, the energy demand associated with DHW needs to be addressed). Yet despite the high capital, maintenance and energy costs that result from high storage and distribution temperatures, DHW systems in such buildings invariably incorporate under-used outlets that could still result in the proliferation of the bacterium.

Research is being undertaken on the efficacy of an electrochemical disinfection system for controlling legionella in DHW systems. Such a method might allow DHW to be distributed at temperatures closer to the 40˚C or so required at the outlets and at the same time reduce the risk of users contracting legionellosis. In this study the following was investigated: the likely costs associated with LD in Europe (arising from healthcare and lost working days through the illness); costs of monitoring DHW systems in non-domestic buildings for legionella; the energy and CO_2 savings that might arise from operating DHW systems at lower temperatures.

2.0 Cost associated with Healthcare and Absenteeism

2.1 The Edinburgh Outbreak in June 2012

Legionella pneumophila serogroup 1 was the cause of the outbreak of Legionnaires' disease in South West Edinburgh, Scotland in June 2012 where 101 people are known to have contracted the disease and sadly three died. Some were hospitalised (intensive care or general ward) whilst others were treated in the community.
Based on data obtained from the NHS [viii] and typical treatment costs [ix], an estimate of the likely direct and immediate costs to the health service of this outbreak has been made. These are set out in the table below:

	Average number of patient days	Cost per patient per day	Cost
Intensive care unit	260	£ 2 478	£ 644 280
High Dependency	80.6	£ 1 800	£ 25 200
General ward	613.6	£ 350	£ 21 250
Total			**£ 884 730**

Table 1: Estimated costs to the health service of Edinburgh outbreak

This excludes the costs of treating patients who were not hospitalised. Also excluded are costs of drugs used and diagnostic tests. Total health service costs are therefore likely to be in the order of £1M.
There are also costs to the country's economy due to lost working days. Symptoms include cough, fatigue, memory loss, headaches and loss of concentration, muscle/joint pain, muscle weakness and tingling in feet fingers and arms. There have been cases where patients improved after seven months, cases of permanent disability and cases where people were not capable of returning to full-time employment [x]. A follow-up study of 122 survivors of an outbreak in the Netherlands in 1999 reported that the majority had not completely recovered after 17 months and 15% of patients presented Posttraumatic Stress Disorder [xi].

Unfortunately, no data on long-term illness is available for the Edinburgh outbreak. It is possible however to make an order of magnitude estimate of cost to the economy through lost productivity. It is thought that for the UK this is about £300/man-day lost or £6 250/man-month[1]. So, for the 98 survivors of the Edinburgh outbreak, assuming that half were in full-time employment and were off work for three months on average, the cost to the UK economy was about £900 000. This is comparable to the health service costs. Overall, then, the Edinburgh outbreak probably cost about £1.8M – or about £18 000 per person who contracted the disease (not considering mortality).

[1] It was assumed that the total revenue per employee is three times the average salary of £ 25.000 and that each employee works 250 days a year.

2.2. Number of cases of Legionnaires' disease in the UK and Europe

The European Legionnaires' Disease Surveillance Network (ELDSNet) collects and disseminates information on the incidence of LD as reported by member states. Over the last few years, the number of cases reported has been about 12 per million of the population per annum [xii]. In 2010, 6 296 cases were reported, 376 of which were in the UK – roughly 6 cases per million of the population. However, it is considered that under reporting occurs in most member states[2]. In the EU as a whole the ELDSNet data suggests as many as 50 500 cases or about 100 per million of the population. Welte et al. [xiii] carried out a detailed review of several years worth of data on pneumonia cases throughout the EU and concluded that in the UK some 9% of all hospitalised pneumonia cases might be LD. In the UK in 2010 there were nearly 140 000 hospital admissions due to pneumonia [xiv]. This implies 12 500 cases of LD – some 33 times as many as those reported.

Table 4 shows the combined health care and days lost costs for the UK and the EU based on the costs derived from the Edinburgh study using the reported numbers, the numbers suggested by the ELDSNet the ones suggested by Welte et al. (UK only). The estimation includes reported cases from all sources.

Country	Number of cases in 2010	Cost per person	Cost
United Kingdom (reported)	376	£ 18 000	£ 6.7 million
United Kingdom (ELDSNet)	6 200	£ 18 000	£ 111.5 million
United Kingdom (Welte)	12 500	£ 18 000	£ 225 million
Europe (reported)	6 296	£ 18 000	£ 113.3 million
Europe (ELDSNet)	50 500	£ 18 000	£ 909 million

Table 4: Reported and possible numbers and cost of LD in the UK and Europe.

[2] The number of confirmed cases could be underestimated for a number of reasons. To begin with, Legionellosis became a reportable disease in the UK only in April 2010 [xv]. It is not possible to distinguish the disease from other forms of pneumonia with chest x-rays and further tests should be prompted by the clinician. An American study reported that microbiological tests for the identification of Legionella are performed in less than half of patients with pneumonia [xvi]. However, the urine antigen test can only identify Legionella serogroup 1 and often it is difficult to obtain sputum for analysis. Other reasons include the tendency of clinicians to administer antibiotics prior to diagnosis, preventing the identification of the pathogen. The lack of record on number of patients treated at home may further increase underestimation.

3.0 Costs associated with the control of Legionella

Showers, hot water taps, air conditioning, spas, swimming pools, cooling towers, ornamental fountains and car washes are aerosol producing systems and potential sources of Legionnaires' disease and so require measures to minimize the risk. The demand for these is increasing. One of the purposes of the present study is to estimate the cost of managing Legionella in non-domestic buildings that contain such equipment. This is dominated by universities, hospitals, schools, health clubs, leisure centres and hotels. 25% of known outbreaks in the UK are due to DHW systems according to the Health and Safety Executive (HSE) [v]. The true number of LD cases related to DHW systems is far greater as individual cases are more likely to be missed than outbreaks.

3.1 Universities in the UK

In the last financial year, the cost incurred by the Estates of a UK university for monitoring and sampling domestic hot water systems in academic/administrative buildings and the halls of residences was £74 000 and £80 000 respectively. These costs exclude the risk assessments and any remedial work. This equates to £4.4 per person per annum using the academic/administrative buildings (students and staff) and £17.7 per resident per annum in the halls. Since the university in question is an average-sized UK university, the above costs can be extrapolated to cover all UK universities (see Table 2).

UK universities	Number of student/staff	Yearly Cost/person	Cost
Academic/ administrative buildings	2.88 million	£ 4.4	£ 12.7 million
Halls of residence	960 000	£ 17.7	£ 17 million
Total cost for monitoring and sampling			£ 29.7 million

Table 2: Estimated costs of Legionella control in the UK universities [xvii].

3.2 Hospitals in the UK

The chief executive of Basildon and Thurrock University Hospitals reported £3 million were invested in Legionella control in the last decade [xviii] equivalent to £356 per bed per annum. NHS data give a total of 140 000 beds available in NHS hospitals in England [xix]. Extrapolating this number of beds to the whole of the UK and assuming that Basildon and Thurrock University Hospitals is typical, leads to a total cost of £59M per annum. This excludes private health hospitals.

3.3 Schools in the UK

The management of Legionella in schools is not as complex as in hospitals or universities but it should not be overlooked. Risk assessments, temperature monitoring, descaling of showers and inspection of water tanks are required to comply with Health and Safety. It is thought that the cost of attending the site by a water treatment contractor is £80- £100. So, each of the 28 916 [xx] [xxi] [xxii] schools in the UK could spend up to £1000 a year, excluding remedial work. That is about £29 million in Legionella control.

3.4 Health Clubs, Leisure Centres and Hotels

Leisure centre and health clubs present higher risks of exposures than schools and would be expected to carry out more frequent inspections, monitoring and sampling. Assuming that each of the 5 900 leisure facilities in the UK [xxiii] could spend double the amount of a school, the total cost could be as high as £12 million per annum. The yearly expenditure for the management of Legionella in hotels is comparable to the one for the universities halls of residences. So, assuming there are 700 000 rooms, the yearly estimated cost for hotels is in the region of £12 million.

4.0 A possible way forward: electrochemical disinfection

Water pathogens are traditionally controlled in DHW systems, with biocides or by maintaining water at temperatures above 55˚C. However, both methods fail to penetrate biofilms and to kill protozoa hosts. This is due to the difficulty associated with maintaining high temperatures across the whole system and the ability of bacteria to adapt to disinfectants. Of the many alternative water treatments in the market, many researchers have identified electrochemical disinfection to have the potential to overcome those limitations [xxiv] [xxv] [xxvi] [xxvii].
With this method of disinfection, bacteria are inactivated in two stages: firstly by direct contact with the positively charged electrode and secondly, as electrolysis continues, the cell wall proteins vital to their nutrition are destroyed by oxidants generated in the electrolysis of water [xxviii] [xxix].

The aim of the research being undertaken at Brunel University is to investigate and optimise the efficacy of a prototype device in eliminating Legionella and other pathogenic bacteria. Consequently it will be possible to evaluate if DHW systems could be maintained at lower temperatures.

Small-scale laboratory experiments carried out to date have confirmed that electrochemical disinfection has the potential to kill *Legionella Pneumophila*. A fluid mechanics rig has been designed to simulate a typical DHW system where additional tests will be carried out to assess the efficacy of the prototype device and in particular evaluate its effectiveness on biofilms. The results will be presented in further publications.

DHW systems in hospitals, hotels, leisure centre and schools often comprise central hot water storage with extensive pipework. Heat losses for this pipework leads to very poor efficiency, particularly at times of low hot water demand. Reducing the temperature at which the water is circulated would lead to a significant decrease in energy consumption and resultant CO_2 emissions. An estimation of this reduction has been made by using energy statistics data for the UK [xxx]. The results are set out in Table 3.

End user	**DHW consumption Natural Gas (toe)[3]**	**Energy Savings (GWh)**	**Emission reduction (tCO_2)**	**Energy savings (£)**
Commercial offices	58 000	152	30 050	£ 4.5 million
Education	198 000	518	102 587	£ 15.5 million
Government	73 000	191	37 822	£ 5.7 million
Health	111 000	290	57 510	£ 8.7 million
Hotel and catering	256 000	670	132 637	£ 20 million
Sport and leisure	97 000	254	50 257	£ 7.6 million
Total	793 000	2 075	410 866	£ 62.3 million

Table 3: Estimated CO_2 emission reduction if DHW is circulated at 45˚C (adapted from reference [xxx])

By reducing the temperature of DHW systems from 60˚C to 45˚C, there could a reduction of 0.41 $MtCO_2$. The total emission from the UK non-domestic building stock could be reduced by 0.59% [xxxi]. The energy consumption could be reduced by 2 075 GWh per annum, generating savings of £62 million[4] [xxxii].

For new buildings, the percentage savings would be considerably larger as space heating, cooling and lighting demands are considerably reduced. The energy statement of a planning application for a new hotel examined by the author shows DHW system is responsible for 62% of the energy demand of the building [vii]. However, if the temperature is decreased, the emissions associated with heating water could be decreased.

A further advantage of lowering temperatures in hot water systems is the lower risk of scalding. Hospitals, schools and nursing homes could save by reducing the installation of thermostatic mixing valves that are costly to install and maintain.

[3] Tonnes of equivalent oil (toe)
[4] Assuming an average cost of 3p/KWh of natural gas [xxv]

5.0 Conclusions

In Europe, the annual cost associated with LD arising from healthcare and absence from work was estimated at £1 billion and in the UK at £100M. The study has highlighted likely under-reporting of cases of suspected LD: actual costs may be higher.

This study also estimated the costs associated with controlling *Legionella* in DHW systems in different types of non-domestic buildings. In the UK, the cost of controlling Legionella could amount to around £140M per annum. This paper has highlighted the need for better understanding the cost of monitoring and controlling legionella to identify areas of improvements.

Overall, this investigation has identified the need for new methods of disinfection that control the legionella bacteria effectively and efficiently. If new non-domestic buildings are to achieve zero carbon from 2019, the energy demand associated with DHW needs to be addressed.

Research is being undertaken on the efficacy of an electrochemical disinfection system for controlling *Legionella* in DHW systems. Possible savings in CO_2 emission have been estimated at 0.41 $MtCO_2$ per annum, generating savings of £62M/annum if the DHW distribution temperature is reduced to from 55˚C to 40˚C.

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